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Social Determinants of Health Influence on Surgical Morbidity after Colorectal Surgery

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This is to certify that the doctoral study by

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has been found to be complete and satisfactory in all respects,
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Abstract

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Koianka J. Ivanova Trencheva

MS, Cornell University, Graduate School of Medical Sciences, 2009

BSN, The City University of New York, Hunter College, 2001

Doctoral Study Submitted in Partial Fulfillment

of the Requirements for the Degree of

Doctor of Public Health

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Abstract

Decreasing surgical morbidity and improving surgical safety is a public health priority. With same-day or early hospital discharge after surgery, knowledge about social determinants of health (SDOH) impact on surgical morbidity is vital for surgical safety improvement. This study's aim was to evaluate SDOH association with surgery-related morbidity after colorectal surgery in an adult population. This quantitative cross-sectional study used New York Statewide Planning and Research Cooperative System (SPARCS) secondary data from 2006 –2016 on 130,731 patients linked to SDOH. Dependent variables were anastomotic leak (AL), surgical site infection (SSI), Not SSI related, and overall complications (COMPL) within 30 days after surgery. The WHO conceptual model for SDOH was used to explain the study outcomes as social production. Bivariate analysis (chi-square) and binomial logistic regression were used. The results showed: social vulnerability (SVI) increased the odds for AL, SSI, Not SSI, and COMPL. Socioeconomic status vulnerability increased odds for SSI, Not SSI, and COMPL. African Americans had higher odds for AL, SSI, and COMPL. Both "Limited English All Households" ≤ 8.2 % and "Associate degree" >8.8% on zip code decreased the odds for AL, SSI, Not SSI, and COMPL. SDOH are associated with surgical morbidity and should be considered in patients' surgical care. The study results can be utilized for positive social change by professionals and programs, to develop strategies and policies considering SDOH to decrease surgical morbidity, improve surgical safety; and to address upstream SDOH to improve surgical care by reducing racial disparity gap, and provide more equitable healthcare, ultimately improving the population health.

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Dedication

In honor of my parents and grandparents, and to all patients who have suffered the social determinants of health implications, with the hope that this modest work will facilitate the postsurgical recovery for the future ones.

Acknowledgments

It has been a great honor to work with many extraordinary professors, researchers, and clinicians in the past two years without whom this doctoral study would not be possible. First, I would like to express my profound gratitude to Dr. Vasileios Margaritis, Ph.D., MSs, DDS, my doctoral study Chair and advisor, without whom this doctorate project would not have been completed as it is. Dr. Margaritis mentorship equipped me with the necessary skills to transform just an idea for doctoral work into a significant doctoral proposal and a real-time doctoral study evaluating a major public health problem. Dr. Margaritis' generous support and dedicated guidance throughout the progression of this complex doctoral work has allowed me the necessary academic space to think, learn, and complete this work. I am sincerely grateful to Professor Patrick Dunn, Ph.D., MS, MBA, and Professor Daniel Okenu, PhD., MPH, whose indispensable critical revisions were instrumental in strengthening this doctoral work and its significance. Also, I would like to extend my thanks to Program Director Michelle Burcin, Ph.D., and Walden University for the opportunity to work on this doctoral study and for the tremendous support throughout my doctoral degree program. This doctoral work was challenging but exciting and inspiring experience for me, which not only greatly enhanced my knowledge about the social determinants of health and postoperative morbidity after colorectal surgery but also helped me know myself better, find my own research voice and shape my research interest further.

I like to express my deep appreciation, especially to the New York State Department of Health SPARCS data team, particularly Mr. Sheldon Vosburgh, SPARCS

Governance and Professor Art Sedrakyan, MD, Ph.D., who were extraordinarily helpful in the process of approval to use the SPARCS data and providing the SPARCS datafile de-identified. Without the SPARCS datafile, this project would not have been possible. Instrumental in the final data file creation was Paul Christos, Dr.PH, M.S., and his team, especially Xian Wu, who was essential in the process of data extrapolation from the master SPARCS data file and subsequently linking the study SPARCS data file with the SDOH and providing a de-identified file for this study. This task was one of the most challenging. I am grateful for the professionalism demonstrated during this process and the knowledge I gained about data crosswalking on different geographical levels.

Furthermore, I would like to express my appreciation to Alexander Din, U.S. Department of Housing and Urban Development, DC, for his time and selflessness in helping me understand the complexities of crosswalking ZIP codes to census geographies when I most needed it and for sharing valuable information and experience with me. I cannot thank enough the CDC Social Vulnerability Index team, including Barry Flanagan, PhD, Elaine Hallisey, MA, and the SVI Lead Coordinator Danielle Sharpe, MS, who advised me professionally and approved the method for crosswalking and linking the SVI estimates for New York State on zip code level with the SPARCS data file, and for truly guiding this complex process. It was an excellent learning experience. I am genuinely grateful.

To Dr. Heather Yeo, I am deeply thankful for her support and clinical advice on postoperative colorectal morbidity and particularly for reviewing the ICD 10 and ICD 9 CM codes for colorectal diseases, surgical procedures, and study outcomes before the

SPARCS data file was extrapolated. I would like to express my profound appreciation to Dr. Mary E. Charlson for her inspirational mentorship and abundant support throughout my academic development in the past several years and during this doctoral work. I am obliged to Dr. Parul J. Shukla, for his encouragement, support, and valuable clinical advice on postoperative morbidity. Also, I would like to thank Dr. Brendan Finnerty for his continuous support of my academic work and highly appreciated help when most needed. Especially, I would like to convey my genuine gratitude to Dr. Fabrizio Michelassi, Dr. Jeffrey Milsom, and Dr. Kevin P. Morrissey for their many years of clinical and academic mentorship, generous support, and consideration of my research interests and this doctorate project. It has been a privilege to know you and work with you. Without you, this work would not have been possible.

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Section 1: Foundation of the Study and Literature Review

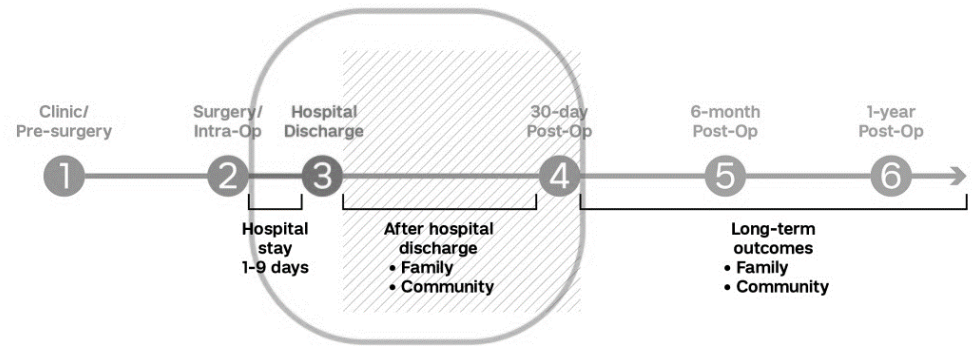
Introduction Heading

Regardless of new technological, medical, and surgical advances, as well as public health patient safety initiatives, surgical morbidity and mortality after surgery continue to remain a challenge and paramount concern for surgical safety (Centers for Disease Control and Preventions [CDC], 2017a; Kim et al., 2015; Miller et al., 2016; Sparreboom et al., 2016). While the introduction of minimally invasive surgery (laparoscopic, robotic and endoscopic), advanced diagnostic tools such as magnetic resonance imaging (MRI), positron emission tomography (PET) scan, and pharmaceutical improvements have a significant impact on the reduction of the surgical risk and surgical morbidity and mortality, surgical adverse events rates are still high nationally and globally (Kim et al., 2015; Makin et al., 2001; Panteleimonitis et al., 2017; Wyld et al., 2015). As curative and preventive role of the surgery toward various malignancies (colorectal, breast, ovarian, and other cancers) and many chronic medical conditions (e.g. obesity, diabetes, drug-resistant tuberculosis) increases, especially after the completion of the human genome project, improving surgical safety by reducing the risk of surgical morbidity and mortality has become a global and U.S. Public Health priority (Frühbeck, 2015; Hartmann & Lindor, 2016; Kempker et al., 2012; Kim et al., 2015; Möslein et al., 2003; World Health Organization [WHO], 2008; You et al., 2007). Some reports showed that globally 143 million new surgical procedures are needed annually, and that between two billion and 4.8 billion people lack access to surgical care (Alkire et al., 2015; Funk et al., 2010; Weiser et al., 2008). It is estimated that in the United States, between six and 10 million surgeries are performed annually due to digestive diseases (CDC, 2017b; Hall et al., 2017; Miller et al., 2016; National Institute of Diabetes and Digestive and Kidney Diseases [NIDDK], 2014; Stanford Health Care, 2020).

In the United States, new technological and medical advances, as well as rapid recovery protocols, have increased same-day or early-hospital discharges after surgery (Miller et al., 2014). Thus, the postoperative surgical complications such as surgical site infection (SSI), anastomotic leak (AL), and nonsurgical site related (Not_SSI) hospital acquired infections (HAI), to mention a few, have shifted from in hospital setting problem to an outpatient and community health issue (Chung & Kotsis, 2012; Den et al., 2013; Ghaferi et al., 2009; Kalra et al., 2010; Kazaure et al., 2012). There are approximately 1.7 million health care-associated infections annually in the United States (Klevens et al., 2007; Magill et al., 2014). Reports from the published literature show that 26.1% of total postsurgical colorectal complications, 34% – 42% of all AL cases, and 50% of SSI occur in the out-patient community setting after surgery (Figure 1; CDC, 2017a; Hayman et al., 2007; Kazaure et al., 2012; Trencheva et al., 2013). Postsurgical patients in socioeconomically disadvantaged areas have seven times higher likelihood to develop HAI methicillin-resistant staphylococcus aureus (MRSA) than people in higher socioeconomic status areas (Bagger et al., 2004).

Figure 1

Chronological Steps of Surgical Treatment.



Note. The diagram shows the basic process through which a surgical patient passes through from pre-surgery clinic visit to one year postoperative follow up as part of the regular medical care of large intestinal surgery Source: Original drawing

One of the goals in Healthy People 2020 and subsequently in Healthy People 2030, is to prevent, reduce, and ultimately eliminate HAI, reduce SSI, and AL after colorectal surgery is part of this goal (Healthy People 2020, 2018; Healthy People 2030, 2021). SSI after large intestinal surgery has been reported to be higher compared to other surgical fields, with variable rate range 5% to 25% (Paulson et al., 2017). Since 2017, the CDC has recommended that SSI prevention guidelines be integrated into surgical quality improvement programs to improve surgical safety for the patients (Berrios-Torres et al., 2017). Most of the current studies have evaluated AL, SSI, and other surgical complications and mortality in hospital settings, leaving a gap of necessary and critical information about the impact of community factors and social determinants of health (SDOH) on the postsurgical recovery and the occurrence of the surgical morbidity and mortality (Ashraf et al., 2013; Hammond et al., 2014; Koperna, 2003; Nasirkhan et al., 2006; Rickles et al., 2013; Trencheva et al., 2013; Turrentine et al., 2015). Understanding the impact of the SDOH on patients after colorectal surgery, and what factors in the community play a role in the recovery process after hospital discharge is essential to appreciate and reduce the risk of and prevent AL, SSI and other surgical complications and mortality after colorectal surgery (Meyers et al., 2014; Robinson, 2017). Furthermore, surgical morbidity has been associated with increased hospital cost, and with a significant personal financial burden, causing additional stress to the patients and families, and could lead to non-adherence to the recommended treatment and recovery after colorectal surgery (Regenbogen et al., 2014; Zoucas & Lydrup, 2014). There are very few studies that have evaluated the association between SDOH, economic burden, and non-adherence to therapy behavior (Patel et al., 2016).

In this study, I addressed the association between the SDOH and surgical morbidity occurrence after large intestinal surgery. More specifically, I evaluated individual and area-based levels SDOH influence on AL, SSI, Not_SSI related HAI, and overall surgical complications (COMPL) (infectious and noninfectious complications) within 30 days of initial colorectal surgery in an adult population in New York State. The study could have potential positive social change implications in four aspects: inform; provide novel information; support further research; and potentially help in setting up integrative health promotion, education and surgical morbidity prevention programs involving hospitals, communities, and public health. The study results may help both public health and the medical care programs to advance individual and population health. The three public health priority programs and goals; Safe Surgery Saves Lives, Healthy People 2030, Surgical Site Infection prevention and other HAI reduction goals, and colorectal cancer prevention, can be informed about the role of selected SDOH on AL, SSI, Not SSI related (nosocomial) and overall surgical complications occurrence after colorectal surgery (CDC, 2017a; Healthy People 2020, 2018; WHO, 2008). By evaluating race as SDOH, this study provides information about disparities in surgery-related morbidity after large intestinal surgery (Fiscella et.al., 2005). In addition, this doctoral project provides valuable information to the community from a scientific inquiry guided by theoretical frameworks specifically designed to evaluate SDOH and the outlined health issues. Further, this study presents a novel explanation for the surgical complication's occurrence as a social production. Moreover, the results from this study could inform future research studies with more robust design, as well as to guide spatial and spatio-temporal analyses and mapping of postoperative complications after colorectal surgery in New York State with the goal to identify and help communities in need. Finally, the results from this study can be used to improve outcomes centered on both a public health and medical care approach, and in setting up integrative health promotion, education and surgical morbidity prevention programs involving communities and hospitals to decrease surgery-related morbidity, improve surgical safety, and thus the population health and wellbeing through utilizing resources and modifiable SDOH.

Problem Statement

Globally, about 312.9 million people undergo surgical procedures, and 143 million additional surgeries are needed annually due to growth of surgical procedures (Rose et al., 2015; Weiser et al., 2008; WHO, 2008). According to the WHO (2008), surgical complications affect approximately seven million people globally, and about one million people die due to surgical complications with an estimated 25% being preventable (WHO, 2008). It is estimated that between two billion and 4.8 billion people lack access to surgical care (Alkire et al., 2015; Funk et al., 2010). In the United States, there are approximately 1.7 million health care-associated infections annually and between 500 000 and 750 000 patients suffer SSI with 50 % occurring after hospital discharge, making its prevention a U.S. Public Health priority (CDC, 2017a; Chung & Kotsis, 2012; Healthy People 2020, 2018; Klevens et al., 2007; Magill et al., 2014; Zinn, 2013). AL is one of the most deleterious surgical site complications after intestinal surgery and occurs when the reconnecting line of bowel ends does not heal, allowing bowel contents to escape into the abdominal cavity causing a life-threatening infection. The overall prevalence of the clinically manifested AL after colon ranges variably from 3% to 33% and between 8% and 41% after rectal surgery (Nasirkhan et al. 2006; Rose et al., 2004; Trencheva et al., 2013; Turrentine et al., 2015). Of the six million surgeries performed annually due to digestive diseases in the United States (using the lower estimate), one to 1.2 million are large bowel surgeries for colorectal cancer, cancer prevention, inflammatory bowel diseases (IBD), diverticulitis and other medical conditions. Based on the published AL rate after bowel surgery, using a conservative overall of 3 –10% AL rate, there are between 36 000 and 120 000 estimated AL cases per year in the United States (CDC, 2017b; Miller et al., 2016; NIDDK, 2014).

Despite current efforts to improve surgical safety by decreasing AL, surgical complications and mortality, AL remains a significant surgical safety problem; it is a devastating surgical site complication that results in a life-threatening infection, increases the rate and the severity of overall surgical complications and SSI, and is responsible for 30% of the postsurgical mortality after colorectal surgery (Kim et al., 2015; Sparreboom et al., 2016). Furthermore, AL impacts the public health outcomes of colorectal cancer by: (a) affecting cancer preventive therapy after colorectal surgery, thus decreasing overall survival and recurrence-free survival, (b) increasing local and distant recurrence, and negatively impact colorectal cancer-specific mortality, and (c) delaying health promotion of physical activity and proper nutrition after surgery. Overall, AL disturbs the routine postoperative recovery and delivery of adjuvant treatments necessary for cancer recurrence prevention, overall well-being, and improved gastrointestinal health (Aoyama et al., 2017; Nordholm-Carstensen et al., 2017; Sammour et al., 2016, Takahashi et al., 2018). In addition, AL increases post-operative in-patient length of stay with approximately 8.3 days in patients with AL, increases readmission rates (26.1% in AL versus 6% in no AL patients), and rates of reoperation (up to 50% of all AL cases require reoperations; Ashraf et al., 2013; Hammond et al., 2014; Koperna, 2003; Rickles et al., 2013).

While the WHO and CDC have introduced surgical checklists to improve surgical safety by decreasing the risk of the preventable intraoperative complications and mortality, there are no specific public health preventive programs or predictive tools to identify and to decrease the risk for AL, SSI and other preventable surgical complications after colorectal surgery in hospital or post-hospital discharge (Lacassie et al, 2016; WHO, 2002, 2008). The extensive treatment of AL involving multiple readmissions and many complex surgical interventions terms AL as a significant surgical site related health issue to evaluate as it is also not known how AL cost affects patients, providers, public health and medical care economically, and especially the socioeconomically disadvantaged population (Rickles et al., 2013). The limited number of AL cost analyses after colon resection usually lack individual perspective that would include indirect cost of AL incurred due to health insurance coverage, loss of wages, productivity loss, and missed days of work, thus leaving a gap in the literature of a much-needed comprehensive AL economic evaluation (Ashraf et al, 2013; Hammond et al., 2014; Ioannidis & Garber, 2011; Rickles et al., 2013; Vonlanthen et al., 2011). There are no studies identifying cost drivers for AL, and it remains unclear what the relationship between AL occurrence and cost is with regard to access to care and other social determinants of health in the community after hospital discharge (Davenport et al., 2005; Vonlanthen et al., 2011).

The role of the SDOH and other factors in the community on the postoperative recovery after colorectal surgery has been noticeably understudied. Ethnic disparities in colorectal cancer incidence and mortality have been well described; however, disparities in surgical complications, AL, and mortality following colorectal surgery and their relationship with SDOH such as access to care, health literacy, education, community setting, geographic location urban or rural, community resources, poverty and poverty index, socioeconomic status, and social vulnerability have not been well explored yet (Debarros & Steele, 2013; DeSantis, 2013). Agabiti et al. (2008) reported higher mortality amongst people with socioeconomic disadvantage after cardiac surgery, and the Vanderbilt Cohort Study has been one of the first exploring health literacy and social support after hospital discharge, but also in cardiac patients (Agabiti et al., 2008; Meyers et al., 2014). One study from the Netherlands reported that high socioeconomic status had been associated with more favorable surgical treatments in patients with colorectal cancer compared to patients with low socioeconomic status. However, this study was performed in a different country with a different health care system setting, and the results may not be applicable to the U.S. population (Dik et al., 2014). It is important to note, that in the United States during hospitalization, patients are subjected for a standardized health care post-surgery, regardless of the health insurance and the socioeconomic status. The WHO High 5s project is a multilevel initiative to improve patient safety in a hospital setting through standardizing care in critical risk areas such as assuring medication accuracy, correct surgery site by using the surgical checklist, improved hygiene to decrease the hospital-associated infection, just mention a few, and has been adopted in several countries including United States (Leotsakos et al., 2014). Despite vigilant post-operative outpatient follow-up within 90 days, once patients are discharged from hospitals, the responsibility for daily medical care is transferred to the individual patients who have differential individual capacity and vulnerabilities in the community environment, while still in the acute phase of postsurgical recovery. Surgical patients are a vulnerable population as they are at higher risk for developing SSI, Not_SSIs HAI, and poorer health outcomes after surgery compared to the population with no surgery, and as such are public health concern (Sebastian, 2008; Zinn, 2013). A study done by Hole and McArdle (2002) in United Kingdom on 2269 patients undergoing colorectal resection for cancer showed lower survival rate in patients with low socioeconomic status.

A limited number of studies have addressed the role of SDOH in postsurgical recovery, and very few in the United States (Agabiti et al., 2008; Meyers et al., 2014). Despite that some studies have reported an increase of hospital readmission rate within 30 days due to early hospital discharge, especially amongst the socioeconomically disadvantaged population, the role of the SDOH on the postsurgical complications, mortality and readmission have not been studied comprehensively (Kalra et al., 2010). There are no medical or public health programs in the community with the goal of decreasing surgical morbidity after hospital discharge, improving surgical safety, and reducing hospital readmission (Kalra et al., 2010; WHO, 2002). Modifiable SDOH factors could be utilized for positive social change by communities and hospitals in an effort to decrease surgical morbidity and mortality, to improve surgical safety, and the health and the wellbeing in the community and the population. Hence, the problem I addressed in this study was the SDOH association with AL, SSI, Not_SSI related HAIs, and overall surgical COMPL (infectious and noninfectious complications) occurrence within 30 days after colorectal surgery in adult population in New York State, in the United States.

Purpose of the Study

The goal in this quantitative cross-sectional study was to evaluate the association between individual and area-based levels SDOH and AL, SSI, Not SSI related infections, and overall surgical COMPL (infectious and noninfectious complications) occurrence within 30 days after surgery in and out of the hospital in adult patients after initial colorectal surgery in New York State, in the United States. The following four research questions were addressed in this study:

1. Research Question 1 (RQ1): Is there an association between SDOH and AL occurrence within 30 days after colorectal surgery in and out of the hospital in adult patients?

Null Hypothesis ($H_0 1$): SDOH are not associated with AL occurrence within 30 days after large intestinal resection in and out of the hospital in adult patients.

Alternative Hypothesis ($H_1 1$): SDOH are associated with AL occurrence within 30 days after large intestinal resection in and out of the hospital in adult patients.

The outcome or dependent variable was AL after colorectal surgery within 30 days after surgery in or out of the hospital measured as a binary outcome-"yes" or "no". The ICD 9 and ICD 10 identification codes are listed in Appendix B, Table B2. The independent variables were individual level and area based (zip code and county code) SDOH and included: home setting Metro/Nonmetro area, race, nativity status, language proficiency, education, employment, unemployment, median household, median family and per capital income, different levels of poverty status, GINI inequality index, Social Vulnerability Index at zip code level and county levels (the overall theme and the four themes [Theme1: Socioeconomic Status, Theme 2: Household Composition and Disability, Theme 3: Minority Status and Language, Theme 4: Housing and Transportation], as well as the flagged version of the themes which present the 90th percentile vulnerability within each of the themes), access to health care by health insurance type at individual level and as estimate for the community on zip code level, hospital case volume, transportation ability by owning a vehicle (see Appendix B, Table B4). The covariates were age, sex, preoperative diagnosis, surgical procedure, surgical approach, anastomosis type, diverting stoma, and comorbidity at time of surgery using all patients refined severity of illness (APRSOI) index, and admission type. Each variable is defined in the definition section and Appendix A and Appendix B, Table B1.

2. Research Question 2 (RQ2): Is there an association between the SDOH and the surgical site infection (SSI) within 30 days after colorectal surgery in and out of the hospital in adult patients?

Null Hypothesis ($H_0 2$): SDOH are not associated with SSI occurrence within 30 days after large intestinal resection in and out of the hospital in adult patients.

Alternative Hypothesis ($H_1$2): SDOH are associated with SSI occurrence within 30 days after large intestinal resection in and out of the hospital in adult patients.

The outcome or dependent variable was “surgical site infection” (SSI) after colorectal surgery measured as a binary outcome “yes" or "no" within 30 days after surgery and in or out of the hospital. “SSI” in this study included the following surgical site infectious complications within 30 days of the surgery: wound infection, abdominal abscess, pelvic abscess, retroperitoneal abscess, and AL. The definitions of each of the infectious complication are listed in the Appendix A and the ICD 9 and ICD 10 identification codes in Appendix B, Table B2.

The independent variables were individual level and area based (zip code and county code) SDOH and included: home setting Metro/Nonmetro area, race, nativity status (U.S. native/Foreign born), language proficiency, education, employment, unemployment, median household, median family and per capital income, different levels of poverty status, GINI inequality index, Social Vulnerability Index at zip code level and county levels (the overall theme and the four themes [Theme1: Socioeconomic Status, Theme 2: Household Composition and Disability, Theme 3: Minority Status and Language, Theme 4: Housing and Transportation], as well as the flagged version of the themes which present the 90 percentile within each of the themes), access to health care by health insurance type at individual level and as estimate for the community on zip code, uninsured hospital days, hospital case volume, household transportation ability by owning a vehicle. The covariates were: age, sex, preoperative diagnosis, surgical procedure, surgical approach, admission status, diverting stoma, anastomosis type and comorbidity at time of surgery by APRSOI. Each variable is defined in the definition section and Appendices A and B.

3. Research Question 3 (RQ3): Is there an association between SDOH and overall surgical complications (infectious and noninfectious) occurrence within 30 days after colorectal surgery in and out of the hospital an adult population?

Null Hypothesis ($H_0$3): SDOH are not associated with overall surgical complications occurrence within 30 days after large intestinal resection in and out of the hospital in adult patients.

Alternative Hypothesis ($H_1$3): SDOH are associated with overall surgical complications occurrence within 30 days after large intestinal resection in and out of the hospital in adult patients.

The outcome or dependent variable was “overall surgical complications” (COMPL) after colorectal surgery measured as a binary outcome – "yes" or "no" within 30 days after surgery and in or out of the hospital. COMPL included infectious (wound infection, abdominal abscess, pelvic abscess, retroperitoneal abscess, AL, septicemia, MRSA, VRE, pneumonia, and clostridium difficile, infectious colitis, and urinary tract infection), and non-infectious (myocardial infarction and cardiovascular, stroke, pulmonary embolism, deep vein thrombosis [DVT], bleeding, bowel obstruction, and postoperative ileus) surgical complication within 30 days of the surgery in and out of the hospital (see Appendix B, Table B2).

The independent variables were individual level and area based (zip code and county code) SDOH and included: home setting Metro/Nonmetro area, race, nativity status (U.S. native/Foreign born), language proficiency, education, employment, unemployment, median household, median family and per capital income, different levels of poverty status, GINI inequality index, Social Vulnerability Index at zip code level and county levels (the overall theme and the four themes [Theme1: Socioeconomic Status, Theme 2: Household Composition and Disability, Theme 3: Minority Status and Language, Theme 4: Housing and Transportation], as well as the flagged version of the themes which present the 90 percentile within each of the themes), access to health care by health insurance type at individual level and as estimate for the community on zip code, uninsured hospital days, hospital case volume, household transportation ability by owning a vehicle. The covariates were: age, sex, preoperative diagnosis, surgical procedures approach, admission status, diverting stoma, anastomosis type and comorbidity at time of surgery. Each variable is defined in the definition section and in Appendix A and Appendix B, Table B1.

4. Research Question 4 (RQ4): Is there an association between the SDOH and Not SSI related (hospital acquired) infectious complications within 30 days after colorectal surgery in and out of the hospital in adult patients?

Null Hypothesis ($H_0$4): SDOH are not associated with Not SSI (hospital acquired) infectious complications occurrence within 30 days after large intestinal resection in and out of the hospital in adult patients.

Alternative Hypothesis ($H_1$4): SDOH are associated with Not SSI related (hospital acquired) infectious complications occurrence within 30 days after large intestinal resection in and out of the hospital in adult patients.

The outcome or dependent variable was “Not SSI” hospital acquired infectious complications" after colorectal surgery measured as a binary outcome "yes" or "no" within 30 days after surgery and in or out of the hospital. Not SSI (nosocomial or hospital acquired) infectious complications include septicemia, MRSA, VRE, pneumonia, urinary tract infection, and clostridium difficile and infectious colitis all caused by bacteria, virus, or fungi. The definitions of each of the infectious complications are listed in Appendix A and ICD 9 and ICD10 codes used for identification are listed in Appendix B, Table B2.

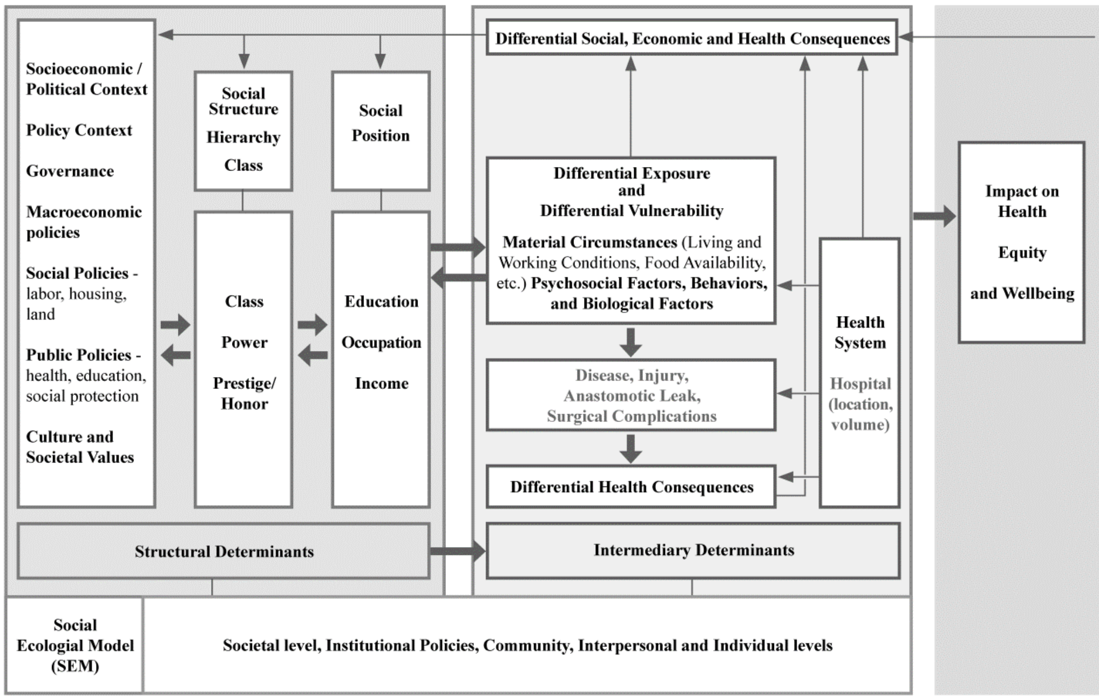
The independent variables were individual level and area based (zip code and county code) SDOH and included: home setting Metro/Nonmetro area, race, nativity status (U.S. native/Foreign born), language proficiency, education, employment, unemployment, median household, median family and per capital income, different levels of poverty status, GINI inequality index, Social Vulnerability Index at zip code level and county levels (the overall theme and the four themes [Theme1: Socioeconomic Status, Theme 2: Household Composition and Disability, Theme 3: Minority Status and Language, Theme 4: Housing and Transportation], as well as the flagged version of the themes which present the 90 percentile within each of the themes), access to health care by health insurance type at individual level and as estimate for the community on zip code, uninsured hospital days, hospital case volume, household transportation ability by owning a vehicle. The covariates were age, sex, preoperative diagnosis, surgical procedures, surgical approach, admission status, diverting stoma, anastomosis type, length of hospital stay, and comorbidity at time of surgery. Each variable is defined in the definition section in Appendices A and B.

Theoretical Foundation for the Study

Two theoretical models were utilized in this study: The WHO conceptual frameworks for the social determinants of health (CSDH) model, and Socio-Ecological Model (SEM) which is already embedded in CSDOH (Solar & Irwin, 2010; WHO, 2010). The CSDH model was used to explain the social production perspective of the disease/surgical complications occurrence (health outcomes in the study) in relation to SDOH. The SEM model as integral part of WHO CSDH was utilized to identify SDOH at individual, family, community, and societal levels as the data permits (WHO, 2010). The Diderichsen's aspect in the CSDH model explains the occurrence of diseases and in this study AL, SSI, Not SSI related and the overall surgical COMPL using the interplay between socioeconomic position and socio-political context as a key concept, with structural and intermediary determinants of health concepts (WHO, 2010). The CSDH model has incorporated in its constructs largely the Diderichsen model of social production of diseases and it is sometime referred as Diderichsen model, and it was authored by Solar and Irwin in 2010 (Diderichsen et al., 2001; Solar & Irwin, 2010, WHO, 2010). The CSDH model is a dynamic and incorporates social, economic and political mechanisms that are playing a role in the creation of the social position and social stratification, which is leading to health inequalities through differential exposure, differential vulnerability, and differential consequences (Solar & Irwin, 2010; WHO, 2010). According to the WHO definition in 1998, SDOH are behavioral, biological, socio-economic and environmental factors that influence the health of individuals or populations (Nutbeam,1998; WHO, 2010). In CSDH model, there are two types of SDOH: a) Structural (such as socioeconomic position defined by income, education, and occupation, gender, and ethnicity, race); and b) Intermediary SDOH addressing material conditions (living and working condition, food availability, neighborhood quality), psychosocial factors (stress, social support, social isolation), and behavior and biological factors (smoking, alcohol use, genetic factors, and others). The theoretical foundation model for this study presented on Figure 2 was adopted from the WHO 2010 CSDH model to reflect the current study outcomes (CDC, 2017c; WHO, 2010, p.48).

Figure 2

Study Theoretical foundation.



Note. The model is an adaptation of the WHO 2010 CSDH and includes SEM for this study. Source: Diderichsen et al.,2001; Solar & Irwin, 2010; WHO, 2010, p. 48

This model was selected for a few main reasons: a) the model has been explicitly constructed to explain the role of the SDOH on health outcomes; b) it provides an explanation of the social production of health and disease by placing the "social position" as central role in the SDOH inequalities, and c) the study evaluates the role of SDOH on health outcomes (surgical complications) after colorectal surgery in hospital and community settings. Even though SDOH affect the health status of individuals or populations in and out of the hospital, inpatient recovery after surgery ensures a standardized health care plan for all patients regardless of the insurance, socioeconomic status, or education level, to mention a few SDOH factors. After hospital discharge, the care lands in the individual patients with differential exposures and vulnerabilities, even though patients in the United States report to their surgeon up to 90 days after surgery. The different individual social position and social stratification according to CSDH model determine the deferential exposure and vulnerability, and subsequently the deferential consequences in this study the surgical complications. This theoretical model can provide the best explanation of the SDOH association and influence on the postsurgical complications as the study evaluates SDOH at individual and at contextual or community environment levels that are part of the model. What factors influence health outcomes after surgery and after hospital discharge in the community is essential information, especially if the factors are modifiable, for improvement of the population and individual health, and for improving the hospital care. Health system in the CSDH's framework is SDOH as well (WHO, 2010). The second model incorporated in Figure 2, is SEM.

The currently used SEM was proposed in 1988 by McLeroy, Bibeau, Steckler, and Glanz and it is based on previous psychological and public health concept and theories (Glanz et al., 2008). SEM specifically guided the selection of SDOH level-individual, family, and community from the secondary data. The SEM framework was selected because it is constructed and focused on the interaction between people and their environment. SEM is an integral part of CSDH model. As a model framework, SEM can adopt any concepts and constructs from any theory and provide a comprehensive approach to study design (Glanz et al., 2008). SEM also guided the selection of covariates at each level to control for confounding factors. The SEM as part of the CSDOH model provided an additional explanation of the level of influence of SDOH. Both theoretical frameworks CSDH and SEM are part of the main theoretical foundation currently used in the social epidemiology (Krieger, 2001). Furthermore, these two theoretical models also present both the ecological system and social system perspectives and allow for both positivism's (evidence oriented) and constructivism's philosophical views (the reality is socially constructed and modifiable) to be applied (Israel et al.,1998). While the study would like to find information and evidence about the influence of SDOH on postsurgical recovery (positivism's view), the constructivism's philosophical paradigm informs that the AL, SSI, and the other surgical complications are occurring in a socially constructed and modifiable environment. By using these specifics-to-the objectives theoretical frameworks this doctoral project can provide valuable information to the community from a scientific inquiry guided by frameworks specifically designed to evaluate the outlined health issues.

Nature of the Study

This research inquiry was a retrospective quantitative cross-sectional study evaluating the association of individual and area-based levels SDOH with AL, SSI, Not SSI related, and overall surgical COMPL (infectious, and noninfectious) within 30 days after surgery in male and female patients above 18 years of age after initial large intestine resection, using state secondary data. The primary objective of the study was to evaluate the SDOH as risk factors for AL, SSI, Not SSI related and overall surgical COMPL (infectious and non-infectious) in patients undergoing colon and rectal surgery in the New York State. The primary outcomes of the study were AL, SSI, Not SSI related infections, and COMPL within 30 days after colorectal resection with anastomosis in or out of the hospital, and were explicitly defined and described how they were identified from the SPARCS state data (Appendix B, Table B2).The independent variables SDOH on individual and community levels (zip code and county level) reflected the following areas: economic stability, education (literacy and level of education), social and community context, social vulnerability, health and health care, and neighborhood and built environment as the data allows (Healthy People 2020, 2018). The secondary outcomes were infectious surgical complications, noninfectious complications, and overall complications after hospital discharge out of the hospital within 30 days after surgery.

Literature Search Strategy

A literature review was conducted using OVID, PubMed, Embase, and Medline engines for related publication from 1990 up to today. Articles from the 1990s are related to the theoretical framework publications, and the information about the health issues is from within the last 20 years. Older sources were used when needed. Some of the key search terms included: anastomotic leak, surgical complications, surgical site infection, mortality, colorectal surgery, colectomy, proctectomy, socioeconomic factors, social vulnerability index, social determinants of health, health literacy, education, anastomotic leak cost, and others. This literature review includes only articles in English and directly related to the topic and the study goals. Unpublished work has not been searched. After reviewing all the abstracts first, the selected articles and websites present: the public health issues related to this study and to the epidemiology of AL and its effect on the surgical safety, SSI, cancer prevention, cancer mortality, and the challenges AL presents to population with other chronic diseases, SDOH, the issues of economic analyses, and cost drivers in surgery.

Literature Review Related to Key Variables and/or Concepts

Surgical Complications

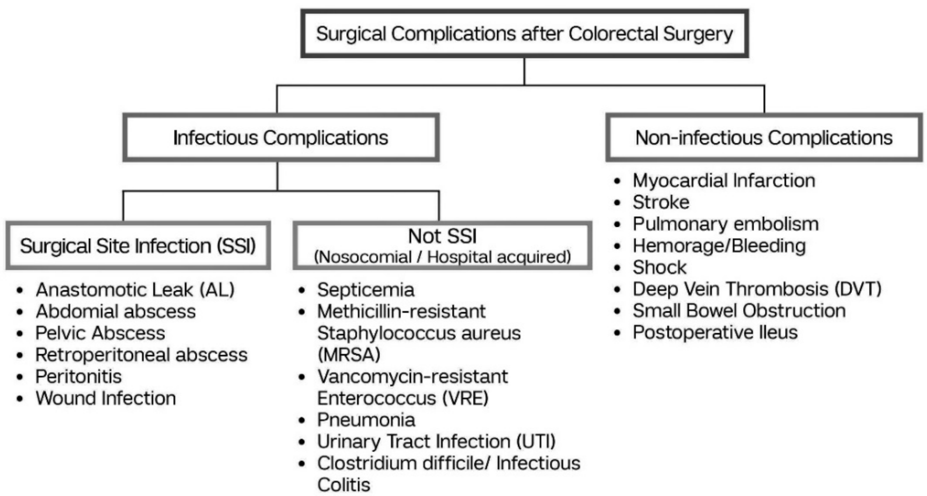
Despite medical and technological advances in health care, surgical complications still challenge health care and public health professionals nationally and globally and continue to pose a threat to patient safety. Approximately 312.9 million surgical procedures are performed annually worldwide, 48.3 million of which are done in the United States (Hall et al., 2017; Rose et al., 2015; Weiser et al., 2008, WHO, 2008). According to the WHO (2008) and other publications, surgical complications affect approximately seven million people globally, and about one million people die due to surgical complications with an estimated 25% being preventable (CDC, 2017a; International Surgical Outcomes Study Group, 2016; Kim et al., 2015; Miller et al., 2016; Rose et al., 2004; Sparreboom et al., 2016; Weiser et al., 2008; WHO, 2008). There are approximately 1.7 million health care-associated infections annually in the United States (Klevens et al., 2007; Magill et al., 2014). Between 500,000 and 750,000 patients suffer SSI with 50 % occurring after hospital discharge, making its prevention first United States public health priority (CDC, 2017a; Chung & Kotsis, 2012; Healthy

People 2020, 2018; Zinn, 2013). Surgical complications are estimated to affect around 20% of the people after surgery in high-income countries, and the percentage is higher in middle and low-income countries (Ghaferi et al.,2009; International Surgical Outcomes Study Group, 2016). Kazaure et al. (2012) using NSQIP data in a retrospective study, reported that 41.5% of the surgical complications occur after hospital discharge and in the rectal surgery alone 14.5%, with a significantly higher mortality rate in patients with surgical complications.

Even though there is not only one definition of surgical complication, generally, surgical complication is defined as "any deviation from the normal postoperative course" (Dindo et al., 2004, p. 206). The standard reporting of postsurgical complications in the United States and worldwide is usually from the completion of the surgery to 30 days after surgery. The overall surgical complication rate after colectomy is 27.7%, of which 38.3 % is occurring in the community, and after rectal resection 30.3% with half occurring after discharge (Kazaure et al., 2012). Many classifications are categorizing and grading surgical complications based on different grading factors such as the type of therapy used to resolve the complication. The most widely used classifications are Dindo–Clavien offering seven grades, and the definition from the National Healthcare Safety Network also used by the American College of Surgeons in the NSQIP data (Dindo et al., 2004; Fry, 2013; Kazaryan et al., 2013). Furthermore, surgical complications are divided into infectious and non-infectious complications (Figure 3). The diagram below presents common surgery related complications groups after large intestinal resection during 30 days after surgery (Figure3). Brief review of each complication group from the diagram is presented in this section as these groups are the study outcomes

Figure 3

Surgical complications after large intestinal surgery



Source: Original drawing

Infectious Complications - Surgical Site Infections and Not_SSI Infections

The infectious complications further are grouped into SSI and Not_SSI related infectious complications. The SSI infections are related to the actual surgical resection site and are also considered hospital acquired infections in surgical patients if they occur within 30 days after surgery at the actual surgical site, regardless if they occurred in the hospital or outside the hospital (Alkaaki et al., 2019; Horan et al., 2008). The SSIs are categorized additionally into three main groups: superficial, deep and organ/space infection depending on the level of the surgical incision site involved in the infection (Fry, 2013). Based on the grading of the complications, some authors report them as major (such as AL, intra-abdominal abscess, abdominal abscess) and minor complications referring to complication events that were resolved without treatment or any other intervention, or medical management only. According to National Healthcare Safety Network, organ space SSI occurs within 30 days after surgery and involves signs and symptoms of infection as purulent drainage, fluid collection, or abscess in the examination or imaging test, and an isolated organism in the microbiological test (National Health Care Network, 2021). In the same review article, Fry (2013) reported that SSI infection affects about 20% –25% of elective large bowel surgery in the United States. Multiple factors may cause SSIs and the treatments are associated with multiple hospitalizations and reoperations (Min, 2015). These treatments can cost between one and 10 billion of dollars annually in the United States (Azoury et al., 2015; Perencevich et al., 2003). One such devastating surgical site complication after large intestinal surgery is AL which falls into the organ/space SSI group. Other SSI are abdominal abscess, pelvic abscess, retroperitoneal abscess, and peritonitis.

The Not_SSI related infections are infections after surgery not related to the surgical site incision but other parts of the body and include infections such as pneumonia, bloodstream infections, Clostridium difficile colitis, MRSA, Vancomycin-resistant Enterococci (VRE) and urinary tract infection, caused by bacteria, virus or fungi and requiring treatment. The Not_SSI infections are called hospital acquired infections in the surgical patients if any of the Not-SSI infectious complication occur within 30 days after the surgical procedure, regardless if it was diagnosed during the hospital stay or after discharge (Alkaaki et al., 2019; Horan et al., 2008). Hospital acquired infections after large intestinal resection are higher than the other surgical fields and are reported to be up to 33 % and even 40% if untreated and decreasing them have been a public health priority (Paulson et al., 2017). A study from 2015 reported estimation of 453 000 Clostridium difficile cases in United States, and that the cost associated with this HAI is nearly 4.8 billion dollars (Guh et al., 2020; Lessa et al., 2015). Hospital acquired pneumonia after abdominal surgery has been reported to affect 10.7% of patients (Thompson et al., 2006). Most studies have reported patient-related factors, contaminating organisms, and the type of operative procedure as the main determinants for surgical infectious complications, but few studies have reported the impact on SDOH on Not SSI infectious complications (Min, 2015). A study from United Kingdom reported that postsurgical patients in socioeconomically disadvantaged areas have seven times higher likelihood to develop HAI MRSA than people in higher socioeconomic status areas (Bagger et al., 2004). One of the goals in Healthy People 2020 is to prevent, reduce, and ultimately eliminate healthcare-associated infection and surgical site infection (Healthy People 2020, 2018).

Non-Infectious Surgical Complications.

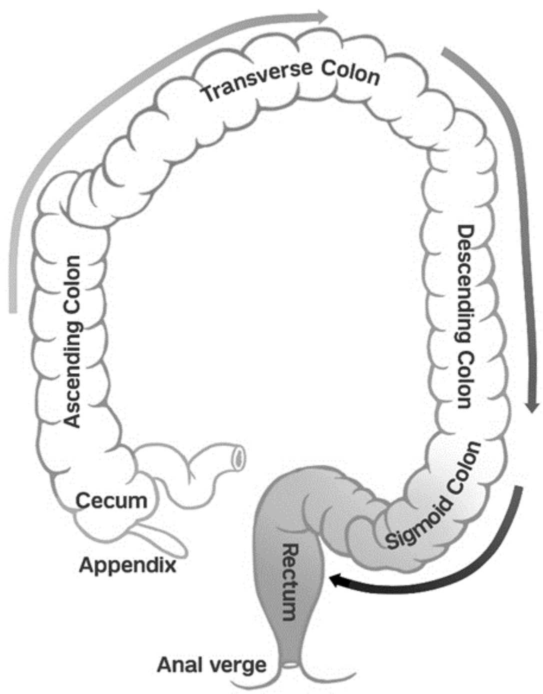
Non-infectious surgical complications are myocardial infarction (MI), stroke, pulmonary embolism, deep vein thrombosis (DVT), bleeding, bowel obstruction, and postoperative ileus, which are not caused by infectious agent but from other factors such as physiological, environmental, behavioral, and genetic factors after surgery and are considered surgical complications, and if they occur within 30 days are reported as short term noninfectious surgical complications (Figure 3). A study from 2015, reported that 28.5% of in-hospital mortality is associated with postoperative myocardial infarction, and that colorectal surgical patients with this postoperative surgical complication are six time more likely to die (Moghadamyeghaneh et al, 2015). Information on what SDOHs are related to noninfectious postsurgical complication may help in reducing and preventing them but has been understudied.

Anastomotic Leak

The human large intestine is five feet in length and anatomically has been divided on caecum and appendix, colon, rectum, and anal canal. The colon has four segments: ascending (right colon), transverse, descending (left colon) and sigmoid and recto-sigmoid (Figure 4; Ellis & Mahadevan, 2014; Mahadevan, 2017). The large intestines contain a diverse bacterial load of about 100 trillion microbes with the lowest bacterial load in the cecum and highest in the rectum. The bacterial load distribution affects the contamination severity during anastomotic leaks (Ley et al., 2006; Murray et al, 2016; Ohland & Jobin, 2015; Rolhion & Chassaing, 2016). The main groups of colon and rectum diseases are: a) neoplasms (benign and malignant); b) IBDs (ulcerative colitis and Crohn's disease), c) diverticulosis; d) perianal diseases; and e) others benign conditions such as rectal prolapse, volvulus, to name a few.

Figure 4

Anatomy of large intestine



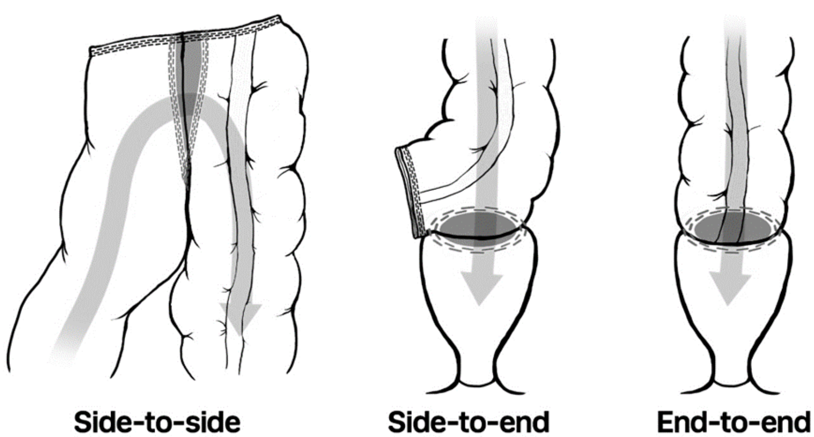
Note. The black arrow shows the gradual increase in AL rate as the anastomotic connection moves from cecum toward the rectum

Source: Original drawing based on the anatomy (Ellis & Mahadevan, 2014; Mahadevan, 2017)

The surgical treatment of colon and rectal diseases usually requires bowel resection, and in some cases removal of the entire large bowel, by applying different surgical techniques such as open, laparoscopic, or robotic. Subsequently, the continuity of the bowel tract is restored by reconnecting the bowel ends by using variety of anastomotic fashions such as end-to-end, side-to-side, and different anastomotic techniques as handsewn method, surgical staplers or compression devices (Figure 5; Goulder, 2012; Ho & Ashour, 2010; Neutzlinget al., 2012; Slesser et al., 2016). Once the surgery is completed, the healing of the anastomosis follows the three healing stages: a) inflammatory-lag, b) proliferation-collagen synthesis; and c) maturation-collagen differentiation (Sinno & Prakash, 2013).

Figure 5

Different types of anastomoses based on surgical techniques



Note. The dotted line shows the reconnection of the bowel ends (the anastomosis). Source: Original drawing based on surgical techniques (Milsom et al., 2006).

AL is leakage of bowel content from the intestinal lumen into the abdominal cavity after intestinal surgery. AL occurs when the reconnecting line of bowel ends, presented as dotted line in Figure 5, cannot heal, allowing bowel content to escape into the abdominal cavity causing a life-threatening infection. The prevalence of the AL after large bowel surgery is in the wide range of 3% to 30% depending on multiple factors. The overall rate of clinically manifested AL is between 3% to 29%, and 8% to 41% in rectal resection (NasirKhan et al., 2006; Trencheva et al., 2013; Turrentine et al., 2015). AL often occurs between Days 4 and 6 after surgery, but it can manifest itself at any day after surgery to up 6 weeks or later, contributing to a large number of ALs to occur in the community after hospital discharge (Hayman et al., 2007).

Multiple risk factors contribute to AL occurrence, and many of the predisposing AL factors have been extensively studied mostly through retrospective studies, systematic reviews, and secondary data analyses. Some of these risk factors associated to AL described in the literature are: male sex, surgical technique, level and type of anastomosis, degree of tension on the anastomosis, insufficient blood supply to the anastomosis, preoperative chemoradiation, diabetes, use of immunosuppressant, obesity, tobacco use, and others (Frasson et al, 2015; McDermott et al., 2015; NasirKhan et al., 2006; Nikolian et al., 2017; Turrentine et al., 2015). One of the very few prospective observational studies of AL risk factors was done by Trencheva et al. (2013) on a prospective cohort of 616 consecutive patients undergoing large bowel resection as regular care for their medical condition. The patients were followed before, during, and after surgery until one-year post surgery. The study results were consistent with some previously reported risk factors such as level of anastomosis, male gender, intraoperative adverse events, and also showed some new risk factors for AL such as Charlson Comorbidity Index (CCI) of score three or above three, preoperative diagnosis, presence of infectious condition at the time of the surgery (Trencheva et al., 2013). While AL patient and clinical risk factors have been comprehensively studied, there are no studies that have evaluated risk factors for AL after hospital discharge, neither there are studies that have assessed the role of the SDOH on the surgical complications, AL, and mortality after colorectal surgery.

AL significantly increases morbidity and mortality after colorectal surgery. AL increases the rate and the severity of surgical complications, the rate of SSI infection, and is responsible for 30% of the postsurgical mortality after colorectal surgery (Sparreboom et al., 2016; Van et al., 2015). Using retrospective data from the American College of Surgeons National Surgical Quality Improvement Program database (NSQIP), Midura et al. (2015) evaluated the morbidity and mortality after AL at the national level on a sample of 13,684 patients who had undergone partial colectomy with anastomosis. The authors reported that morbidity and 30-day mortality was significantly higher in patients with AL versus no leak (6.8% vs. 1.6%; $p < 0.001$respectively) (Medura et al., 2015). A retrospective cohort study on 551 510 patients from the NSQIP database reported that of all surgical complications, 41.5% occurred post-discharge. In the same study, the authors reported that patients with surgical complications had a higher mortality rate (6.9 % versus 2%) (Kazure et al., 2012). Ziegler et al. (2012) in a study using a statewide database with 5123 patients who had a large intestinal resection, reported that patients with diabetes and AL had a significantly higher mortality rate than patients with diabetes without AL (26.3% vs. 4.5%). (Ziegler et al., 2012).

Furthermore, AL impacts the public health prevention of colorectal cancer by: a) affecting the cancer preventive therapy after colorectal surgery, thus decreasing the overall survival and the recurrence-free survival; b) increasing local and distant recurrence, and negatively impacting colorectal cancer-specific mortality; and c) delaying health promotion of physical activity and proper nutrition after surgery thus disturbing the healing process after surgery for cancer prevention and treatment, and other digestive diseases (Aoyama et al., 2017; Krarup et al., 2014; Nordholm-Carstensen et al., 2017; Sammour et al., 2016, Takahashi et al., 2018). Cancer of the colon and rectum is the second most common cancer in the United States currently affecting 724,690 people, of which 50 % were diagnosed in the past decade, and nearly 50% are above age 70 years (Miller et al., 2009). Due to early diagnostic abilities and new and more effective medical and surgical treatments, cancer survivors after colorectal surgery by 2026 will increase, and in 2030 will double making post-surgery cancer preventive program a public health priority (Miller et al., 2009). A large cohort study of 9333 patients using data from three Danish' registries, showed that AL increased the distant recurrence of colorectal cancer, increased long-term mortality rates, and delayed the administration of the adjuvant therapy in patients with Stage 3 cancer with 16 days in patient with AL (Krarup et al., 2014).

The impact of the AL on local recurrence has been conflicting from multiple studies. A systematic review of the effect of the AL on the local and distant recurrence by Mirnezami et al. (2011) demonstrated that AL is a negative predictive factor for local recurrence in patients who had undergone rectal resection (Mirnezami et al., 2011). Sammour et al. (2016) and Nordholm-Carstensen et al. (2017) reported that AL decreases the 5-year overall survival and delay adjuvant therapy in colon cancer patients. Analyses from three randomized trials evaluating the impact of the postsurgical complication on the on colorectal cancer survival in a total of 5530 patients, showed that overall survival and the disease-free survival were significantly decreased in patients with AL (Ayoama et al., 2017). While all these studies demonstrate the devastating impact of the AL on cancer outcomes after surgery, they do not offer suggestions for AL prevention, neither discuss the role of SDOH and modifiable SDOH factors to decrease AL, surgical complications and improve the primary, secondary and tertiary cancer prevention.

Furthermore, AL delays the hospital discharge with approximately 8.3 days in patients with AL, increases readmission rate (26.1% in AL versus 6% in no AL patients), and reoperation rate (up to 50% of all AL cases require reoperations). (Ashraf et al., 2013; Hammond et al., 2014; Koperna, 2003; Rickles et al., 2013). The extensive treatment of AL requiring multiple readmissions and many complex surgical interventions terms AL as an important health issue to evaluate as it is also not known how AL cost affects patients, providers, public health and medical care economically, and especially the socioeconomically disadvantaged population (Rickles et al., 2013).

Current Preventive Strategies for AL and Surgical Complications

The high prevalence of surgical complications, SSI, and mortality has brought concern about the surgical safety around the world as half of the surgical complications are considered preventable (Alkaaki, et al., 2019; Horan et al., 2008; WHO, 2008). In 2007, the WHO addressed the surgical safety issue through the Global Patient Safety challenge called "Safe Surgery Saves Lives" with the goal to improve the safety of the surgical care and reduce mortality and surgical complications during surgery. The WHO introduced the Surgical Safety Checklist to improve four areas starting from the intraoperative care: a) prevention of the SSI; b) safe anesthesia; c) safe surgical team and d) evaluation of surgical services (WHO, 2008). The Surgical Safety Checklist is practiced globally and was launched in the United States in 2008. The CDC has recommended the proposed 2017guidelines for SSI prevention to be integrated with surgical quality improvement programs to improve surgical safety for the patents (Berrios-Torres et al., 2017).

A systematic review of WHO Surgical Safety Checklist use showed a significant decrease in overall complications, SSI and mortality (Bergs et al., 2014; Lacassie et al., 2016). The use of the Surgical Safety Checklist has decreased overall SSI rates from 6.2% to 3.4% (p<0.001) (Chung & Kotsis, 2012). However, current preventive measure for surgical complications, SSI, AL, and mortality are focused primarily on intra-operative and post-operative factors in the hospital setting (WHO, 2002). Chung and Kotsis (2012) discussed preventive measures for surgical complications and SSI through communication, surgical safety checklist, reporting systems, and use of evidence-based medicine to reduce SSI, while Fry (2013) focused more on the intraoperative measurements as preventive antibiotics, correct surgical site, colon preparation, and others. In the United States, there are no specific public health preventive programs or predictive tools to identify patients at risk for AL and other preventable surgical complication after surgery in the hospital or post-hospital discharge in the community (Chung & Kotsis, 2012; Fry, 2013; Lacassie, et al., 2016;

WHO, 2008). One intervention to prevent the occurrence of AL or to decrease the severity of the AL after occurrence is diverting stoma creation. However, the reports of the role of the diverting stoma are conflicting (Floodeen et al., 2017; Koperna, 2003; Stey et al., 2014). In an tempt to decrease the hospital acquired preventable complications, in the United States the Centers for Medicare and Medicaid Services (public health insurance coverage) implemented a non-payment policy for specific hospital acquired conditions deemed preventable, amongst which is SSI. However, there are studies suggesting that this is excessively penalizing method not affecting the outcomes as many risk factors for the hospital acquired conditions are not considered in this policy (Molena et al., 2015)

Social Determinants of Health

People are born in different environmental, political, socioeconomic and cultural conditions which give a different start in life that influences their health status. According to the Healthy People 2020, SDOH are defined as conditions in which persons are born, grow, live, work and age that influence their health, functioning and quality of life outcomes and risks (Healthy People 2020, 2018, "Understanding Social Determinants of Health" section). In 2010, Healthy People 2020 introduced SDOH topic reflecting five key categories: economic stability, education, social and community context, health and health care, neighborhood and built environment (Donkinet al., 2018; Healthy People 2020, 2018). Each of these five key areas reflects specific key issues such as employment, income, poverty, education level, literacy, discrimination, access to health care, access to primary care, health literacy, access to food, access to social networks, and environmental conditions just to mention a few (CDC, 2017c; Healthy People 2020, 2018; WHO, 2008). Further, the SDOH could be categorized depending on their presentation level (individual vs. contextual level), method of information measurement (direct measurement or estimates such as ACS 5-years), type of composition (single variable, or composite such as socio-economic status [SES]) and geographic level of presentation (U.S. Census block, block group, census tract, zip code, county, region, state or country) (American Psychological Association, T. F. O. S. S., 2007; Berzofsky et al., 2014; Shavers, 2007). Some SDOH such as education, income, race, poverty may have different definition and meaning in different cultures (Braveman, et al., 2005).

Income

It has been well described in the literature that income is directly related to socioeconomic status, education, occupation, job availability, and the physical environment people live in. Income as social determinant has been used as cross-sectional single measurement showing the economic resources of an individual, family or household at certain time period on individual or contextual level. Most often the median family, medial household and per capital income have been used as measures either as single measurement direct or estimate, or used as part of the calculation for SES, social vulnerability index (SVI) or in GINI index. Some published studies report that people with high income have better health as they can afford access to better health care resources (Bravemanet al., 2005; Shavers, 2007). Lower income has been related to all-cause mortality, and people with income less than $10 000 per year have been reported to have 177% higher risk of death and living about eight years less compared to people with high income as $30 000 per year. Income inequality in rich countries has been correlated with lower life expectancy in men and women (Wilkinson & Pickett, 2010). Furthermore, income influences access to health care, through the ability to obtain health insurance, pay out of pocket cost, or have transportation to health care facility (Bolin et al., 2015). Surgical morbidity has been correlated with a significant increase of the hospital cost, and with increased personal financial constraints, causing additional stress to the patients and families and non-adherence to the recommended treatment and recovery after colorectal surgery (Regenbogen et al., 2014; Zoucas & Lydrup, 2014). According to a CDC report on health disparities and inequalities (2013), in most of the Healthy People 2020 objectives, health disparities have not improved, leaving a gap in health outcomes between different segments of the population (CDC, 2011). While the influence of the SDOH on health status has been well described in the literature, the role of SDOH on health outcomes after surgical care has been understudied. Information about what kind of factors after surgery influence patient's recovery process is important to understand in order to improve population health. This includes improving health outcomes after surgery and improving health equity, especially now when people undergo same-day surgical procedures or are discharged within few days after surgery (Miller, et al., 2014)

Socioeconomic Status (SES)

SES present the social position of an individual, family, household or other groups within the society and with respect to access to the societal resources (financial, social, and others), and in terms of healthcare SES would reflects the access to healthcare resources needed to attain and support health status (American Psychological Association, T. F. O. S. S, 2007; Shavers, 2007). In the CSDH theoretical model, used in this study, the occurrence of the diseases and other health outcomes, are explained as a result of interplay between SES and socio-political context as a key concept, with structural and intermediary determinants of health concepts (WHO, 2010). SES usually has been used in the literature as composite measure that includes income, education and occupation at individual level regardless of the geographical position of the individual, or as contextual(area) measure presenting the social and the ecologic environment such as neighborhood the individuals or families live in (Berzofsky et al.,2014; Shavers, 2007). Some of the currently existing SES indices are Towsend, Carstairs, Hollingshead and Duncan (Berzofsky et al.,2014). Some composite SES measures present material and social deprivation, and others the social standing but overall SES show the social position of a person or a family in a specified social structure the person is living in. SES measures may also include poverty level in addition to the traditional three variables as it is in the SVI. SVI Theme 1 presents SES calculated using the flowing four variables: income, education, employment, and poverty status from U.S. Census ACS (Flanagan et al., 2011).

Socioeconomic status has been most often evaluated measure in health research and found to increase mortality in economically disadvantages population after cardiac surgery, and lead to better postsurgical outcomes in high socioeconomic status patients after colorectal surgery. Dik et al. (2014) evaluated the association between the socioeconomic status and surgical treatment and mortality in patients who have undergone colorectal surgery for cancer. Using data on 4422 patients from one of the Netherlands registries, the authors reported that colorectal cancer patients with high socioeconomic status have significantly better surgical treatment compared to patients with low socioeconomic status. This study did not show an association between socioeconomic status and mortality, but instead explains the low mortality rate with correlation to patient's specific and surgical factors (Dik et al., 2014). However, other studies have reported that low socioeconomic status has been contributing to higher mortality risk in colorectal cancer patients within 30 days after surgery. Aarts and colleagues (2010) and other studies reported that that low SES patients had less neo-adjuvant therapy, had lower survival rates, and had significantly higher mortality rates. (Aarts et al., 2010; Møller et al., 2012). However, these studies were not done in the United States. Agabiti et al. (2008) reported higher mortality amongst people with socioeconomic disadvantage after cardiac surgery.

Poverty and Inequality

Poverty is another social determinant that has been correlated with health outcomes and has been used as a strong predictor for death and poor health especially in communities with concentrated poverty where poverty rate is above 20% (Goodmanet al., 2018). The American College of Physician position paper on SDOH reported that in United States in year 2000 there have been 133 000 deaths due to poverty at individual level, and 119 000 due to income inequality (Daniel et al., 2018; Galea et al., 2011). It is important to understand the multidimensional aspects of poverty when using it in health research as poverty has been used as a central tenet when SES is evaluated on contextual or macro level (Berzofskyet al., 2014). Agabiti et al. (2008) reported higher mortality amongst people with socioeconomic disadvantage after cardiac surgery, but there are no studies that have evaluated the poverty and surgical morbidity after colorectal surgery. The Vanderbilt Cohort Study has been one of the first exploring health literacy and social support after hospital discharge, but also in cardiac patients (Agabiti et al., 2008; Meyers et al., 2014). Meyers et al. (2014) in the Vanderbilt Cohort Study supported by National Institute of Health (NIH), is one of the first prospective study following 3000 cardiac patients from 2011 to 2015 to evaluate the role of the health literacy and social support after hospital discharge, accentuating that as hospital stay shortens, community factors must be studied in order to offer safe preventive and medical care.

Ethnic Disparities

Ethnic disparities in colorectal cancer incidence and mortality have been well described, however, disparities in surgical morbidity and AL, and their relationship with social determinants of health following colorectal surgery such as access to care, health literacy, education, community setting, geographic location urban or rural, community resources, and poverty index, and social vulnerability have not been explored adequately (Debarros & Steele, 2013; DeSantis, 2013). Using the NSQIP data, Gunnels and colleagues (2016) evaluated the association of race to readmission in colorectal surgery for IBDs. The study results showed that black patients with IBD were at significantly higher risk for readmission 20% vs. 15% in white patients, $p<0.05$

(Gunnels et al., 2016). Multiple studies have shown a significant disparity in poverty, education level, income, morbidity, mortality and life expectancy between people in rural and urban settings (CDC, 2017d).

Social Vulnerability Index

Social vulnerability index (SVI) is part of the neighborhood and built environment key areas of SDOH and shows the social vulnerability of the communities described as community resilience during external stresses such as natural of human disaster as disease outbreaks. SVI is being used to assess the community in needs for hazard preparedness and support (Agency for Toxic Substances and Disease Registry, 2018; CDC, 2017e; Flanagan et al., 2011). SVI uses data from U.S. Census, and it is measured by rank score. The SVI has four themes that are composite variables accessible on different geographical level and comprised as follow: Theme 1:Socioeconomic Status (including income, poverty, employment, and education variables); Theme 2: Household Composition and Disability (age, single parenting, and disability variables); Theme 3: Minority Status and Language (race, ethnicity, and English language proficiency variables); Theme 4: Housing and Transportation (comprising housing structure, crowding, and vehicle access variables), and overall or summary ranking variable of vulnerability RPL-Themes (Flanagan et al., 2011). The SVI has been used more for geospatial analyses and mapping of different medical chronic conditions such as asthma and obesity in relation to the area SVI (CDC, 2017e). An and Xiang (2015) using data from Behavioral Risk Factor Surveillance System (BRFSS) 2011 and 2012 and SVI, reported SVI as an independent community-level factor affecting obesity (An & Xiang, 2015). Even though SVI Themes are well designed contextual composite variables using 15 single SDOH variables from U.S. Census data, very few studies have used to evaluate the surgical outcomes in the community levels (Carmichael et al., 2019; Flanagan et al., 2018; Mehta et al., 2019). Carmichael et al., just recently in 2019 used SVI to evaluate disparities in elective and emergent cholecystectomy. The authors reported that patients with emergency surgery lived in areas with higher SVI compared to patients with an elective surgery $p<0.001$. In the same article, the authors further discussed the SVI potential utility for use in evaluation of health care disparities, and the opportunity to link SVI as composite index to variety of other dataset as it is calculated on census track and other geographical levels. There are no studies that have evaluated the influence of the SDOH after colorectal surgery in rural and urban settings.

Economic Burden of AL and Surgical Complications

Economic assessment of surgery is still limited likely due to the complexity of surgical procedures, lack of economic training and cost evaluation methodology (Kotsis & Chung, 2010). Chew et al. (2005) reported in a systematic review that there were 649 medical, economic evaluation and only 57 surgical economic studies published in the six-year period. Even a more limited number of economic analyses have been published evaluating AL cost in patients undergoing colon and rectal resection. Economic evaluations are usually performed from a different perspective or standpoint: patient, hospital, third-party payer, and societal aspects (Kotsis & Chung, 2010; Muennig & Bounthavong, 2016). Including comprehensive perspective is very important because different direct and indirect cost applies to different perspective. The direct cost includes items related directly to the intervention performance, and the indirect cost is the cost incurred due to intervention such as loss of wages, productivity loss, a missed day of work (Getzen, 2013). Limited number of economic analyses have been published evaluating the AL cost in patients undergoing colorectal resection at the local hospital level, limiting the studies to one perspective, usually the hospital or to a single surgical procedure, single disease, or a single postsurgical complication (Iyer et al., 2009; Vonlanthen et al., 2011)

The Societal Perspective

The economic evaluation of AL from both a societal and individual perspective has been understudied mainly due to the intricate nature of the AL problem, the variety of the pricing system between hospitals within and between the states, and different nomenclature of the surgical procedures and coding of AL complication after bowel resection between the payers (Reinhardt, 2006; Reinhardt, 2011; Rickles et al., 2013). It is critically important to have the societal perspective included in the economic analysis, as it will show the total effect of the AL and the other surgical complications affecting patients and family, the public and government cost for all health intervention related to AL recovery (Jönsson, 2009; Polimeni et al., 2013). However, no studies have been found to present a comprehensive analysis of the societal perspective of AL. The societal perspective describes the indirect cost. For example, some cancer studies have reported that the average indirect cost of home care cancer is similar to the direct cost (Polimeni et al., 2013). The AL indirect cost has not been evaluated. Health-related productivity loss in the United States has been reported to cost more than $260 billion annually, and in some instances more than direct cost (Mitchell & Bates, 2011).

Hospital Perspective

Only a small number of studies have attempted to present the cost of AL from hospital perspective beyond the local or state level, but they have presented the AL economic impact, only from one perspective, and thus leaving the economic evaluation incomplete and leaving a significant gap in the scientific literature about this issue (Ashraf et al., 2013; Frye et al., 2009; Hammond et al., 2014; Ioannidis & Garber, 2011; Koperna, 2003; Rickles et al., 2013). A retrospective analysis of prospectively collected data in an observational cross-sectional study evaluated the economic impact of AL complication after anterior resection at the national level in England. The authors reported a significant difference between the actual cost of AL complication (17 220) versus 9 606 regularly assigned for AL, showing 1.1 million to 3.5 million dollars additional cost for AL (Ashraf et al., 2013). Hammond et al. (2014) evaluated the AL cost at the national level in the United States using Premier Perspective database from 2005-2009 and found that AL complication extended the length of hospital stay with 7.3 days and the hospital cost with $24,129 within the first hospitalization. The study estimated that for 1000 patients AL extended the hospital stay 9 500 days and led to increased cost of additional $28.6 million (Hammond et al., 2014). While these studies involved a broad spectrum of colorectal procedures and pointed out the significant cost of AL complication, the report is only from the hospital perspective and does not include the indirect cost of AL. Also, studies that have different perspectives cannot be compared.

Payer Perspective

Payer's perspective is another challenging perspective to evaluate. The wide variety of third-party payer (public, commercial and private), different pricing system with the individual hospitals, and various coding system amongst the health plans require good comprehension of the complex payment system to conduct economic evaluation from payer’s perspective (Reinhardt, 2006). It is vital to distinguish well the meaning of "cost" and "charges" when performing economic analysis. Reinhardt (2006) reported that only 38% of all charges that hospitals submitted to the third-party payers were paid. Private insurance can discount the hospital charges up to 50 %, and Medicare pays flat fees (Reinhardt, 2006). Payers have demonstrated an interest to work closely, with manufacturers, hospitals and health programs to optimize the payments and allocation of the scarce resources (Bankhead, 2015). The third party does not reimburse the full amount billed thus making the results not applicable to studies from a societal perspective (Kotsis & Chung, 2010). Currently, the Health Care and Utilization Project dataset and Medicare Provider Analyses and Review (MedPAR) are used for economic evaluation of health care utilization (Kotsis & Chung, 2010). There have not been published studies presenting the cost of AL complication after the colon and rectal resection from the payer's perspective, and how that affects patients and families, especially patients with surgical complications and low socioeconomic status.

Individual Perspective

The third-party reimbursement is directly related to out-of-pocket cost for individual patients, representing a portion of the cost from an individual perspective. The first study that has provided a more comprehensive evaluation of the indirect cost form individual perspective was from Stommel et al. (1993). The authors included in the economic evaluation employment condition of family members taking care of the patient in addition to income loss, and out of pocket cost, and reported that the homecare cost for three months was comparable to the cost in nursing home care (Stommel et al.,1993). Multiple hospital readmissions, reoperations, radiological procedures and outpatient visits to recover the AL complication after colorectal resection certainly increases the cost and the financial stress for the individual patient and families, affecting the adherence to the recommended recovery (Regenbogen et al., 2014; Zoucas & Lydrup, 2014). However, the complex payment system, health coverage and differences between health care providers, have precluded comprehensive evaluation of AL cost from an individual perspective. Indirect cost which includes productivity lost due to morbidity and mortality related to health intervention, in this case recovery of AL, is a substantial part of macroeconomic effect of AL recovery and thus critical to health policy development (Mitchell & Bates, 2011; Polimeni et al., 2013; Stewart et al., 2003).

Factors Increasing Cost

Furthermore, there are very few studies that have evaluated predisposing factors at the patient, family, hospital, health plans and government levels leading to an increased health care cost after AL occurs. Knowledge about these predictive cost factors at the individual (patient), hospital, insurers, and societal levels is critical for the development of predictive models and mechanisms to decrease the AL cost at each level and increase the quality of care. Postsurgical complications have been reported as drivers for hospital cost. Using the National Surgical Quality Improvement Program Data and a random sample of 5 875 participants from six different surgical services in a single center, Davenport (2005) evaluated if preoperative, surgical complexity and postsurgical outcomes factors were predictive factors for hospital cost. The regression analyses showed that postsurgical complications predicted 20% of cost variation. The authors suggested this information be used by payers and regulatory agencies for risk-adjustment of hospital cost (Davenport et al., 2005). Similar results were reported by Vonlanthen et al. (2011) showing five times higher cost in patients with postoperative complications US $ 159,345 versus US $ 27,946 (patients with no complications) and suggesting the importance of relevant saving capacity of cost-saving initiatives. The hospital cost been associated with surgical complications, and with a significant personal financial burden, causing additional stress to the patients and families leading to non-adherence to the recommended treatment and recovery after colorectal surgery (Regenbogen et al., 2014; Zoucas & Lydrup, 2014).

Study Operational Definitions

Dependent Variables

The primary dependent outcome variable was AL within 30 days after surgery in or out of the hospital. For this study AL was defined as bowel leakage from the anastomosis into the abdomen, pelvis or perianal area and collection around anastomotic site, or extension out from the surgical wound, drain site or anus, causing fever, abscess, organ-space infection, septicemia, peritonitis and/or organ failure (Trencheva et al., 2013, p.109). This definition of AL was adopted and modified from Trencheva et al (2013) prospective study to guide the selection of the diagnostic ICD-9-CM and ICD 10 -CM codes for AL in this study during the study data sample extrapolation from the SPARCS master datafile (Appendix B, Table B2). Most definitions of AL include similar elements such as leakage into the abdominal cavity with a manifestation of clinical symptoms and infection, and confirmation of the AL with some type examination either by the physician or the imaging technique. The more significant challenge with AL definition is when it needs to be coded with The International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9-CM and ICD 10 -CM) as complication, because there is no separate specific code, but it is within the ICD-9 and ICD-10 codes of gastro-intestinal postsurgical or post-procedure complications and multiple codes are used to present AL according to the clinical manifestation. Some of the ICD-9-CM code used for AL are 997.49, 997.4, 567.22, 569.81, 567.21,469.4, 567.29, and 567.9, and from ICD -10 –CM the following K91.89, K65.1, K63.2 K91.81, K91.89, K65.8, K65.9, T81.32XA, T81.89XA, K91.85 codes are designed to reflect AL. However, sometimes AL is coded as peritonitis with ICD 10 K65.9, organ space infection, diffuse peritonitis or bacterial also code ICD 10 K65.0 (Topaz et al., 2013). The coding is important to note, especially if AL is being extrapolated from the large secondary dataset as the SPARCS state data, to correctly account for all AL cases. The codes that were used to identify AL and the other study outcomes in New York SPARCS data are listed on Appendix B, Tables B1, B2, and B3. All the codes used for this study have been confirmed by trained coder and a colorectal surgeon.

Other dependent/outcome variables were SSI, overall surgical COMPL, and Not_SSI related infections all within 30 days after colorectal surgery. Postsurgical complication with 30 days in this study were defined as any adverse event or deviation from the normal recovery course following surgery in or out of the hospital within 30 days after colorectal surgery (Dindo et al., 2004). This definition was modified from Dindo-Clavien (2004) regarding the time interval of 30 days, and the setting of the complication occurrence, and it is similar to the definition from other published studies (Dindo et al., 2004; Fry, 2013; Kazaryan et al., 2013). The post-surgical complications after large intestinal surgery may include but not limited to: infectious complications (SSI, AL, peritonitis, sepsis, organ space infection, VRE, MRSA, etc.) and non-infectious (stroke, myocardial infarction, organ failure, pneumonia, pulmonary embolism, deep vein thrombosis, ileus, etc.). The postsurgical complications that were used as outcomes of this study are listed in Figure 3. Each complication listed on Figure 3, was codded in the SPARCS data using ICD 9 and ICD 10 diagnostic codes and complications specific ICD-9-CM and ICD-10-CM codes were used to identify all complications in this study from the SPARCS master secondary data file. The outcome variables were created as binary categorical variables “Yes” or “No” and were “Yes” if any of the complications listed in the group were present within 30 days. All complications in this study were categorical dichotomous variables within 30 days. All codes that were used for the complications coding are listed on Appendix B, Table B2.

Independent Variables

The independent variables were SDOH from SPARCS data on individual and community level, U.S. Census ACS 5 year's estimates, CDC SVI estimates and USDA 2013 Rural Urban continuum codes on community level-zip code and county code. All independent SDOH variables that were used in this study are listed in Appendix B, Table B4. Some SDOH were used as single measurement and some such as SVI Themes are composite variables on contextual level. The following SDOH were included in this study from SPARCS data at individual patient level: race, health insurance, and hospital annual volume of cases (Appendix B, Table B4).

Specific ACS independent SDOH variables were: U.S. native, English language proficiency, education level, employment and unemployment status, income, poverty status, GINI inequality index, health insurance type, presence of a vehicle. These SDOH were single measurements variables at community level -zip code. Since these variables were part of a secondary data, the definitions from that dataset were applied in this study. These SDOH were already linked to SPARCS clinical data on patient zip code level by the data provider. GINI inequality index shows the national income distribution amongst population and shows inequality measured by the difference between the observed income distribution and the perfectly equal income distribution and ranges from 0 to 1, as 0 being perfect equality and 1 is perfect inequality (U.S. Census Bureau, 2016). The income variable usually includes wages, dividends, pensions any other income and can be presented as gross income, net income, or households' income. According to WHO Conceptual Framework for action on SDOH, household income is better indicators for the material resources of the families, and was used in this study (WHO, 2010)

SVI is part of the neighborhood and built environment key areas of SDOH and is being used to assess the community in needs for hazard preparedness and support (Agency for Toxic Substances and Disease Registry, 2018). According to CDC Social vulnerability shows the “resilience of communities during external stresses on human health, such as natural or human-caused disasters, or disease outbreaks" (Agency for Toxic Substances and Disease Registry, 2018; CDC, 2017e). SVI is measured by total percentile rank score and has four themes that are composite variables comprised as follow: Theme 1:Socioeconomic Status (including income, poverty, employment, and education variables); Theme 2:Household Composition and Disability (age, single parenting, and disability variables); Theme 3:Minority Status and Language (race, ethnicity, and English language proficiency variables); Theme 4: Housing and Transportation (comprising housing structure, crowding, and vehicle access variables); and Overall Theme-summary of all themes (Flanagan et al., 2011). These five composite variables were evaluated as contextual SDOH on both zip code and county level in this study, as they are integral part of CSDOH Diderichsen's theoretical model and encompass all five areas of SDOH (Healthy People 2020, 2018; WHO, 2010). The SVI index offers also variables flagged at 90^{th} percentile rank to present areas of extreme vulnerability and they were included in the evaluation of this study. The SVI is constructed using 15 single variables from U.S. Census ACS data, and available to use freely on different geographic levels in all United States' states. These SDOH are already linked to SPARCS data on patient zip code and county level. CDC SVI data dictionary will be used as operational definitions (Agency for Toxic Substances and Disease Registry, 2018)

USDA Rural-Urban Continuum Codes groups the counties on metropolitan or nonmetropolitan, urban and rural by the population size of their metro area, and by degree of urbanization and adjacency to a metro area (United States Department of Agriculture Economic Research Service [USDARS], 2019). These data were used to evaluate urban and rural home settings.

Covariates

Several clinical and hospital covariates were included in the data analyses as some of these covariates are confounding factors influencing the outcome. Some of the covariates were: age, sex, preoperative diagnosis, surgical procedure, surgical approach, anastomosis distal end location, admission type, diverting stoma creation, and APRSOI at the time of surgery

Assumptions

This study utilized secondary data sets from: New York State Department of Health Statewide Planning and Research Cooperative System (SPARCS) clinical data from 2006-20016, data on SDOH from U.S. Census ACS estimates, CDC SVI data, and USDA data on rural urban continuum. All datasets were government and state data and assumed to be high-quality data. The secondary data sets were prospectively collected and have all the necessary variables to apply the research design and methodology of the current study and conduct the study analyses. Since data were already collected, it was assumed that the data were collected according to the ethical and regulatory research standards in the United States. Since SPARCS data were collected from more than 200 New York State hospitals and state-required strategic planning, the data is out the control of the current study researcher. It was assumed that all hospital adhered the state definitions of the data points for the data, that all hospital followed the ethical regulation for collecting protected health information and collected it by trained persons. Even though that SPARCS data is a high-quality data from New York State, this study results could be applicable only to the local, city and state levels. ACS is U.S. Census Bureau annual survey collecting data on housing, educational attainment, income, language proficiency, migration, disability, employment, and poverty in all United States 'states and Puerto Rico from randomly selected individual household with 95% response rate as it is mandatory survey. Therefore, it was assumed the survey sample is representative for the United States population and for the individual state. The CDC SVI uses data from ACS, therefor it was assumed is representative for the state. The assumptions mentioned above are important because this study uses secondary data which already has been collected and thus out of the control of the current researcher using the data, but it may affect the internal validity of the study.

Scope and Delimitations

This study's aim was to address the role of the SDOH on AL, SSI, Not_SSI related and overall surgical complications occurrence within 30days after colorectal surgery, in and out of the hospital. Further, the study utilized secondary data of already existing data sets. The delimitations of the study are first set by the boundary of the dataset itself, and the existing variables in the data. This study included male and female patients 18 years of age and above undergoing initial colorectal surgery for treatment of their medical condition. Placing this delimitation on the population that was included in the sample, focused the study on the specific community and allow to minimize the study bias, and improve the validation. The colorectal population was selected because the overall surgical morbidity, SSI and HAI rates are higher after colorectal surgery compared to other surgical fields, incidence rate of colorectal cancer continues to grow, and the incidence of colorectal cancer will double by 2030 (Alkaaki et al., 2019; Horan et al., 2008). The incidence rate of IBDs is also increasing (CDC, 2017b; Miller et al., 2016; NIDDK, 2014).

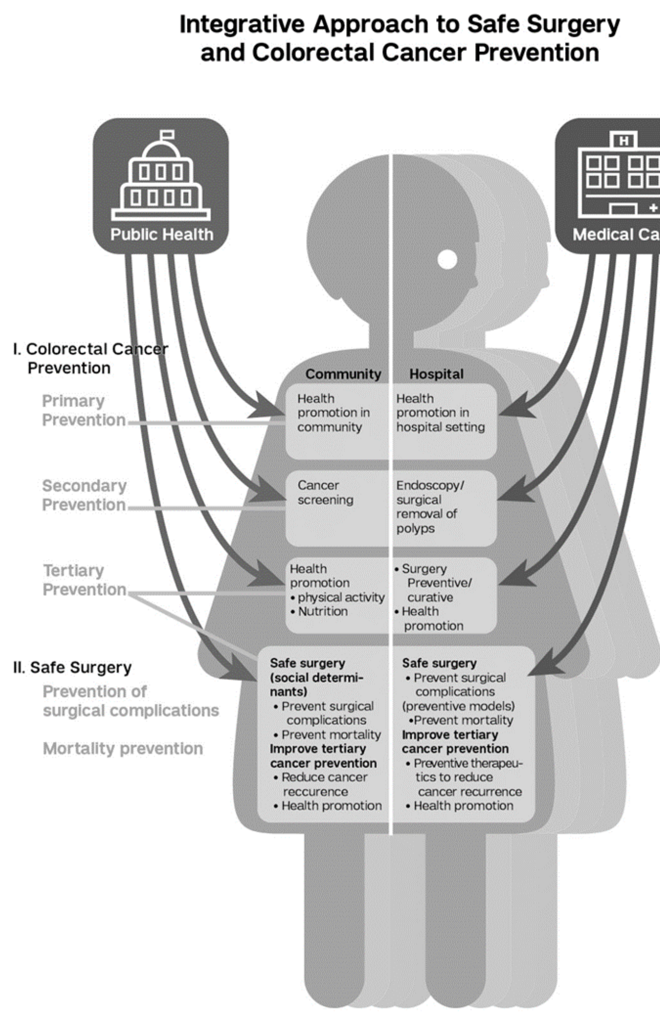
Some of the limitations in secondary data analyses are related to lack of enough data, the quality of the data, missing data, and the way the variables were defined in the datasets. The data may be missing important variables needed to answer the question. Analyses were limited to the data available in the dataset, and some important factors may not be part of the dataset (Cheng & Phillips, 2014). The results from the SRARCS data can be generalized only to the New York City and New York State. Some limitation in SDOH data were related to the socio-cultural aspect of the SDOH, and lack of SDOH data on individual level. The strength and the limitation of each variable included in the SES measure, either as single or in composition measure, has to be taken under consideration, as the different measures such as income, education and occupation are not interchangeable and may be culturally defined, depended or influenced by other social factors. For example, it is well known that income is age and sex dependent and influenced (Bravemanet al., 2005).

Significance, Summary, and Conclusions

Understanding the role of SDOH on patients after colorectal surgery, and what community determinants play a role in the recovery process after hospital discharge is important information in order to decrease surgical morbidity and mortality, improve overall safety and wellbeing of the patients, advance cancer prevention, and other public health programs, and improve the health equity (Meyers et al., 2014; Robinson, 2017). The colorectal surgery field is associated with public health in health promotion and secondary cancer prevention through colonoscopy screening and polyp removal, and tertiary colorectal cancer prevention through surgical bowel resection, including before and after cancer preventive therapies (Figure 6). This study can further support this mission through informing the programs about influential SDOH that can be considered and modified through policies and program interventions. As a multidisciplinary field, it is public health mission to prevent injuries and assure quality and accessibility of health services, and it is an essential public health task to monitor communities and identify health issues, to mobilize the community partnership to resolve the identified health problems, and to improve the health and wellbeing of community (Shi & Johnson, 2014). The Figure 6 exemplifies the mutual goals public health and the medical care have, and possibility for integrative approach between medical care and public health toward individual and population health.

Figure 6

Example of integrative approach between public health and medical care



Source: Original drawing

The concept of socially responsible surgery (SRS) specifically emphasizes the integration of surgical care and public health to evaluate the influence of the SDOH impacts on patients, and this study aim is in line with this concept and the public health mission (Robinson et al., 2017; Rothstein, 2014). Furthermore, this study information could provide trends and could help in narrowing the gap of the needed scientific knowledge and understanding of the role of the SDOH on surgery related morbidity based on theoretically and scientifically guided research. Moreover, the study informs about racial disparities in surgery related morbidity, provides foundation for future studies, and may help in setting integrative programs between public health, medical care and community for achieving optimal social change and to succeed in better individual and population health.

This literature review showed the epidemiological burden of the surgical complications, AL and mortality, and the AL economic burden after large intestinal surgery. Furthermore, this review described the current public health initiatives to improve surgical safety and standardized patient safety in hospital settings, as well as their limitation to address the health problem beyond the hospital setting. The literature review also showed the lack of public health and medical initiatives to identify and prevent, and thus decrease the surgery related morbidity after colorectal surgery. Furthermore, the review demonstrated the role of SDOH on overall health and life expectancy, and the need of national and global strategies to address the SDOH role on the surgical morbidity and mortality after surgery, with the aim to reduce health inequalities, improve health outcomes and population wellness through health promotion and disease prevention. In summary, in this literature review several gaps were identified in the scientific literature for valuable and highly needed information from clinicians, hospital administrators, and policy decision-makers that could potentially help to decrease surgical morbidity and mortality, improve surgical safety, and ultimately improve health equity by decreasing the health inequality. Thus, a comprehensive evaluation of SDOH influence on AL, SSI, Not_SSI related and overall surgical COMPL, as predictive factors is warranted and would benefit the patients, hospitals, and the society.

While in this section the study rationale was provided, in the next section a detailed description of the study implementation plan is presented. This research inquiry's research approach and the selected research design and method suitable for the selected approach, and the rationale for choosing the design are explicitly described in the study implementation plan. The methods part shows specific information about the study population selection, study inclusion and exclusion criteria, sampling strategies, the datasets and the data collection methods used in the secondary datasets, and the statistical data analysis plan. Lastly, Section 2 describes the ethical considerations, and the proposed study potential benefits and influence on the public health, medical practice, policy and future research.

Section 2: Research Design and Data Collection

Introduction

The purpose of this quantitative cross-sectional study was to explore the association of individual and area-based levels SDOH with surgical complications occurrence within 30 days in adult patients after initial colorectal surgery in or out of the hospital. While in section one the study rationale comprising of an in-depth literature review on the health topic background, the problem statement, the study purpose with the research questions and hypothesizes, the conceptual frameworks of the study, and the delineators were presented, in this section, the study implementation plan is described. This includes the description of the research approach, selected research design, and method suitable for the selected approach. Threats to study validity and ethical considerations were addressed as well in this section.

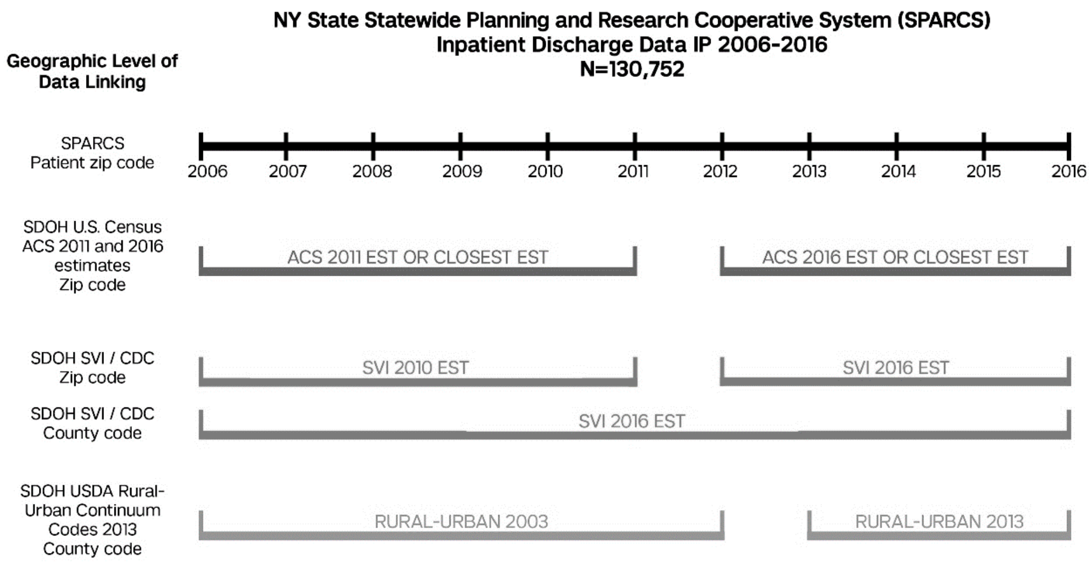
Research Design and Rationale

This research study was a nonexperimental quantitative cross-sectional study using a secondary clinical data from New York State Department of Health, Statewide Planning and Research Cooperative System (SPARCS) from 2006 to 2016, and social determinants of health (SDOH) data from U.S. Census American Community Survey (ACS) 2011 and 2016 5-years estimates, CDC Social Vulnerability Index (SVI) 2010 and 2016 estimates, and 2003 and 2013 Rural-Urban Continuum Codes data from United States Department of Agriculture Economic Research Service. Figure 7 below demonstrates all secondary data sets included in this study sample and the level at which were linked to SPARCS clinical data. Because the clinical SPARCS data is from

2006 to 2016, appropriate and closest time estimates for New York State from all SDOH data were selected for better accuracy of the final study sample as demonstrated below.

Figure 7

Secondary data sets in the study sample and geographic level of linking



Source: Original drawing

The research approach to inquiry was quantitative because the variables included in this study and the data sets were either categorical or numerical and have one of the four measurement level assigned: nominal, ordinal, interval scale or ratio scale, requiring quantitative statistical analyses. The nonexperimental design is also called correlational, and it aligns with the main purpose of the study and the research questions. The research design was selected because: a) the study used existing data collected at certain time period, b) the variables included in the analyses already occurred, and although all variables are measured, they cannot be manipulated, and c) the primary aim of the study is to understand the association between the SDOH and the study outcomes and these data sets contain the necessary information to answer the research questions.

One of the main disadvantages of nonexperimental design is that it cannot make a causal inference or explain the influence effect of the confounding variables. However, the aim of the current study was to evaluate SDOH association with postsurgical complications occurrence, and not to make causal inference. Nonexperimental quantitative studies have been used to predict health outcomes, and cross-sectional studies on existing data have the advantage of taking less time and to be less costly (Burkholder et al., 2016; Hulley, 2007). The main drawback in using secondary data is that the population and the variables were already selected and collected, making the choice of what can be studied limited, as the data may not have all the variables needed. However, this design can contribute to the scientific community by providing novel information about the role of the SDOH on the postoperative surgical morbidity especially the infectious complication such AL, SSI, Not SSI related (hospital acquired) infections as well as the overall postoperative morbidity, as well as it can provide information about ethnic disparities in surgery related complications. The methodology and the results from this study can be used as a foundation for setting up future studies with more robust design to evaluative additional factors that were not part of the secondary data during the time period when the study data were collected.

Study Variables

Outcome Variables

The main outcomes or the dependent variables were: AL, SSI, Not_SSI related infections, and overall surgical COMPL (infectious and noninfectious) within 30 days after large intestinal surgery. All outcomes were defined as categorical dichotomous variables “Yes_No” (Appendix B, Table B2). Some of the most common infectious and noninfectious surgery related complications after large intestinal resection that were included in this study are listed on Figure 3. Except the AL, the other outcomes include multiple specific complications listed on Figure 3 and were coded in the SPARCS data by ICD-9 and ICD-10 codes, thus these codes were used to extrapolated them from the already existing master SPARCS data file.

Independent Variables

The independent variables were the SDOH variables from the five areas: economic stability, education (literacy and level of education), social and community context, health and health care, and neighborhood and built environment and as the data allowed (Healthy People 2020, 2018). Individual level and area based (on zip code and county code) single measurement and composite variable such as SES were used in this study. All SDOH variables, the type and the source of the variables are listed in Appendix B, Table B4. The covariates included in the study were: age, sex, preoperative diagnosis, surgical procedure, surgical approach, type of anastomosis, diverting stoma creation, APRSOI, admission type, length of stay in the hospital and others listed in Appendix B, Table B3.

Methodology

Population

The target population was adult male and female patients who underwent in-hospital initial large bowel resection with anastomosis with or without diverting stoma for regular treatment of their medical condition in New York State, United States in the period of 2006 to 2016. Some of the medical conditions requiring large intestine surgery were colon and rectal cancer, inflammatory bowel diseases (IBD) (ulcerative colitis and Crohn’s disease), diverticular disease, volvulus, and bowel obstruction, just to mention the main groups. Approximately between 60 and 70 million people suffer from digestive disorders in the United States of which colorectal cancer, IBDs, and diverticulosis are the leading once, and the reason for about six million digestive disease surgeries annually of which 1-1.2 million are large bowel surgical resections (NIDDK, 2014; Peery et al., 2012).

Sampling Technique, Sampling Frame and Sampling Procedures

Sampling Technique

For this research study, the nonrandom probability sampling technique was used to define the study sample. A nonrandom sample was selected from New York State SPARCS inpatient discharge secondary data from 2006 to 2016. The sample is a state population-based sample because the database includes records from more than 200 hospitals in New York State, United States. The final study sample was created by linking the clinical secondary data sample from SPARCS data with the SDOH from U.S. Census American Community Survey (ACS) 2011 and 2016 estimates for New York State, CDC SVI 2010 and 2016 estimates for the New York state, and USDA 2003 and 2013 rural urban codes on zip code and county levels (Figure 7). All four research questions were addressed by using the final data sample. The final data sample was sufficient in size and data content to provide response to the research questions on several levels-individual, zip code, county and state levels.

Although SPARCS data set include patients from hospitals throughout the entire New York state, not all patients that had required surgery might have their surgery at New York state-based hospital, and not all hospital from the state may have entered data at SPARCS, making the sample nonrandom as not all existing patients had an equal chance to be selected to participate in this study. However, the SPARCS data sample is a representative sample, as it was drawn from a statewide data, which reduces the sampling error.

Sampling Frame

Inclusion Criteria. The following were the inclusion criteria for the sample:

- Male and female patients
- Age 18 years to 100
- All Ethnic groups
- Patients who underwent initial large bowel surgery for regular treatment of their medical conditions from 2006 to 2016 including but not limited to: colon and rectal cancer, IBDs, diverticulitis, and other large bowel diseases, and had

reconnection of the bowel (anastomosis) at time of surgery, with creation of diverting stoma or not. In this study, 'Initial Large Bowel Surgery/Resection (colon and rectal) was defined as "no previous surgery for large bowel resection exist in the data provider's master New York SPARCS secondary data file from where the study sample is extrapolated".

- Patients who underwent large intestinal surgery either by the conventional open or laparoscopic surgery method
- Elective, emergent and urgent
- Patient with the following ICD9 and ICD10 surgical procedure codes will be included in the study sample. These codes denote variety of large bowel resection with anastomosis.

The ICD9 procedure codes included in the sample were: 458, 1731, 1732, 1733, 1734, 1735, 1736, 1739, 4571, 4572, 4573, 4574, 4575, 4576, 4579, 4581, 4582, 4583, 459, 4593, 4594, 4595, 4840, 4842, 4843, 4849, 4862, 4863, 4869, and 4874.

The ICD10 procedure codes included in the sample were: 0D1N0ZP, 0DBB0ZZ, 0DBE0ZZ, 0DBE4ZZ, 0DBE8ZX, 0DBE8ZZ, 0DBH0ZZ, 0DBK0ZZ, 0DBL0ZZ, 0DBL4ZZ, 0DBL8ZX, 0DBM0ZZ, 0DBM4ZZ, 0DBN0ZZ, 0DBN4ZZ, 0DBN8ZX, 0DBP0ZZ, 0DBP4ZZ, 0DTB0ZZ, 0DTB4ZZ, 0DTE0ZZ, 0DTE4ZZ, 0DTF0ZZ, 0DTF4ZZ, 0DTF8ZZ, 0DTG0ZZ, 0DTG4ZZ, 0DTH0ZZ, 0DTH4ZZ, 0DTK0ZZ, 0DTK4ZZ, 0DTL0ZZ, 0DTL4ZZ, 0DTM0ZZ, 0DTM4ZZ, 0DTN0ZZ, 0DTN4ZZ, 0DTN8ZZ, 0DTP0ZZ, 0DTP4ZZ, 0DTP7ZZ, 0DTP8ZZ, and 0WQF0ZZ.

Exclusion Criteria. The exclusion criteria for the study were as follows:

- Above 100 years of age
- Patients who had large intestinal resection but did not have anastomosis
- Temporal stoma creation alone as surgical procedure
- Abdominoperineal resection/surgery with permanent stoma presented by the following ICD codes (ICD 9 4850, 4851, 4852 and 4859, and ICD 10 codes Z90.49, 0DTP0ZZ with 0D1N0Z4, 0DTP4ZZ with 0D1N0Z4, 0DTP7ZZ with 0D1N0Z4, 0DTP8ZZ and 0D1N0Z4
- Permanent stoma creation ICD 9 code 46.13, 0D1N0Z4
- All patients who had surgery in New York state but live out of New York state
- All patients that do not have SDOH or cannot be linked to the SDOH data from the ACS, CDC and USDA data sets due to lack of zip code or county code
- All patients with categorical variable that cannot be imputed
- Medical records are incomplete or missing the outcome variables

Sampling Procedures

The specific procedures for how the sample was drawn from the secondary dataset are described as follows.

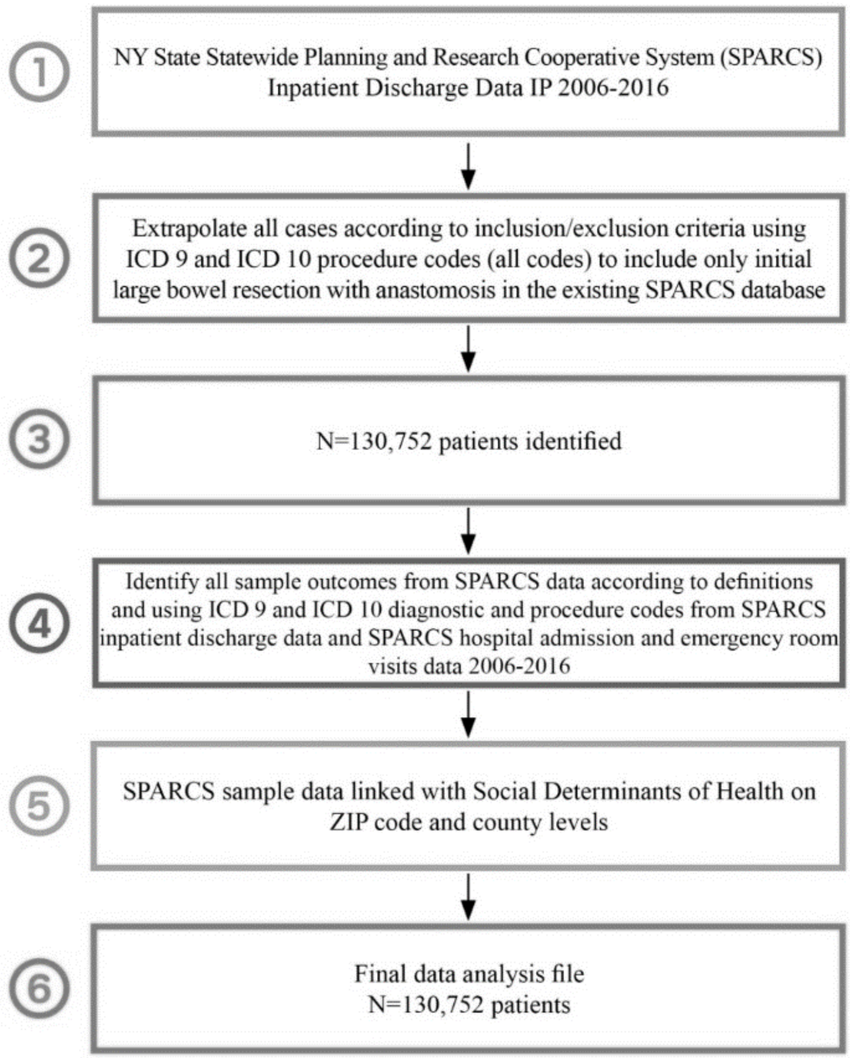
New York State SPARCS Data Sampling Strategy

The sample from the New York State SPARCS data file was extrapolated from the New York State Inpatient Hospital Discharge Data files from 2006-2016. Patients were identified from the secondary data sets using ICD-9 codes and ICD-10 surgical procedure codes listed in the inclusion and exclusion criteria. All ICD codes that were used to extrapolate the study variables from SPARCS are listed in Appendix B, Table

B1, B2 and B3. Once all patients who had undergone initial large bowel resection with anastomosis were identified, all subjects below age 18 years and above 100 years of age were excluded, as this study included only adult patients. Further, all exclusion criteria were applied. All records were reviewed for completeness and missing data. This final sample from New York SPARCS dataset was revised for power according to the statistical recommendation of this study. The final SPACRS sample was linked with SDOH from U.S. Census ACS, CDC SVI and USDA appropriate year estimates for New York State on patient zip code and county code levels. Since the sample included clinical data from 2006 to 20016, the patients from 2006 to 2011 were linked with SDOH estimates appropriate for that period of time, and patients from 2012 to 2016 were linked with estimates from 2016. The estimates used in this study have different period and that was considered when the data were linked. The sample selection steps are demonstrated in Figure 8, and the final sample structure with linking levels is presented on Figure 7.

Figure 8

Sampling technique for SPARCS data sample extrapolation



Source: Original drawing

The Secondary Datasets

In this study the following secondary datasets were utilized to create the data sample needed to evaluate the research questions: a) clinical data from SPARCS New York State from 2006-2016; b) SDOH from U.S. Census ACS 2011 and 2016 five years estimates for New York State; c) SDOH from CDC SVI 2010 and 2016 estimates for New York State; and d) SDOH from USDA 2003 and 2013 Urban Rural Continuum codes for New State. All data sets contain secondary data and are described in detail below.

New York State SPARCS Inpatient Discharge Data

The clinical data sample for this study was withdrawn from a large secondary data from SPARCS New York State data from 2006-2016. The data were appropriate as it is an inclusive all-payers data reporting system and has the clinical variables needed for this study (New York State Department of Health, 2016). The SPARCS database collects records from more than 200 hospitals in New York State. The data have information on patient demographics, preoperative diagnoses and surgical treatments, health insurance type, preoperative morbidity and postsurgical complications, readmission, and information about the hospital providing the care. One challenge was the coding of the complications, as SPARCS does not have a separate one variable or data point specifically for the anastomotic leak, other single complications or composite outcomes such as surgical site infection, and the other outcomes, but rather has the information for each complication coded as part of the digestive system complications and several codes for a single complication may be used according to the clinical manifestation of the complication.

In order to identify each complication all, the codes from ICD- 9 and ICD- 10 related to that complication has to be used. For example, intra-abdominal abscess could be codded differently depending on the place in the abdomen it occurs like pelvic abscess, abdominal abscess or retroperitoneal abscess. For this study, AL and the other study outcomes from SPARCS data were identified by using ICD-9 and ICD-10 codes listed in Appendix B, Table B2. The patients undergoing large bowel resection were identified by the appropriate procedure ICD-9 and ICD- 10 codes. All surgical complications needed for the outcome variables were identified from the SPARCS data at index admission as a diagnosis “Not Present on Admission or upon readmission” to any hospital in New York State within 30 days of surgery. Present on Admission (POA) indicator 1-24, page 153 NYS SPARCS Dictionary Version 1.0 2014 was be used. All the codes were reviewed by professional coder and a colorectal surgeon before submitting for the final sample extrapolation. All codes used for the sample inclusion and exclusion criteria and for the study outcomes are listed in detail in Appendix B.

The New York State SPARCS data are available in many health care institutions and kept on the institutional servers as per New York State requirement. The data has data manager at each institution responsible for the housing of the data and its proper use. An access to the New York State SPARCS data can be obtained after IRB approval and by mandatory signing of the custom SPARCS Limited and Identifiable Individual Data Use Agreement from New York State SPARCS office

(New York State Department of Health, 2016). SPARCS offers three levels of access to the data (public, limited, and identifiable) and depending on the needed data documentation to access the data and approval from SPARCS is needed. Documentation submission is required for limited or identifiable data. The public dataset is freely available for use. The SPARCS agreement had to be signed by the individual user and also by the SPARCS data manager providing the data. All the available data elements from the SPARCS data are listed in Appendix B, Table B4. The SPARCS data have some social determinants of health variables at individual patient level (Appendix B, Table B4) such as race, health insurance type, and hospital volume which were used on individual level. The SPARCS data were linked to SDOH data from U.S. Census ACS, CDC SVI, and USDAER estimates for New York State on zip code and county code levels, thus composing the sample used to evaluate the study objective on the zip code and county level and provide generalizability of the results to New York State.

U.S. Census American Community Survey SDOH Data

ACS is U.S. Census Bureau annual survey collecting data on housing, educational attainment, income, language proficiency, migration, disability, employment, and poverty in all United States' states and Puerto Rico. The data from the ACS have been used from programs and policy planners for the communities (US Census Bureau, 2018). Individual variable such as educational attainment, median household income, occupation, language, GINI index of inequality, and others from 2011 and 2016 5-year estimates of ACS for New York State were linked on patient' zip code level with SPARCS data file. Since the clinical data includes patients from 2006 to 2016 the data were linked with the appropriate year estimates or the closest available estimates for better accuracy. (Figure7) ACS data estimates with ZCTA (ZIP Code Tabulated Area) are publicly available and free to use from U.S. Census American Fact Finder (U.S. Census Bureau, 2018c). New York State SPARCS data office has been notified for linkage with the preliminary application for permission to use SPARCS data. ACS data is appropriate as it contain SDOH variables needed for this study.

Centers for Disease Control and Prevention Social Vulnerability Index

The CDC SVI estimates for New York States from 2010 and 2016 were used in this study and linked on patient zip code and county code levels. CDC SVI was developed based on 15 variables from the U.S. Census ACS data, grouped in four categories composite variables, also called themes, and measured by total rank score. The four themes are composite variables comprised as follow: Theme 1: Socioeconomic Status (including income, poverty, employment, and education variables); Theme 2: Household Composition and Disability (including age, single parenting, and disability variables); Theme 3: Minority Status and Language (including race, ethnicity, and English language proficiency variables); Theme 4: Housing and Transportation (including housing structure, crowding, and vehicle access variables) (Flanagan et al., 2011). SVI themes as composite variables are part of key areas of SDOH and appropriate to use when evaluating SDOH association with health outcomes. SVI themes are already calculated with considering the multidimensional aspect of the key social determinants such as poverty and income just to mention a few.

The flagged version of the themes shows the 90 percentile vulnerability or the most vulnerable layer of the population (CDC, 2017e). SVI originally has been designed to assess the community resilience and vulnerability during stresses from natural or human-caused disasters or disease outbreaks and is used for assessment in needs for hazard preparedness and support and is also recommended for assessment of medical situation (Agency for Toxic Substances and Disease Registry, 2018; Flanagan et al., 2018).

The SVI data is publicly available and can be downloaded free from data and tool download of the CDC site (CDC, 2017e). No special permission is required. The crosswalk method from census tract to zip code using the closest ZCTA centroid was approved by the CDC SVI coordination team with the assumption that the closest ZCTA centroid presents the largest population in the zip code. The ArcGIS 10.2 and SAS software were used for the crosswalk from census tract to zip code. The SVI on county code was already available from CDC SVI site and no crosswalk was needed for the data linking on this level (Figure 7). The CDC SVI estimates from 2016 and 2010 on census tract for New York State were cross walked from census tract to zip code and were linked to the data on patient zip code level using SAS and ArcGIS 10.2 software. SVI 2016 estimates were linked to clinical data from 2012 to 2016, and the SVI 2010 estimate were used and linked to data from 2006 to 2011. On county level CDC SVI 2016 estimates were linked to the available study data sample as this is the only county estimate. The following steps were used for linking SVI on zip code level using SAS and ArcGIS: Step 1) Zip codes in SPARCS dataset were linked to zip code tabulation areas (ZCTAs) using SAS; Step 2) The Centroids of the ZCTAs were linked to the ZIP codes using SAS; Step 3) The census tract in which the ZCTA centroids fall in was the tract used for assigning the CDC SVI to the centroid as well as the ZIP code. ArcGIS 10.2 software was used to determine this step.

USDA 2013 Rural Urban Continuum Codes Data

The final portion of the data sample is data related to urban and rural assignment in New York State geography from United States Department of Agriculture Economic Research Service (USDAER, 2019). USDA Rural-Urban Continuum Codes groups the counties on metropolitan or nonmetropolitan, urban and rural by the population size of their metro area, and by degree of urbanization and adjacency to a metro area (United States Department of Agriculture Economic Research Service [USDARS], 2019). The data is publicly available and can be downloaded from USDA site. For this study, the 2003 and 2013 Rural-Urban Continuum Codes were used to evaluate urban, rural and metro versus not, as social determinants in the study. The 2013 updates were used for the clinical data from 2013 to 2016, and the 2003 rural urban codes were used for the data from 2006 to 2012 as these codes were valid until 2013 and thus provided more accurate representation of the areas (Figure7). The data come with county codes and was linked on patient county level.

This study used limited identifiers SPARCS data, with the only limited identifier being “age” as continuing variable, and that variable was used as categorical in the analyses. All the rest of the data were completely deidentified including the zip code which was provided only with the last 3 digits. Permission from the IRB, the New York State SPARCS office and the primary holder of the SPARCS master file were obtained, in order to extrapolate and present the specific data required for this study. New York SPARCS custom Individual Disclosure Agreement was signed by the data user and the data primary holder. This approach to data acquisition was applied to avoid a conflict of interest or HIPAA violation. The data file needed for this study was extrapolated by the data holder using ICD 9 and ICD 10 codes (Appendix B, Tables B1, B2, and B3) and was linked to the SDOH data files by the data provider. After all the files were linked, the final study file was deidentified by the data provider and presented to the data user for this doctoral project use.

Sample Size

This was a quantitative cross-sectional study using secondary data, and power calculation was needed especially if no statistical difference is detected in the analyses. The sample for the analyses included all the available cases in the secondary datasets that meet the inclusion and exclusion criteria. Lack of data on the effect size of the SDOH on the study outcomes in the current study (AL, SSI, Not_SSI, and overall surgical COMPL) makes challenging to determine how much should the effect size be to have meaningful statistical differences. Therefore, after data collection and analysis, post hoc power analysis was conducted to confirm the sufficiency of the samples. The final study sample size (SPARCS data linked with SDOH data) after the final data cleanup during which an additional 21 subjects were removed, is total of 130 731 patients, and it is representative for the New York State population undergoing initial large bowel resection. The current study outcomes rates within 30 days after surgery completion in this study sample of *N*=130 731 were: AL-13.33 %, SSI-16.4%; Not SSI-related complications-13.8%, Infectious complications(all)-22.51%; Non-Infectious complication- 17.25%, and overall surgical morbidity-28.71%. The in-hospital mortality was 5 082(3.9%). Even though during preparation for the analyses and data cleanup period small number of patient (21 patients) were excluded from the analyses, this sample size is considered large and was sufficient for the evaluation of the four research questions in this study.

Instrumentation and Operationalization of Constructs

In this study data instrumentation was not used as the data were already collected. The theoretical framework applied in the study was already developed and utilized for study purpose and can be used without special approval. Furthermore, the International Classification of Diseases, Ninth and Tenth Revision, Clinical Modification (ICD-10) coding system as well as ICD-9 system was used if needed to identify the patients that could be included in the sample from the SPARCS data, as well as to identify the study outcomes and the covariate from SPRARCS data.

World Health Organization Conceptual Model for SDOH

For the theoretical constructs of this study, the WHO conceptual model was adopted to explain the study outcomes as social production. Initially, the model was developed by Diderichsen (2001) based on the theory of the social production of the diseases and adopted by WHO in their CSDH framework. This framework also utilizes the SEM model which allowed for selection and classification of the SDOH at each

SEM level. As the framework is adopted and WHO SDOH Conceptual model cited, no special permission is required as the model is constructed to be used for SDOH evaluation and policies development subsequently.

Operationalization of Constructs

The definition and measurement of each variable was used according to the data dictionaries from the secondary data sources. The definition of each variable was described including how it was measured and the type of measurement unit. An example of the variables is provided as well as the website link to each data dictionary in Appendix A. Some of the variables were categorized further and regrouped for the analyses of the current study. For example, “age” from SPARCS data was provided as continuous variable but used as categorical variables. The ACS 2016 dictionary is at the following link: https://www2.census.gov/programs-surveys/acs/tech_docs/subject_definitions/2016_ACSSubjectDefinitions.pdf?#, and the CDC SVI dictionary has been listed in details in this link https://svi.cdc.gov/Documents/Data/2016_SVI_Data/SVI2016Documentation.pdf.

The Outcome/Dependent Variables Definitions

Anastomotic Leak within 30 Days

Anastomotic Leak 30 days was defined for this study as bowel leakage from the anastomosis into the abdomen, pelvis or perianal area and collection around anastomotic site, or extension out from the surgical wound, drain site or anus, causing fever, abscess, organ-space infection, septicemia, peritonitis and/or organ failure (Trencheva et al., 2013, p.109). This definition of AL was adopted and modified for this study from Trencheva et al. (2013) prospective study to guide the selection of the diagnostic ICD-9-CM and ICD-10 -CM codes for AL during the study data sample extrapolation from the SPARCS master datafile (Appendix B, Table B2). In the SPARCS data, AL was identified by the following ICD-9 Codes 997.49, 997.4, 567.22, 569.81, 567.21,469.4, 567.29, and 567.9, diagnostic system, and from ICD -10 -CM the following K91.89, K65.1, K63.2 K91.81, K91.89, K65.8, K65.9, T81.32XA, T81.89XA, K91.85 codes are designed to reflect (Appendix B, Table B2). Every subject who had one or more of these codes was considered to have AL presented as dichotomous "Yes" or "No" variable.

Overall Surgical Complications within 30 Days

Overall surgical complications (COMPL) within 30 days were: any adverse events or deviation from the normal recovery course following surgery in or out of the hospital within 30 days in patients after colorectal surgery (Dindo et al., 2004). This definition was modified from Dindo-Clavien (2004) regarding the time interval of 30 days, and the setting of the complication occurrence. The overall post-surgical complications after large intestinal surgery may include but not limited to: infectious complications (SSI, AL, abdominal abscess, pelvic abscess, retroperitoneal abscess, peritonitis, sepsis, organ space infection, VRE, MRSA, pneumonia etc.) and non-infectious (stroke, myocardial infarction, organ failure, pulmonary embolism, deep vein thrombosis, ileus, etc. (Figure 3 and Appendix B, Table B2). All surgical complications needed for the outcome variables were identified from the SPARCS data at index admission as a diagnosis "Not Present on Admission or upon readmission" to any hospital in New York State within 30 days of surgery. Present on Admission (POA) indicator 1-24, page 153 NYS SPARCS Dictionary Version 1.0 2014 was used. In the SPARCS dataset, the surgical complications in the sample were identified by the following ICD 9 and ICD 10 Codes: '9974', '56722', '56981', ‘56721’, ‘5695’; ‘998.59’, and many other codes presented in Appendix B, Table B2. The overall surgical COMPL were measured as dichotomous “Yes” or “No” variable. In every subject who had one or more surgical complications, this variable was considered “Yes”. In this study the post discharge overall surgical complications were defined as surgical complications which occurred from date of discharge to 30 days after completion of surgery. This outcome provides only the fraction of overall surgical morbidity that occurs outside the hospital after discharge. This was a secondary outcome.

Infectious Surgical Complications within 30 Days

Infectious complication after surgery was any infection caused by bacteria, virus or fungi within 30 days after surgery and requiring treatment. As an outcome, “infectious surgical complications” were measured as a binary outcome “Yes" or "No" within 30 days after surgery and in or out of the hospital. The infectious surgical complications included both surgical site and non-surgical site infectious complications such as: wound infection, abdominal abscess, pelvic abscess, retroperitoneal abscess, AL, septicemia, MRSA, VRE and pneumonia, caused by bacteria, virus or fungi (Figure 3). The definitions of each of the infectious complications were listed in the Appendix A and were identified ICD 9 and ICD 10 codes from SPARCS data as listed in surgical complications section above and in Appendix B, Table B2.

Surgical Site Infection (SSI) within 30 Days

SSI after surgery was any infection related specifically to the surgical resection site and caused by bacteria, virus or fungi within 30 days after surgery date and requiring treatment. As an outcome, SSI were measured as a binary outcome "Yes" or "No" within 30 days after surgery and in or out of the hospital. The SSI complications included only complications related directly to the surgical site such as: wound infection, abdominal abscess, pelvic abscess, retroperitoneal abscess, AL, and septicemia (Figure 3) The definitions of each of the infectious complications are listed in the Appendix A and were identified via corresponding ICD 9 and ICD 10 codes from SPARCS data as listed in surgical complications section above and in Appendix B, Table B2.

Not SSI Related Infectious Complications within 30 Days

Not SSI are infections after surgery not related directly to the surgical site incision but to other areas of the body and include infections such as pneumonia, bloodstream infections, Clostridium difficile colitis, MRSA, VRE, urinary tract infection and infectious colitis, caused by bacteria, virus or fungi and requiring treatment (Figure 3) The Not SSI infections are also called nosocomial or since 2008 hospital acquired infections (HAI). In the surgical patients any of the Not SSI complication are considered hospital acquired (nosocomial) if they occurred within 30 days after the surgical procedure regardless if diagnosed during the hospital stay or after hospital discharge (Alkaakiet al., 2019; Horan et al., 2008). The Not SSI related (nosocomial) infectious complications may be caused by bacteria, virus , fungi, or surgical devices within 30 days after surgery date in or out the hospital and requiring treatment (WHO, 2002). As an outcome, “Not SSI”” were a composite variable measured as a binary outcome, “yes" or "no" within 30 days after surgery in or out of the hospital. The ICD 9 and ICD 10 codes used to identify the infections included in the outcome Not SSI related infectious complications are listed in Appendix B, Table B2.

Non-Infectious Surgical Complications within 30 Days

The outcome “Non-infectious surgical complications " after colorectal surgery were measured as a binary outcome “yes" or "no" within 30 days after surgery and in or out of the hospital. The Non-infectious surgical complications include major surgical complications within 30 days of the surgery such as: myocardial infarction, stroke, pulmonary embolism, deep vein thrombosis (DVT), bleeding, bowel obstruction, and postoperative ileus, which were not caused by infectious agent but from other factors such as physiological, environmental, behavioral, and genetic factors just to mention a few (Figure 3). Each noninfectious complication was identified from the SPARCS data by using ICD 9 and ICD 10 codes listed in Appendix B, Table B2. The mortality rate was reported separately.

Independent Variables SDOH

The independent variables were single measure or composite SDOH at individual or area-based levels- zip code and county code. Some of the SDOH such as race, medical insurance coverage, hospital volume, hospital county code/location, hospital volume is from SPARCS data itself, and some related to economic stability (median household income, poverty rate, GINI index) are from ACS estimates. The composite SDOH variables related to neighborhood and built environment and social and community context as Social Vulnerability Themes (Theme 1: Socioeconomic Status, Theme 2: Household Composition and Disability; Theme 3: Minority Status and Language; Theme 4: Housing and Transportation) and the Overall Themes score were evaluated on zip code and county code levels (Flanagan et al., 2011). All the SDOH independent variables are listed in Appendix B, Table B4.

Covariates from SPARCS data were age, sex, preoperative diagnosis (neoplasm, IBD, diverticulitis, and others), surgical procedure, surgical approach, anastomosis type, diverting stoma, and others. The definition of each variable was according to the definitions of the SPARC data dictionary, ACS, and CDC SVI dictionaries accordingly as well as the concept definitions provided in Appendix A.

Confounding Variables

As in this study a secondary data was used, it was important to take under consideration confounding variables that could influence the study outcomes, and that may not be part of the dataset. It is critical to consider possible confounders as they introduce bias to the study and affect the study validity. Bias, confounding and random error has to be eliminated in order the results to be considered true (Aschengrau & Seage, 2014). Confounding variables may be lack of community hospital, emergency rooms or medical clinics in the neighborhood, or perhaps a lack of trained medical personnel in the community clinics. This information may impact the time of accessing care in case of emergency and may affect the development of the postoperative adverse event. Also, there is no information on the distance from the index hospital, which could be related to timely access to health care.

Research Question(s) and Hypotheses

The following four research questions were addressed in the study:

1. Research Question 1 (RQ1): Is there an association between SDOH and AL occurrence within 30 days after colorectal surgery in and out of the hospital in adult patients?

Null Hypothesis ($H_0 1$): SDOH are not associated with AL occurrence within 30 days after large intestinal resection in and out of the hospital in adult patients.

Alternative Hypothesis ($H_1 1$): SDOH are associated with AL occurrence within 30 days after large intestinal resection in and out of the hospital in adult patients.

The outcome or dependent variable was AL after colorectal surgery within 30 days after surgery in or out of the hospital measured as a binary outcome "yes" or "no". The ICD 9 and ICD 10 identification codes are listed in Appendix B, Table B2. The independent variables were individual level and area based (zip code and county code) SDOH and included: home setting Metro/Nonmetro area, race, nativity status, language proficiency, education, employment, unemployment, median household, median family and per capital income, different levels of poverty status, GINI inequality index, Social Vulnerability Index at zip code level and county levels (the overall theme and the four themes [Theme1: Socioeconomic Status, Theme 2: Household Composition and Disability, Theme 3: Minority Status and Language, Theme 4: Housing and Transportation], as well as the flagged version of the themes which present the 90 percentile within each of the themes), access to health care by health insurance type at individual level and as estimate for the community on zip code level, hospital case volume, transportation ability by owning a vehicle (see Appendix B, Table B4). The covariates were age, sex, preoperative diagnosis, surgical procedure, surgical approach, anastomosis type, diverting stoma, and comorbidity at time of surgery using APRSOI index, and admission type. Each variable is defined in the definition section and Appendix A and Appendix B, Table B1.

2. Research Question 2 (RQ2): Is there an association between the SDOH and the surgical site infection (SSI) within 30 days after colorectal surgery in and out of the hospital in adult patients?

Null Hypothesis ($H_0 2$): SDOH are not associated with SSI occurrence within 30 days after large intestinal resection in and out of the hospital in adult patients.

Alternative Hypothesis ($H_1 2$): SDOH are associated with SSI occurrence within 30 days after large intestinal resection in and out of the hospital in adult patients.

The outcome or dependent variable were “surgical site infection” (SSI) after colorectal surgery measured as a binary outcome “yes" or "no" within 30 days after surgery and in or out of the hospital. “SSI” in this study included the following surgical site infectious complications within 30 days of the surgery such as: wound infection, abdominal abscess, pelvic abscess, retroperitoneal abscess, and AL. The definitions of each of the infectious complication are listed in the Appendix A and the ICD 9 and ICD 10 identification codes in Appendix B, Table B2.

The independent variables were individual level and area based (zip code and county code) SDOH and included: home setting Metro/Nonmetro area, race, nativity status (U.S. native/Foreign born), language proficiency, education, employment, unemployment, median household, median family and per capital income, different levels of poverty status, GINI inequality index, Social Vulnerability Index at zip code level and county levels (the overall theme and the four themes [Theme1: Socioeconomic Status, Theme 2: Household Composition and Disability, Theme 3: Minority Status and Language, Theme 4: Housing and Transportation], as well as the flagged version of the themes which present the 90 percentile within each of the themes), access to health care by health insurance type at individual level and as estimate for the community on zip code, uninsured hospital days, hospital case volume, household transportation ability by owning a vehicle. The covariates were: age, sex, preoperative diagnosis, surgical procedure, surgical approach, admission status, diverting stoma, anastomosis type and comorbidity at time of surgery by APRSOI. Each variable is defined in the definition section.

3. Research Question 3 (RQ3): Is there an association between SDOH and overall surgical complications (infectious and noninfectious) occurrence within 30 days after colorectal surgery in and out of the hospital an adult population?

Null Hypothesis ($H_0$3): SDOH are not associated with overall surgical complications occurrence within 30 days after large intestinal resection in and out of the hospital in adult patients.

Alternative Hypothesis ($H_1$3): SDOH are associated with overall surgical complication occurrence within 30 days after large intestinal resection in and out of the hospital in adult patients.

The outcome or dependent variable was “overall surgical complications” (COMPL) after colorectal surgery measured as a binary outcome – "yes" or "no" within 30 days after surgery and in or out of the hospital. COMPL included infectious (wound infection, abdominal abscess, pelvic abscess, retroperitoneal abscess, AL, septicemia, MRSA, VRE, pneumonia, and clostridium difficile, infectious colitis, and urinary tract infection), and non-infectious (myocardial infarction and cardiovascular, stroke, pulmonary embolism, deep vein thrombosis [DVT], bleeding, bowel obstruction, and postoperative ileus) surgical complication within 30 days of the surgery in and out of the hospital (see Appendix B, Table B2).

The independent variables were individual level and area based (zip code and county code) SDOH and included: home setting Metro/Nonmetro area, race, nativity status (U.S. native/Foreign born), language proficiency, education, employment, unemployment, median household, median family and per capital income, different levels of poverty status, GINI inequality index, Social Vulnerability Index at zip code level and county levels (the overall theme and the four themes [Theme1: Socioeconomic Status, Theme 2: Household Composition and Disability, Theme 3: Minority Status and Language, Theme 4-Housing and Transportation], as well as the flagged version of the themes which present the 90 percentile within each of the themes), access to health care by health insurance type at individual level and as estimate for the community on zip code, uninsured hospital days, hospital case volume, household transportation ability by owning a vehicle. The covariates were: age, sex, preoperative diagnosis, surgical procedures approach, admission status, diverting stoma, anastomosis type and comorbidity at time of surgery. Each variable is defined in the definition section and in Appendix A and Appendix B, Table B1.

4. Research Question 4 (RQ4): Is there an association between the SDOH and Not SSI related (hospital acquired) infectious complications within 30 days after colorectal surgery in and out of the hospital in adult patients?

Null Hypothesis ($H_0$4): SDOH are not associated with Not SSI (hospital acquired) infectious complications occurrence within 30 days after large intestinal resection in and out of the hospital in adult patients.

Alternative Hypothesis ($H_1$4): SDOH are associated with Not SSI related (hospital acquired) infectious complications occurrence within 30 days after large intestinal resection in and out of the hospital in adult patients.

The outcome or dependent variable was “Not SSI” hospital acquired infectious complications" after colorectal surgery measured as a binary outcome "yes" or "no" within 30 days after surgery and in or out of the hospital. Not SSI (nosocomial or hospital acquired) infectious complications include septicemia, MRSA, VRE, pneumonia, urinary tract infection, and clostridium difficile and infectious colitis all caused by bacteria, virus, or fungi. The definitions of each of the infectious complications are listed in Appendix A and ICD 9 and ICD10 codes used for identification are listed in Appendix B, Table B2.

The independent variables were individual level and area based (zip code and county code) SDOH and included: home setting Metro/Nonmetro area, race, nativity status (U.S. native/Foreign born), language proficiency, education, employment, unemployment, median household, median family and per capital income, different levels of poverty status, GINI inequality index, Social Vulnerability Index at zip code level and county levels (the overall theme and the four themes [Theme1: Socioeconomic Status, Theme 2: Household Composition and Disability, Theme 3: Minority Status and Language, Theme 4: Housing and Transportation], as well as the flagged version of the themes which present the 90 percentile within each of the themes), access to health care by health insurance type at individual level and as estimate for the community on zip code, uninsured hospital days, hospital case volume, household transportation ability by owning a vehicle. The covariates were age, sex, preoperative diagnosis, surgical procedures, surgical approach, admission status, diverting stoma, anastomosis type, length of hospital stay, and comorbidity at time of surgery. Each variable is defined in the definition section in Appendices A and B.

Data Analysis Plan

In this study the statistical software SPSS v.25 (Walden University) was utilized to conduct the statistical analyses. The secondary data cleaning process for each sample were described below.

Data Cleaning

The study file was provided deidentified and with all SDOH linked to zip code and county code by the data provider. New York State SPARCS study data file first was extrapolated from the overall master SPARCS data by using ICD-9 and ICD-10 codes. The codes that were used to identify the SPARCS data sample and the outcome variables are listed in Appendix B, Tables B1, B2 and B3. All records missing SDOH were removed, as it is not possible to replace the data. The incomplete file records were noted with “I” in the SPARCS data and easily were removed from the sample, through running frequencies analysis. The missing data from the numerical continuous variables were substituted with the average value of that variable based on the completed cases. The missing categorical data were re-categorized if needed. Variables presented with a numerical value of 10 and below were not used and not reported as separate variable per the New York State SPARCS data use agreement but were clustered with other similar categories. For example, if mortality was a total of 10 patients, it would not be evaluated or reported as separate outcome.

ACS missing data in the cases with zip codes from ACS 2011 and 2016 estimates were imputed with the median of the data point calculated within the county the missing data belongs to in the ACS year of estimate. For SPARCS cases with zip codes not in ACS files estimates, the missing data were imputed with ACS data using the median calculated from the data from the Zip codes available in the county the missing data zip code belongs to. In the ACS data total of 899 cases out of 130 752 cases were missing some ACS estimates on zip code, only 0.7% of the sample, therefore the missing data impute won't impact the results.

The SVI missing values on the Zip code level for 351 cases (12 unique Zip codes) were imputed. Using ArcGIS software, the closest census tract with non-zero population to these 12 zip codes was selected. Total of 351 cases out of 130 752 were missing SVI on Zip code, only 0.3% of the sample, therefore the missing data impute will not impact the results. Assumption: The closest census tract was used for data impute based on the following assumption: when the ZCTA centroids fall into a census tract with zero population, or the Zip codes are linked to only one census tract and that census tract has 0 population, there was selected the closest census tract to the ZCTA centroids by assuming that a greater fraction of the population in the closest ZCTA census tract would fall into the zip code. In the final data cleaning prior to analyses and additional 21 cases were removed, leaving the total sample of *N*=130 731 patients.

Statistical Analysis Plan

Each hypothesis was evaluated with the final study data sample. The final New York State SPARCS dataset linked with the SDOH, provides information about the SDOH association with the outcomes on zip, county, city and state level. The overall statistical analysis plan included: a) Descriptive analysis; b) Univariate/ bivariate analysis; c) Regression analysis to evaluate for the association of the SDOH and the outcome variables in the models. All results are presented in tables and graphs appropriately in Section 3. Research questions 1, 2, 3, and 4, all have categorical binary outcome variables as "Yes" and "No" and have same independent SDOH variables, and covariates included in the analyses. Therefore, the statistical analyses for each research questions and hypothesis are the same.

Analyses Research Questions 1, 2, 3, and 4

The descriptive analyses included frequencies, distribution, and measures of central tendencies and dispersion. Next, comparisons were done by using bivariate analysis such as Chi-square test for categorical data. Non-parametric Fisher exact test was used for the comparison of the subgroup analysis in the data sample, if needed. Since the outcomes AL, SSI, overall surgical COMP, and Not SSI are categorical dichotomous variables "yes" and "no," binomial logistic regression analysis was used to evaluate the association of the SDOH and the outcomes in the models. Odds ratio and the 95 % Confidence Intervals for the parameter estimates were presented to interpret the results from the logistic regression. Evaluation of the binomial logistic regression seven assumptions were tested prior to analyses of the data. The binomial logistic regression assumptions were as follows: a) dependent or outcome variable is dichotomous or to has only two outcomes; b) one or more independent variables that could be either continuous or categorical; c) there is presence of independence of observations, and mutually exclusive categories in the dependent variable(s); d) there is existence of linear relationship between the continuous predictor variables and the log odds of the dependent variable; e) absence of extreme outliers in the continues predictor variables; f) there is little or no multicollinearity among the independent variables; g) large sample size (Laerd Statistics, 2018; Munro, 2005).

Threats to Validity

The goal of this study was to find out if the SDOH (independent variables) influence the occurrence of AL, SSI, Not SSI (nosocomial/ hospital acquired), and overall surgical COMPL (infectious surgical complications and non-infectious surgical complications) within 30 days after surgery in and out of the hospital in patients after colorectal surgery. To ensure valid study findings and conclusions, indicators of quality validity and reliability were considered. The concept of validity is related to the truth and accuracy of the data and how accurately the data present the phenomenon under the study. As this study used secondary data, the validity depends on the quality of the data, measurement level, the method of the data collection, type of variable collected, sample size of the collected data, and the contextual variable in the data. The data used in this research study consist of already collected quantitative data, with standardized definitions and measurements of the variables in the data and are appropriate to answer the specific research questions of this study. Further, the definitions and the measurements used during the time secondary data were collected in the datasets in this study would provide study results that would be comparable to already published studies that have used the same or similar data. Some of the SDOH could be defined also as contextual variables, such as race, and ethnicity. Race and ethnicity are socially constructed variables.

There are three aspects of validity: content validity, construct validity and criterion-related validity. Because the study uses secondary data, construct validity has to be considered to minimize the study bias. The secondary datasets consist of prospectively collected data from hospital electronic medical records. In the SPARCS data, all hospitals that are contributing to the state data, are using the same methodology to collect it and report it to the state, thus increasing the reliability of the data. For the data from U.S. Census, CDC SVI, and USDARS the data are collected under predefined definitions and systematically and updated periodically. The definitions used at the time of the data collection were used in this study to minimize bias (New York State Department of Health, 2016; Trencheva et al., 2013)

Also, post hoc power analysis was conducted to confirm the sample size sufficiency. The sample size is directly related to the accuracy and precision. This study uses a data sample including data from four different sources which were either state or government such as the statewide database (New York State SPARCS), U.S. Census, CDC and USDA. This may affect the external validity of the study. The sample results can apply only for New York State and may not be valid for other states or transferable beyond that. However, the study methodology may be used from other institutions to conduct similar studies. The results from the SPARCS data, could be generalized for New York City and New York State as the data is representative of the NYS population. However, even though SPARCS data can be considered representative for the New York State population, not all existing hospital contributed to the data if they do not meet the SPARCS criteria, and this need to be considered when generalizing the results. Finally, people live in a dynamic continuously changing system, thus the data may not apply for future prediction even in the New York State.

Ethical Procedures

Once the study proposal was approved, applications to the Institutional Review Board committee were submitted to Walden University IRB. The access to the SPARCS data was gained via the Institutional Review Board (IRB) approval and approval from New York State SPARCS data office for the SPARCS data and signing of the mandatory custom SPARCS Limited and Identifiable Individual Data Use Agreement from New York State SPARCS office and the data holder (New York State Department of Health, 2016). To carry this research proposal for doctorate fulfillment, approval from Walden University IRB was obtained. This research study was implemented in accordance with the approved Walden University IRB protocol. Since the data already exist, no new consent from subjects was needed. No approvals were needed to use the data from SDOH from U.S. Census ACS estimates, CDC SVI or USDA Rural urban Continuum codes on zip code level or county level. The information is freely available to use. The New York State SPARCS Data Use agreement was signed. The entire study data sample (SPARCS data linked with the SDOH) was provided for this doctoral study deidentified by the data holder and provider.

All the statistical analyses were conducted on an encrypted computer to ensure data security even though the data were deidentified. Since this is secondary data, there are no recruitment issues to address in this study. The master SPARCS dataset is vast, and thus is stored on a special encrypted institutional server. The New York State SPARCS office requires the SPARCS data with identifiers to be stored in institution's servers. With the permission of New York State SPARCS office, the primary investigator owning the SPARCS data extrapolated the sample needed for this study and connected the sample with all SDOH. Once that was done, the SPARCS data sample identifiers were removed and deidentified data was presented for doctoral study analysis and shared with doctoral study supervisory committee. The SPARCS data sample can be used only for this doctoral study in Walden University. According to December 2019 SPARC data policy regarding publications, all publications utilizing SPARCS data must include the following disclaimer: "This publication was produced from raw data purchased from or provided by the New York State Department of Health (NYSDOH). However, the conclusions derived, and views expressed herein are those of the author(s) and do not reflect the conclusions or views of NYSDOH. NYSDOH, its employees, officers, and agents make no representation, warranty or guarantee as to the accuracy, completeness, currency, or suitability of the information provided here."

The data were analyzed as a cluster, and no individual data will be disseminated. The results are reported as a group, and no personal information or identifiers are to be published. There was no conflict of interest to report in this study. While the data for this study proposal were provided from the institution of the own work environment, there was no conflict of interest as the direct work environment is in a different department. In addition, the study data was already existing in New York State SPARCS data office, U.S. Census ACS, the CDC SVI, and were not collected specifically for this study, neither there was a partaking in the original New York State

SPARCS data collection, or in any of the other data linked to the SPARCS data file. In addition, the data sample was extrapolated by data holder and presented deidentified to the data user. Finally, there was an independent institutional mentor that was monitoring for proper and ethical use of the data, and to ensure there was for conflict of interest.

Summary

In this research study the problem of surgery related morbidity was addressed in and beyond the hospital setting by including data analyses regarding the community environment to where patients are discharged. Understanding the role of SDOH on surgery related morbidity, and what social determinants influence the recovery process after surgery is critical for decreasing surgical morbidity and mortality and improving overall surgical safety and wellbeing of patients, and the health equity in people undergoing colorectal surgery, thus bring about a significant positive social change (Meyers et al., 2014; Robinson, 2017). Therefore, by using the selected secondary data and specific research design and theoretical framework, the main purpose of this research doctoral study was to evaluate the association between the SDOH and AL, SSI and Not_SSI and overall surgical morbidity occurrence after colorectal surgery within 30 days in and out of the hospital in adult patients.

In this section a detailed description of the study implementation plan was provided, which included a description of the research approach, selected research design and rational, and the method suitable for the selected approach. The study population, sampling frame, sample strategy and detailed data analysis plans was presented in the method section. In the method section, study validity threats and ethical concerns were also addressed. This section was the main guideline to the study implementation to test the hypotheses and answer the research questions. In the next section, the actual acquisition of the data, data preparation for analyses, and the results from the data analyses were presented. The results were presented using data tables and figures appropriate for the statistical analyses and for representing the specific data.

Section 3: Presentation of the Results and Findings

Introduction

The purpose of this quantitative cross-sectional study was to explore the association of individual and area-based levels SDOH with surgical complications occurrence within 30 days in adult patients after initial colorectal surgery in or out of the hospital. The following four specific research questions and hypotheses were addressed in the study:

1. Research Question 1 (RQ1): Is there an association between SDOH and AL occurrence within 30 days after colorectal surgery in and out of the hospital in adult patients?

Null Hypothesis ($H_0 1$): SDOH are not associated with AL occurrence within 30 days after large intestinal resection in and out of the hospital in adult patients.

Alternative Hypothesis ($H_1 1$): SDOH are associated with AL occurrence within 30 days after large intestinal resection in and out of the hospital in adult patients.

The outcome or dependent variable was AL after colorectal surgery within 30 days after surgery in or out of the hospital measured as a binary outcome-"yes" or "no". The ICD 9 and ICD10 codes used for identification are listed in Appendix B, Table B2.

2. Research Question 2 (RQ2): Is there an association between the SDOH and the surgical site infection (SSI) within 30 days after colorectal surgery in and out of the hospital in adult patients?

Null Hypothesis ($H_0$2): SDOH are not associated with SSI occurrence within 30 days after large intestinal resection in and out of the hospital in adult patients.

Alternative Hypothesis ($H_1$2): SDOH are associated with SSI occurrence within 30 days after large intestinal resection in and out of the hospital in adult patients.

The outcome or dependent variable was SSI after colorectal surgery measured as a binary outcome “yes" or "no" within 30 days after surgery and in or out of the hospital. “SSI” in this study included the following surgical site infectious complications within 30 days of the surgery such as: wound infection, abdominal abscess, pelvic abscess, retroperitoneal abscess, and AL. The definitions of each of the infectious complication are listed in the Appendix A and the identification ICD 9 and ICD 10 codes in Appendix B, Table B2.

3. Research Question 3 (RQ3): Is there an association between SDOH and overall surgical COMPL (infectious and noninfectious) occurrence within 30 days after colorectal surgery in and out of the hospital an adult population?

Null Hypothesis ($H_0$3): SDOH are not associated with overall surgical COMPL occurrence within 30 days after large intestinal resection in and out of the hospital in adult patients.

Alternative Hypothesis ($H_1$3): SDOH are associated with overall surgical COMPL occurrence within 30 days after large intestinal resection in and out of the hospital in adult patients.

The outcome or dependent variable was “overall surgical complications” (COMPL) after colorectal surgery measured as a binary outcome "yes" or "no" within 30 days after surgery and in or out of the hospital. COMPL included infectious (wound infection, abdominal abscess, pelvic abscess, retroperitoneal abscess, AL, septicemia, MRSA, VRE, pneumonia, and clostridium difficile, infectious colitis, and urinary tract infection), and non-infectious (myocardial infarction and cardiovascular, stroke, pulmonary embolism, deep vein thrombosis (DVT), bleeding, bowel obstruction, and postoperative ileus) surgical complication within 30 days of the surgery in and out of the hospital (see Appendix B, Table B2).

4. Research Question 4 (RQ4): Is there an association between the SDOH and Not SSI related (hospital acquired) infectious complications within 30 days after colorectal surgery in and out of the hospital in adult patients?

Null Hypothesis ($H_0$4): SDOH are not associated with Not SSI (hospital acquired) infectious complications occurrence within 30 days after large intestinal resection in and out of the hospital in adult patients.

Alternative Hypothesis ($H_1$4): SDOH are associated with Not SSI related (hospital acquired) infectious complications occurrence within 30 days after large intestinal resection in and out of the hospital in adult patients.

The outcome or dependent variable was “Not SSI” hospital acquired infectious complications" after colorectal surgery measured as a binary outcome "yes" or "no" within 30 days after surgery and in or out of the hospital. Not SSI (nosocomial or hospital acquired) infectious complications included septicemia, MRSA, VRE, pneumonia, urinary tract infection, and clostridium difficile and infectious colitis all caused by bacteria, virus, or fungi. The definitions of each of the infectious complications are listed in Appendix A and ICD 9 and ICD10 codes used for identification are listed in Appendix B, Table B2.

The independent variables were individual level and area based (zip code and county code) SDOH and include: home setting Metro/Nonmetro area, race, nativity status (U.S. native/Foreign born), language proficiency, education, employment, unemployment, median household, median family and per capital income, different levels of poverty status, GINI inequality index, social vulnerability index at zip code level and county levels (the overall theme and the four themes [Theme1: Socioeconomic Status, Theme 2: Household Composition and Disability, Theme 3: Minority Status and Language, Theme 4: Housing and Transportation], as well as the flagged version of the themes which present the 90^{th} percentile within each of the themes), access to health care by health insurance type at individual level and as estimate for the community on zip code, uninsured hospital days, hospital case volume, household transportation ability by owning a vehicle. Covariates on patient level were age, sex, preoperative diagnosis, surgical procedures site, surgical approach, anastomosis type, diverting stoma, admission status, and APRSOI severity of illness risk in the hospital at time of surgery. For the sample general description, the covariates length of stay in the hospital, readmission, reoperation, out of the hospital overall complications and mortality were included and reported. Each variable is defined in the definition section in Appendix A and Appendix B.

Organization of Section 3

While a detailed description of the study implementation plan was provided in the previous section, which included a description of the research approach, selected research design and rational, the study population, sampling frame, sample strategy and detailed data analysis plans, study validity threats, and ethical concerns, in this section the acquisition of the data, data preparation for analyses, and the results from the data analyses were presented. The results are presented using data tables and figures appropriate for the statistical analyses and for representing the specific data. After presenting the overall sample characteristics and how representative the sample is of the population of interest, the results from the research questions analyses are presented per research questions and include: descriptive analysis and bivariate Chi-square test, followed by testing the assumptions for logistic regressions, and the actual bivariate logistic regression test of the hypotheses. After the results are presented, a summary of the results per research question and an overall summary are presented.

Data Collection of Secondary Data Set

Data Sample Acquisition

After Walden University IRB approval (#12-02-19-0602963), the study data set was requested and retrieved from the data provider using appropriate data agreement. This study used secondary data consisting of clinical data on a patient level and SDOH secondary data on zip code and county code levels. The following secondary datasets were used to create the final data sample needed to evaluate the four research questions: a) clinical data from SPARCS New York State from 2006–2016; b) SDOH from U.S.

Census ACS 2011 and 2016 5- years estimates for New York State; c) SDOH from CDC SVI 2010 and 2016 estimates for New York State; and d) SDOH from USDA 2003 and 2013 Urban-Rural Continuum codes. The sample from the New York SPARCS data was extrapolated from the New York State Inpatient Hospital Discharge Data files from 2006-2016. Access to the New York state SPARCS data was obtained after the IRB approval and by the mandatory signing of the custom SPARCS Limited and Identifiable Individual Data Use Agreement from the New York State SPARCS office (New York State Department of Health, 2016). ICD 9 and ICD 10 diagnostic and procedure codes were used to code and identify the data sample according to the study inclusion and exclusion criteria, and to identify the study independent and dependent variables from SPARCS data. All the codes were reviewed by a professional coder and a colorectal surgeon before submitting the request to the data provider for the final sample extrapolation. All codes used for the sample inclusion and exclusion criteria, for the preoperative comorbidities, and for the study outcomes are listed in detail in Appendix B. The SPARCS data sample was linked to SDOH data from U.S. Census ACS, CDC SVI, and USDAER estimates for New York State on zip code and county code levels by the data provider, thus the final data sample could be able to evaluate the study objective on the zip code, county level, and provide generalizability of the results to New York State. All data files for the SDOH from ACS, CDC SVI, and USDAER are publicly available, did not require any agreement to use the data, and were extrapolated from the data official sites and presented to the SPARCS data' provider by the data user to link all the files. The SPARCS data sample was linked to SDOH data from U.S. Census ACS, CDC SVI, and USDAER estimates for New York State on zip code and county code levels; thus, the final data sample can evaluate the study objectives on the zip code and county and provide generalizability of the results to New York State. In this study, limited identifiers SPARCS data were used, with only one limited identifier being age as a continuing variable, and that variable was used in the analyses as categorical. All the rest of the data were completely deidentified, including the zip code provided only with the last three digits. After all the files were linked, the final study file was deidentified and presented for this doctoral project use by the data provider. The crosswalking between geographical areas was challenging as it is described, and different crosswalking approaches were explored as those used by Din and Wilson (2020), but crosswalking was completed professionally and according to the data providers guidance and expert recommendations from CDC SVI team.

Time Frame for Data Collection, Actual Recruitment, and Response Rates of The Secondary Data Set

The secondary data used in this work were already collected and existed and were not collected specifically for this study. The sample from the New York State SPARCS data was extrapolated from the New York State Inpatient Hospital Discharge Data files for 10-years' time from 2006–2016. The SPARCS database collects records from more than 200 hospitals in New York State annually. The SPARCS data were selected to use for this study because it an inclusive all-payers data reporting system and has the clinical variables needed for this study (New York State Department of Health, 2016). The final study data sample received from the data provider included

130,752 patients. There were no discrepancies in using the secondary data set from the plan presented in Section 2. Once the final data file of 130,752 patients was received from the provider, the records were reviewed for missing data, and study inclusion and exclusion criteria were reviewed. From the initially received file, 130,752 patients, 21 additional patients of age above 100 years were removed from the data as per the SPARCS data requirement. The continuous variables used in this analysis were transformed into categorical using quartiles. The final data sample included in this study analysis consists of *N*=130 731 patients.

Baseline Descriptive and Demographic Characteristics of the Sample.

The final study sample included 130,731 patients from the SPARCS data from 2006-to-2016. The median age and range in years were 65 (18–100), and 70,406 (53.9%) were female, and 60,325 (46.1%) were male. The sample includes 3346 (2.6%) Asian, 14,844(11.4%) Black or African American, 13,491(10.3 %), Other race, and 99,050 (75.8%) White people. All patients underwent large intestinal resection (colorectal) for treatment of their medical condition. The current study outcomes rates within 30 days after surgery completion in this study sample of *N*=130 731 were: AL-13.3 %, SSI- 16.4%; Not SSI-related complications-13.8%, Infectious complications(all)-22.5%; Non-infectious complication-17.2%, and overall surgical morbidity-28.7%. The in-hospital mortality was 5,082 (3.9%). The post-discharge overall complications are 7.2% and the readmission within 30 days is 10.8%. Even though during preparation for the analyses and data cleanup period, 21 patients were excluded from the analyses, this sample size was considered large. It was sufficient for evaluating the four research questions in this study.

Sample Representativeness of the Population of Interest

For this research study, the nonrandom probability sampling technique was used to define the study sample. A nonrandom selection was done from New York State SPARCS inpatient discharge secondary data from 2006 to 2016. The sample is a state population-based sample because the database includes records from more than 200 hospitals in New York State, United States. The final study sample was created by linking the clinical secondary data sample from SPARCS data with the SDOH from U.S. Census ACS 2011 and 2016 estimates, CDC SVI 2010 and 2016 estimates for the New York state, and USDA 2003 and 2013 rural-urban codes on zip code and county levels (Figure 7).

All four research questions were addressed by using the final data sample. The final data sample was sufficient in size and data content to provide a response to the research questions on several levels-individual, zip code, county, and state levels. Although the SPARCS data set included patients from 200 hospitals throughout the entire New York State, not all patients that had required surgery might have had their surgery at a New York State-based hospital, and not all hospital from the state may have entered data at SPARCS, making the sample nonrandom as not all existing patients had an equal chance to be selected to participate in this study. However, the SPARCS data sample is a representative sample for the New York State population of interest in this study. It was drawn from statewide data, which reduces the sampling error.

Further, because secondary data was used in this study, construct validity was considered to minimize the study bias. The secondary datasets consist of prospectively collected data from hospital electronic medical records. In the SPARCS data, all 200 hospitals contributing to the state data are using the same methodology to collect it and report it to the state annually, thus increasing the reliability of the data. The data from U.S. Census, CDC SVI, and USDARS the data were collected under predefined definitions and systematically and updated periodically. The definitions used at the time of the data collection were also used in this study to minimize bias. The data dictionaries for this study are listed in Appendix A.

Statistical Analyses Presentation Organization

The basic univariate analysis justifying the inclusion of covariates in the regression models were provided for each research question separately as each research question has a different dependent variable. The SDOH were evaluated in each research question (RQ) in depth in three binomial logistics regression models. The models were:

- Model-1 in each RQ: single measurement SDOH independent variables at patient level and ACS SDOH at Zip code level were included in Model 1 for analyses with the outcome being the dependent variable of the specific RQ
- Model-2a in each RQ: single measurement SDOH independent variables at patient level and composite SDOH- Social Vulnerability Index (SVI) Overall Themes evaluation on contextual level (ZIP code and County code areas) were included in

Model 2a for analyses with the outcome being the dependent variable of the specific RQ

- Model-2b in each RQ: single measurement SDOH independent variables at patient level and composite SDOH-the social vulnerability specific themes on contextual level (ZIP code and County code areas) were included in Model 2b for analyses with the outcome being the dependent variable of the specific RQ

The binomial logistic models were labeled in a manner to understand which research question and the model number were presented; for example, RQ1-Model-1 means this is the research question one model one. The logistic model's description for each Research Question, are presented in each RQ Appendix together with the multicollinearity tests. Section 3 presents the descriptive and bivariate analyses, the final logistic models included in multivariable analyses based on bivariate analysis and multicollinearity evaluation, and the binomial logistic regression results for each RQ.

Statistical Analysis Findings Organized by Research Questions

Research Question 1

Research Question and Hypothesis

Research Question 1 (RQ1): Is there an association between SDOH and AL occurrence within 30 days after colorectal surgery in and out of the hospital in adult patients?

Null Hypothesis ($H_0$1): SDOH are not associated with AL occurrence within 30 days after large intestinal resection in and out of the hospital in adult patients.

Alternative Hypothesis ($H_1$1): SDOH are associated with AL occurrence within 30 days after large intestinal resection in and out of the hospital in adult patients.

The outcome or dependent variable was AL after colorectal surgery within 30 days after surgery in or out of the hospital measured as a binary outcome-"yes" or "no".

Descriptive and Bivariate Analyzes

Table 1

Descriptive and Bivariate Analyses of the RQ1 AL and SPARCS patient variables (N = 130731)

Variable	AL_No *N (%)*	AL_Yes *N (%)*	Total	Chi-square test χ^2	*p*	*Cramer's V*
Total	113311(86.7)	17420 (13.3)	130731			
Age in years				74.31	.000*	0.024
< 65	57007 (50.3)	8153 (46.8)	65160			
≥65	56304 (49.7)	9267 (53.2)	65571			
Age in years				92.367	.000*	0.027
up to 53	29442 (26.0)	4350 (25.0)	33792			
54 to 65	30277 (26.7)	4237 (24.3)	34514			
66 to 76	27626 (24.4)	4351 (25.0)	31977			
77 and above	25966 (22.9)	4482 (25.7)	30448			
Sex				345.53	.000*	0.051
Male	51148 (45.1)	9177 (52.7)	60325			
Female	62163 (54.9)	8243 (47.3)	70406			
Race				55.808	.000*	0.021
Asian	2982 (2.6)	364 (2.1)	3346			
Black or African American	12623 (11.1)	2221 (12.7)	14844			
Other	11660 (10.3)	1831 (10.5)	13491			
White	86046 (75.9)	13004 (74.6)	99050			
Race minority				13.644	.000*	0.01
White	86046 (75.9)	13004 (74.6)	99050			
Minority races	27265 (24.1)	4416 (25.4)	31681			
Principal Diagnosis				308.42	.000*	0.049
Diverticulitis	27460 (24.2)	3719 (21.3)	31179			
IBD	4494 (4.0)	930 (5.3)	5424			
Neoplasms	54064 (47.7)	7713 (44.3)	61777			
Other	27293 (24.1)	5058 (29)	32351			
APRSOI Severity of Illness risk				7969.2	.000*	0.247
Minor	38267 (33.8)	1731 (9.9)	39998			
Moderate	43113 (38.0)	5319 (30.5)	48432			
Major	20656 (18.2)	5871 (33.7)	26527			
Extreme	11275 (10.0)	4499 (25.8)	15774			

Table 1 continued				Chi-square test		
Variable	AL_No *N (%)*	AL_Yes *N (%)*	Total	χ^2	*p*	*Cramer's V*
Admission Type				937.57	.000*	0.085
Elective	71342 (63.0)	8854 (50.8)	80196			
Emergency	41969 (37.0)	8566 (49.2)	50535			
				239.67	.000*	0.043
Surgical_Procedure_Site						
Colon resection	92837 (81.9)	14147 (81.2)	106984			
Other	5733 (5.1)	1042 (6.0)	6775			
Rectal resection	12025 (10.6)	1521 (8.7)	13546			
Total colectomy	2716 (2.4)	710 (4.1)	3426			
Surgical Approach				683.78	.000*	0.072
Laparoscopic	33707 (29.7)	3549 (20.4)	37256			
Open	66059 (58.3)	11771 (67.6)	77830			
Other	13545 (12.0)	2100 (12.1)	15645			
Anastomosis distal end				96.585	.000*	0.027
Anal	1970 (1.7)	155 (0.9)	2125			
Colon	55402 (48.9)	8967 (51.5)	64369			
Rectal	55939 (49.4)	8298 (47.6)	64237			
Diverting Stoma				1048.7	.000*	0.09
no	98241 (86.7)	13485 (77.4)	111726			
yes	15070 (13.3)	3935 (22.6)	19005			
Health Insurance				155.13	.000*	0.034
Medicaid	5625 (5.0)	1001 (5.7)	6626			
Medicare	47762 (42.2)	8020 (46.0)	55782			
Other	362 (0.3)	61 (0.4)	423			
Private/Commercial	56677 (50.0)	7839 (45.0)	64516			
Self-Pay	2885 (2.5)	499 (2.9)	3384			
Annual Hospital Volume cases				32.559	.000*	0.016
≤ 52	28716 (25.3)	4306 (24.7)	33022			
≥53 and ≤ 123	28942 (25.5)	4533 (26.0)	33475			
>123 and ≤ 201	28786 (25.4)	4705 (27.0)	33491			
>201	26867 (23.7)	3876 (22.3)	30743			

Note. * The Chi-square statistic is significant at the .05 level, *Cramer's V* – values are presented

Table 2

Descriptive and Bivariate Analyzes of the RQ1 AL and Social Vulnerability Index Composite Themes on Zip code and County code (N = 130 731)

				Chi-square test		
Variable SVI COMPOSITE	AL_No *N (%)*	AL_Yes *N (%)*	Total	χ^2	*p*	*Cramer's V*
Total	113311(86.7)	17420 (13.3)	130731			
ZIP CODE LEVEL						
T1z_Socioeconomic Status				43.315	.000*	0.018
≤ .1756	28458 (25.1)	4229 (24.3)	32687			
>.1756 and ≤.3799	28423 (25.1)	4271 (24.5)	32694			
>.3799 and ≤.6453	28461 (25.1)	4218 (24.2)	32679			
>.6453	27969 (24.7)	4702 (27.0)	32671			
T2z_Houshold Composition and Disability				32.195	.000*	0.016
≤ .2863	28423 (25.1)	4404 (25.3)	32827			
>.2863 and ≤.5045	28447 (25.1)	4137 (23.7)	32584			
>.5045 and ≤ .7467	28387 (25.1)	4260 (24.5)	32647			
>.7467	28054 (24.8)	4619 (26.5)	32673			
T3z_Minority Status and Language				22.031	.000*	0.013
≤ .1820	28366 (25.0)	4335 (24.9)	32701			
>.1820 and ≤ .3850	28649 (25.3)	4163 (23.9)	32812			
>.3850 and ≤ .6561	28200 (24.9)	4379 (25.1)	32579			
>.6561	28096 (24.8)	4543 (26.1)	32639			
T4z_Housing and Transportation				20.633	.000*	0.013
≤.2400	28533 (25.2)	4281 (24.6)	32814			
>.2400 and ≤ .4420	28461 (25.1)	4297 (24.7)	32758			
>.4420 and ≤ .7240	28264 (24.9)	4251 (24.4)	32515			
>.7240	28053 (24.8)	4591 (26.4)	32644			
T0z_Overal Themes Summary score				37.48	.000*	0.017
≤.1909	28487 (25.1)	4204 (24.1)	32691			
>.1909 and ≤ .3929	28538 (25.2)	4233 (24.3)	32771			
>.3929 and ≤ .6590	28284 (25.0)	4314 (24.8)	32598			
> 0.6590	28002 (24.7)	4669 (26.8)	32671			
Flags_T1z_Socioeconomic Status				36.603	.000*	0.017
0	99525 (87.8)	15027 (86.3)	114552			
1	7015 (6.2)	1180 (6.8)	8195			
2	3807 (3.4)	679 (3.9)	4486			
3	1503 (1.3)	269 (1.5)	1772			
4	1461 (1.3)	265 (1.5)	1726			

Variable SVI Composite	AL_No *N (%)*	AL_Yes *N (%)*	Total	χ^2	*p*	*Cramer's V*
Flags_T2z_Household Composition & Disability				10.167	.017*	0.009
0	85207 (75.2)	12959 (74.4)	98166			
1	21461 (18.9)	3354 (19.3)	24815			
2	5220 (4.6)	850 (4.9)	6070			
3	1423 (1.3)	257 (1.5)	1680			
Flags_T3z_ Minority Status and Language				21.084	.000*	0.013
0	100636 (88.8)	15266 (87.6)	115902			
1	11228 (9.9)	1901 (10.9)	13129			
2	1447 (1.3)	253 (1.5)	1700			
Flags_T4z_Housing and Transportation				19.218	.001*	0.012
0	75920 (67)	11449 (65.7)	87369			
1	27540 (24.3)	4306 (24.7)	31846			
2	8410 (7.4)	1402 (8.0)	9812			
3	1318 (1.2)	240 (1.4)	1558			
4	123 (0.1)	23 (0.1)	146			
Flags_TOTALz_Themes Sum Flags3				34.492	.000*	0.016
0	55831 (49.3)	8234 (47.3)	64065			
1	30138 (26.6)	4654 (26.7)	34792			
≥ 2	27342 (24.1)	4532 (26)	31874			
COUNTY LEVEL						
T1ct Socioeconomic Status				28.584	.000*	0.015
≤ .1475	28735 (25.4)	4116 (23.6)	32851			
>.1475 and ≤ 0.3934	32485 (28.7)	5118 (29.4)	37603			
>.3934 and ≤ 0.7377	30120 (26.6)	4632 (26.6)	34752			
>.7377	21971 (19.4)	3554 (20.4)	25525			
T2ct Household Composition and Disability				53.421	.000*	0.02
≤ .0984	31548 (27.8)	4765 (27.4)	36313			
>.0984 and ≤ .3115	29923 (26.4)	4383 (25.2)	34306			
>.3115 and ≤ .4754	24794 (21.9)	3678 (21.1)	28472			
>0.4754	27046 (23.9)	4594 (26.4)	31640			
T3ct Minority Status and Language				3.917	*N*S	
≤ .7213	37371 (33.0)	5690 (32.7)	43061			
>.7213 and ≤ .8525	22785 (20.1)	3443 (19.8)	26228			
>.8525 and ≤ .9508	26693 (23.6)	4214 (24.2)	30907			
>.9508	26462 (23.4)	4073 (23.4)	30535			

				Chi-square test		
Variable SVI Composite	AL_No *N (%)*	AL_Yes *N (%)*	Total	χ^2	*p*	*Cramer's V*
T4ct Housing and Transportation				105.31	.000*	0.028
≤ .2787	29740 (26.2)	4300 (24.7)	34040			
>.2787 and ≤ .6230	28238 (24.9)	4380 (25.1)	32618			
>.6230 and ≤ .7869	33560 (29.6)	4850 (27.8)	38410			
>.7869	21773 (19.2)	3890 (22.3)	25663			
T0ct Overall Themes Summary score				33.23	.000*	0.016
≤ .1639	28735 (25.4)	4116 (23.6)	32851			
>.1639 and ≤ 5410	28716 (25.3)	4392 (25.2)	33108			
>.5410 and ≤ .7213	30366 (26.8)	4738 (27.2)	35104			
>0.7213	25494 (22.5)	4174 (24.0)	29668			
Flags_T1ct Socioeconomic Status				92.504	.000*	0.027
0	80231 (70.8)	12329 (70.8)	92560			
1	14958 (13.2)	2156 (12.4)	17114			
2	11765 (10.4)	1721 (9.9)	13486			
3	1249 (1.1)	160 (0.9)	1409			
4	5108 (4.5)	1054 (6.1)	6162			
Flags_T2ct Household Composition and Disability				15.492	.000*	0.011
0	86340 (76.2)	13144 (75.5)	99484			
1	10616 (9.4)	1571 (9.0)	12187			
2	16355 (14.4)	2705 (15.5)	19060			
Flags_T3ct Minority Status and Language				2.872	*N*S	
0	60156 (53.1)	9133 (52.4)	69289			
1	4523 (4.0)	718 (4.1)	5241			
2	48632 (42.9)	7569 (43.5)	56201			
Flags_T4ct Housing and Transportation				0.238	.000*	0.017
0	61689 (54.4)	9072 (52.1)	70761			
1	9156 (8.1)	1533 (8.8)	10689			
2	3666 (3.2)	551 (3.2)	4217			
3	38800 (34.2)	6264 (36)	45064			
Flags_TOTALct_Themes Sum Flags3				6.006	.050	0.007
0	42060 (37.1)	6348 (36.4)	48408			
1	11349 (10)	1692 (9.7)	13041			
≥ 2	59902 (52.9)	9380 (53.8)	69282			

Note. * The Chi-square statistic is significant at the .05 level, Cramer's *V* – values are presented

Table 3

Descriptive and Bivariate Analyses of the RQ1 AL and ACS (American Community Survey) Single Measurements on Zip code level (N = 130731)

Variable				Chi-square test		
	AL_No *N* (%)	AL_Yes *N* (%)	Total	χ^2	*p*	*Cramer's V*
Total	113311(86.7)	17420 (13.3)	130731			
ACS zip code level						
Metro_Nonmetro area				0.537	*NS*	
metro area	103007 (90.9)	15806 (90.7)	118813			
non metro area	10304 (9.1)	1614 (9.3)	11918			
U.S. Native				7.638	0.054	
≤ 69.5484	28287 (25.0)	4426 (25.4)	32713			
>69.5484 and ≤ 87.1795	28223 (24.9)	4452 (25.6)	32675			
>87.1795 and ≤ 94.8691	28419 (25.1)	4301 (24.7)	32720			
>94.8691	28382 (25.0)	4241 (24.3)	32623			
Foreign Born				7.703	0.053	
≤ 5.1308	28418 (25.1)	4242 (24.4)	32660			
>5.1308 and ≤12.8205	28398 (25.1)	4303 (24.7)	32701			
>12.8205 and ≤ 30.4515	28204 (24.9)	4449 (25.5)	32653			
>30.4515	28291 (25.0)	4426 (25.4)	32717			
Language Proficiency						
Speak English well				20.384	.000*	0.012
≤ 84.5	28210 (24.9)	4575 (26.3)	32785			
>84.5 and ≤ 94.3	29093 (25.7)	4403 (25.3)	33496			
>94.3 and ≤ 97.7	27655 (24.4)	4283 (24.6)	31938			
>97.7	28353 (25.0)	4159 (23.9)	32512			
Speak English less than well				17.272	.001*	0.011
≤ 2.3	29413 (26.0)	4341 (24.9)	33754			
>2.3 and ≤ 5.7	27706 (24.5)	4265 (24.5)	31971			
>5.7 and ≤15.6	28203 (24.9)	4283 (24.6)	32486			
>15.6	27989 (24.7)	4531 (26.0)	32520			
Speak Other than English				9.53	.023*	0.009
≤ 7.6	28749 (25.4)	4297 (24.7)	33046			
>7.6 and ≤ 17.8	28150 (24.8)	4266 (24.5)	32416			
17.800001 thru 36.800000=3	28260 (24.9)	4359 (25.0)	32619			
>36.8	28152 (24.8)	4498 (25.8)	32650			

Table 3 continued				Chi-square test		
Variable	AL_No *N (%)*	AL_Yes *N (%)*	Total	χ^2	*p*	*Cramer's V*
Limited English All Households				18.363	.000*	0.012
≤ .7	28727 (25.4)	4274 (24.5)	33001			
>.7and ≤ 2.8	28689 (25.3)	4405 (25.3)	33094			
>2.8 and ≤ 8.2	28163 (24.9)	4230 (24.3)	32393			
>8.2	27732 (24.5)	4511 (25.9)	32243			
Education Level						
Less than 9th grade				23.179	.000*	0.013
≤ 2.3	30041 (26.5)	4485 (25.7)	34526			
>2.3 and ≤ 3.9	28014 (24.7)	4145 (23.8)	32159			
>3.9 and ≤ 7.7	27690 (24.4)	4286 (24.6)	31976			
>7.7	27566 (24.3)	4504 (25.9)	32070			
Has 9th to 12th grade no Diploma				21.898	.000*	0.013
≤4.3	28602 (25.2)	4197 (24.1)	32799			
>4.3 and ≤ 6.8	29064 (25.6)	4406 (25.3)	33470			
>6.8 and ≤ 10.1	28097 (24.8)	4327 (24.8)	32424			
>10.1	27548 (24.3)	4490 (25.8)	32038			
High School GED				8.243	.041*	0.008
≤ 22.9	28349 (25.0)	4388 (25.2)	32737			
>22.9 and ≤ 29.0	29428 (26.0)	4492 (25.8)	33920			
>29.0 and ≤ 33.5	27317 (24.1)	4340 (24.9)	31657			
>33.5	28217 (24.9)	4200 (24.1)	32417			
Some College No degree				14.2	.003*	0.01
≤ 14.3	28515 (25.2)	4203 (24.1)	32718			
>14.3 and ≤ 17.1	29126 (25.7)	4627 (26.6)	33753			
>17.1 and ≤ 19.1	27923 (24.6)	4399 (25.3)	32322			
>19.1	27747 (24.5)	4191 (24.1)	31938			
Associate degree				17.064	.001*	0.011
≤ 6.6	28556 (25.2)	4580 (26.3)	33136			
>6.6 and ≤ 8.8	28214 (24.9)	4403 (25.3)	32617			
>8.8 and ≤ 11.3	29026 (25.6)	4251 (24.4)	33277			
>11.3	27515 (24.3)	4186 (24.0)	31701			
Bachelor's degree				16.324	.001*	0.011
≤13.2	28730 (25.4)	4528 (26.0)	33258			
>13.2 and ≤17.8	27912 (24.6)	4448 (25.5)	32360			
>17.8 and ≤23.1	28559 (25.2)	4189 (24.0)	32748			
>23.1	28110 (24.8)	4255 (24.4)	32365			

Table 3 continued				Chi-square test		
Variable	AL_No *N (%)*	AL_Yes *N (%)*	Total	χ^2	*p*	*Cramer's V*
Graduate/Professional degree				11.412	.010*	0.009
≤ 8.0	28705 (25.3)	4471 (25.7)	33176			
>8.0 and ≤ 11.9	28402 (25.1)	4505 (25.9)	32907			
>11.9 and ≤ 18.4	28069 (24.8)	4130 (23.7)	32199			
>18.4	28135 (24.8)	4314 (24.8)	32449			
High School or Higher				27.915	.000*	0.015
≤ 82.6	28347 (25.0)	4662 (26.8)	33009			
>82.6 and ≤ 89.0	28355 (25.0)	4347 (25.0)	32702			
>89.0 and ≤ 93.1	28272 (25.0)	4254 (24.4)	32526			
>93.1	28337 (25.0)	4157 (23.9)	32494			
Bachelor or Higher degree				13.364	.004*	0.015
≤ 21.3	28475 (25.1)	4463 (25.6)	32938			
>21.3 and ≤ 29.5	28264 (24.9)	4484 (25.7)	32748			
>29.5 and ≤ 41.6	28285 (25.0)	4149 (23.8)	32434			
>41.6	28287 (25.0)	4324 (24.8)	32611			
Employment Status						
Employed Population Ratio 16 yr +				7.028	0.071	0
≤ 55.1	28376 (25.0)	4477 (25.7)	32853			
>55.1 and ≤ 59.4	28566 (25.2)	4462 (25.6)	33028			
>59.4 and ≤ 62.9	28544 (25.2)	4302 (24.7)	32846			
>62.9	27825 (24.6)	4179 (24.0)	32004			
Unemployment rate 16 yr +				44.468	.000*	0.03
≤5.5	29291 (25.9)	4304 (24.7)	33595			
>5.5 and ≤ 6.9	28651 (25.3)	4335 (24.9)	32986			
>6.9 and ≤ 8.9	27645 (24.4)	4118 (23.6)	31763			
>8.9	27724 (24.5)	4663 (26.8)	32387			
Income in the last 12 months/USD						
Median Household Income				41.054	.000*	0.027
≤ 46305	28008 (24.7)	4695 (27.0)	32703			
>46305 and ≤ 60526	28445 (25.1)	4290 (24.6)	32735			
>60526 and ≤ 82738	28437 (25.1)	4195 (24.1)	32632			
>82738	28421 (25.1)	4240 (24.3)	32661			
Median Family Income				37.462	.000*	0.028
≤ 56703	28030 (24.7)	4676 (26.8)	32706			
>56703 and ≤ 72903	28366 (25.0)	4308 (24.7)	32674			
>72903 and ≤ 98250	28520 (25.2)	4198 (24.1)	32718			
>98250	28395 (25.1)	4238 (24.3)	32633			

Table 3 continued				Chi-square test		
Variable	AL_No *N (%)*	AL_Yes *N (%)*	Total	χ^2	*p*	*Cramer's V*
Per Capita Income				23.082	.000*	0.025
≤ 23536	28183 (24.9)	4623 (26.5)	32806			
>23536 and ≤ 29398	28302 (25.0)	4293 (24.6)	32595			
>29398 and ≤37944	28493 (25.1)	4235 (24.3)	32728			
>37944	28333 (25.0)	4269 (24.5)	32602			
Poverty Status in the last 12 months %						
All Families below poverty level				25.263	.000*	0.025
≤ 3.7	29138 (25.7)	4346 (24.9)	33484			
>3.7 and ≤7.1	27780 (24.5)	4165 (23.9)	31945			
>7.1 and ≤ 13.5	28528 (25.2)	4320 (24.8)	32848			
>13.5	27865 (24.6)	4589 (26.3)	32454			
People below poverty level				38.234	.000*	0.029
≤ 5.9	28515 (25.2)	4230 (24.3)	32745			
>5.9 and ≤ 10.4	28702 (25.3)	4294 (24.6)	32996			
>10.4 and ≤ 18.2	28214 (24.9)	4232 (24.3)	32446			
>18.2	27880 (24.6)	4664 (26.8)	32544			
Below Poverty age 18 to 64				36.583	.000*	0.03
≤ 5.8	29565 (26.1)	4341 (24.9)	33906			
>5.8 and ≤9.8	27458 (24.2)	4168 (23.9)	31626			
>9.8 and ≤ 16.7	28415 (25.1)	4266 (24.5)	32681			
>16.7	27873 (24.6)	4645 (26.7)	32518			
Below Poverty age 65 and above				10.416	.015*	0.027
≤ 5.1	28901 (25.5)	4377 (25.1)	33278			
>5.1 and ≤ 8.1	28581 (25.2)	4301 (24.7)	32882			
>8.1 and ≤ 13.2	27691 (24.4)	4221 (24.2)	31912			
>13.2	28138 (24.8)	4521 (26.0)	32659			
GINI index of inequality				11.592	.009*	0.021
≤.3945	28424 (25.1)	4260 (24.5)	32684			
>.3945 and ≤ .4318	28447 (25.1)	4262 (24.5)	32709			
>.4318 and ≤ .4706	28268 (24.9)	4388 (25.2)	32656			
>.4706	28172 (24.9)	4510 (25.9)	32682			
Health Insurance %						
Public Health Insurance alone				30.144	.000*	0.027
≤ 11.50	28676 (25.3)	4189 (24.0)	32865			
>11.50 and ≤ 17.20	28687 (25.3)	4303 (24.7)	32990			
>17.20 and ≤ 26.40	28047 (24.8)	4337 (24.9)	32384			
>26.40	27901 (24.6)	4591 (26.4)	32492			

Table 3 continued				Chi-square test		
Variable	AL_No *N (%)*	AL_Yes *N (%)*	Total	χ^2	*p*	*Cramer's V*
≤ 3.4	28332 (25.0)	4465 (25.6)	32797			
>3.4 and ≤ 4.2	29379 (25.9)	4536 (26.0)	33915			
>4.2 and ≤ 5.1	30195 (26.6)	4603 (26.4)	34798			
>5.1	25405 (22.4)	3816 (21.9)	29221			
Medicaid only				31.632	.000*	0.026
≤ 7.0	29075 (25.7)	4299 (24.7)	33374			
>7.0 and ≤ 12.2	27854 (24.6)	4147 (23.8)	32001			
>12.2 and ≤ 21.6	28517 (25.2)	4358 (25.0)	32875			
>21.6	27865 (24.6)	4616 (26.5)	32481			
Private insurance alone				28.046	.000*	0.027
≤ 46.3	28418 (25.1)	4675 (26.8)	33093			
>46.3 and ≤ 56.7	28708 (25.3)	4365 (25.1)	33073			
>56.7 and ≤ 65.6	27911 (24.6)	4241 (24.3)	32152			
>65.6	28274 (25.0)	4139 (23.8)	32413			
No Vehicle OHU%				24.447	.000*	0.031
≤ 5.1	28682 (25.3)	4230 (24.3)	32912			
>5.1 and ≤ 9.9	28603 (25.2)	4230 (24.3)	32833			
>9.9 and ≤ 33.9	27941 (24.7)	4433 (25.4)	32374			
>33.9	28085 (24.8)	4527 (26.0)	32612			
GINI 2 categories				0.228	NS	
≤0.3	403 (0.4)	66 (0.4)	469			
>0.3	112908 (99.6)	17354 (99.6)	130262			
GINI 4 categories				9.488	.023*	0.015
≤0.3	403 (0.4)	66 (0.4)	469			
> 0.3 and ≤ 0.415	43564 (38.4)	6488 (37.2)	50052			
> 0.415 and ≤ 0.515	59024 (52.1)	9264 (53.2)	68288			
> 0.515	10320 (9.1)	1602 (9.2)	11922			
All Families below poverty >20%				36.308	.000*	0.025
≤ 20% of all families below poverty	99462 (87.8)	15009 (86.2)	114471			
> 20% of all families below poverty	13849 (12.2)	2411 (13.8)	16260			
People below poverty level >20%				46.319	.000*	0.025
≤ 20% of all people	90368 (79.8)	13503 (77.5)	103871			
> 20% of all people	22943 (20.2)	3917 (22.5)	26860			

Note: * The Chi-square statistic is significant at the .05 level., Cramer's V – values are presented

Interpretation of Descriptive Analyses and χ^2 Test RQ1

The results from the descriptive and bivariate statistics of the Research Question 1 related to AL evaluated as a dichotomous outcome- AL _Yes and AL_No are presented on Tables 1, 2, and 3. The total sample size was *N*=130 731. The descriptive statistics are presented as numbers and percentages. The Chi-square test was performed between AL and the independent variables listed on each table, and the χ^2 and *p* values were listed. The expected frequency of the cells was greater than 10 for all cells. *P-value* was considered significant if less than 0.05. As shown on Tables 1, 2, and 3 statistically, a significant association was observed between AL and multiple independent variables Considering these results, we can reject the null hypothesis and accept the alternative hypothesis. The effect size for *χ2*, Cramer's *V* was performed, and considering the degree of freedom, small, medium, and large association are observed (Kim, 2017). *Cramer's V* value is listed in Tables 1 through 3 only for the significant Chi-square statistics. Based on the bivariate analyses, independent variables with a significance of 0.05 and less were selected for the multivariable analysis for RQ1with Dependent Variable: AL.

Testing the Assumptions for Binomial Logistic Regression RQ1

Assumption #1: The dependent variable should be measured on a dichotomous scale. The dependent variable for Research Question 1(RQ1) is AL, and it is measured as dichotomous variables AL _Yes and AL_No, which meet Assumption 1. The independent variables were continuous (interval or ratio) and categorical (nominal) with two to five categories, which meet Assumption#2. The dependent variable is dichotomous and has two mutually exclusive and exhaustive categories which meet Assumption #3. Assumption #4 is related to the sample size, and it is recommended the data to contain a minimum of 15 and up to 50 cases per independent variable (Laerd Statistics, 2018). With conservative recommendation of 50 cases per independent variable and with 38 variables in the model before multicollinearity test, the required sample size supposed to be 1900. The study sample is 130 731, which is sufficient. Another way to establish if the sample size is sufficient is, to use the formula $N = 10K/P$ where P= proportion of the positive outcomes (in this case AL), K = the number of independent variables. The rate of AL is 13.3% or 0.133 in proportion. The potential variables that were planned to be included in the model are total of 38, therefore the sample size needed for this research question Model 1 should be $N = 10 \text{ x } 38/0.133 = 380/0.133 = 2858$. This method of calculation show higher number of cases are needed. Peduzzi et al. (1996) recommend 10 events per independent variable (EPV) in the equations, meaning if we calculate what is the proportion of positive outcomes divided on the number of independent variables, (AL 17420/28 = 622 cases per independent variable, which is more than 10 (Peduzzi et al., 1996). However, the sample size in this study was N=130 731 which provided a sufficient number of cases per each independent variable, thus meet Assumption #4. Since these four assumptions were met, a binomial logistic regression was an appropriate statistical test to analyze the research question. These four assumptions were met for the four research questions in this study.

Assumption 5 is related to multicollinearity, which occurs when there is a correlation between the predictor for the independent variables. To examine for multicollinearity, the Tolerance and the VIF (Variance Inflation Factor) values were evaluated for the independent variables. The cut-off point for tolerance was set for less than 0.2 and VIF above 5, at which point multicollinearity was accepted as problematic. Multicollinearity was evaluated for each model and presented in Appendix C for RQ1.

Appendix C, presents the evaluation of multicollinearity for the initial RQ1-Model-1 and the subsequent multicollinearity evaluation after correction, showing collinearity below the cut-off point for VIF 5 (see Appendix C, Tables C1 and C2). Assumption 6: Assumption 6 requires *a* linear relationship between the continuous independent variables in the model and the logit transformation of the outcome dependent variable. To test linearity, for all continuous independent variables used in the logistic regression model as continuous variables, a natural log transformation is created using SPSS. The created Ln (natural log transformation) variable is a continuous variable. Subsequently, the Box-Tidwell test is performed to test for linearity. This assumption does not need to test linearity for the categorical variables. In the models of RQ1, only categorical variables were used, so assumption six was met. As Assumption 7 is applied only to the continuous variables to check for outliers, and as this evaluation used categorical variables, there were no outliers to be concerned. A binomial logistic regression was performed to analyze the data for RQ1with all the assumptions met.

Binomial Logistic Regression RQ1 Dependent Variable: AL

RQ1-Model-1

In the RQ1-Model-1 n single measurement, patient and ACS SDOH independent variables at the Zip code level were included in the analyses with dependent variable: AL. Based on the bivariate analyses, all independent variables from Tables 1 and 3 with significance 0.05 or below were initially included in RQ1-Model-1 and tested for multicollinearity. Adjustments to correct multicollinearity were made to meet the cut-off marks for the Tolerance factor less than 0.2 and VIF 5 (see Appendix C). The independent variables included for multivariable binomial logistic regression analysis in the final RQ1-Model-1 after multicollinearity test are shown in Appendix C, Figure C1. These variables included two biological, seven clinical covariates, and 15 variables considered SDOH in different categories (see Appendix C, Figure C1).

Table 4

Binomial logistic regression results RQ1-Model-1,Dependent Variable: AL

Variables in the Equation RQ1-Model 1	*B*	*S.E.*	Wald	*df*	*p*	*OR*	95% C.I. Lower	Upper
Age in years (ref: 77 and above)			113.59	3	0.0000			
up to 53	0.336	0.032	113.39	1	0.0000	1.400	1.316	1.489
54 to 65	0.199	0.029	46.697	1	0.0000	1.220	1.152	1.292
66 to 76	0.122	0.024	25.093	1	0.0000	1.129	1.077	1.184
Sex Male	0.281	0.017	269.57	1	0.0000	1.324	1.281	1.369
Principal Diagnosis (ref: Diverticulitis)			44.921	3	0.0000			
IBD	0.015	0.045	0.112	1	0.7380	1.015	0.929	1.11
Neoplasms	0.079	0.026	9.301	1	0.0020	1.083	1.029	1.139
Other	-0.074	0.027	7.318	1	0.0070	0.929	0.881	0.98
Surgical Approach (ref: Laparoscopic)			77.553	2	0.0000			
Open	0.198	0.023	76.58	1	0.0000	1.219	1.166	1.274
Other	0.193	0.047	17.005	1	0.0000	1.212	1.106	1.329
Surgical Procedure Site (ref: Colon resection)			18.979	3	0.0000			
Other	-0.051	0.05	1.041	1	0.3080	0.950	0.861	1.048
Rectal resection	0.04	0.047	0.745	1	0.3880	1.041	0.95	1.141
Total colectomy	0.197	0.05	15.552	1	0.0000	1.218	1.104	1.343
Anastomosis Distal End (ref: Anal)			80.504	2	0.0000			
Colon	0.466	0.094	24.694	1	0.0000	1.594	1.326	1.916
Rectal	0.285	0.092	9.487	1	0.0020	1.329	1.109	1.593
Diverting Stoma - Yes	0.055	0.025	5	1	0.0250	1.057	1.007	1.109
APRSOI risk (ref: Minor)			5792.6	3	0.0000			
Moderate	1.07	0.029	1360.6	1	0.0000	2.917	2.755	3.087
Major	2.024	0.031	4266	1	0.0000	7.567	7.122	8.041
Extreme	2.454	0.036	4702.3	1	0.0000	11.634	10.846	12.479
Admission Type-Elective	0.297	0.022	188.46	1	0.0000	1.345	1.29	1.404
Race (ref: White)			7.838	3	0.0490			
Asian	-0.058	0.06	0.939	1	0.3330	0.943	0.838	1.062
Black or African American	0.068	0.03	5.24	1	0.0220	1.071	1.01	1.135
Other	0.045	0.031	2.205	1	0.1380	1.046	0.986	1.111
Health Insurance (ref: Medicaid)			7.988	4	0.0920			
Medicare	-0.039	0.043	0.822	1	0.3650	0.962	0.885	1.046
Other	0.139	0.149	0.879	1	0.3480	1.150	0.859	1.538
Private/Commercial	-0.002	0.039	0.003	1	0.9530	0.998	0.924	1.077
Self-Pay	0.096	0.063	2.368	1	0.1240	1.101	0.974	1.245
Annual Hospital Volume, cases (ref: ≤ 52)			65.622	3	0.0000			
≥53 and ≤ 123	0.120	0.025	23.536	1	0.000	1.127	1.074	1.183
>123 and ≤ 201	0.194	0.025	61.493	1	0.000	1.214	1.157	1.274
>201	0.080	0.027	9.028	1	0.003	1.084	1.028	1.142

Variables in the Equation RQ1-Model 1	*B*	*S.E.*	Wald	*df*	*p*	*OR*	95% C.I. Lower	Upper
Limited English All Households (ref: >8.2)			6.367	3	0.0950			
≤ .7	-0.049	0.04	1.538	1	0.2150	0.952	0.88	1.029
>.7and ≤ 2.8	-0.042	0.039	1.109	1	0.2920	0.959	0.888	1.036
>2.8 and ≤ 8.2	-0.078	0.033	5.602	1	0.0180	0.925	0.867	0.987
Less than 9th grade (ref: ≤ 2.3)			3.569	3	0.3120			
>2.3 and ≤ 3.9	-0.027	0.027	1.032	1	0.3100	0.973	0.924	1.025
>3.9 and ≤ 7.7	0.023	0.032	0.518	1	0.4720	1.023	0.961	1.09
>7.7	0.016	0.046	0.122	1	0.7270	1.016	0.928	1.113
High School GED (ref: ≤ 22.9)			15.804	3	0.0010			
>22.9 and ≤ 29.0	-0.075	0.031	5.696	1	0.0170	0.928	0.873	0.987
>29.0 and ≤ 33.5	-0.082	0.037	4.994	1	0.0250	0.921	0.857	0.99
>33.5	-0.162	0.042	14.661	1	0.0000	0.850	0.782	0.924
Some College No degree (ref: ≤ 14.3)			13.775	3	0.0030			
>14.3 and ≤ 17.1	0.086	0.028	9.388	1	0.0020	1.090	1.032	1.152
>17.1 and ≤ 19.1	0.1	0.033	9.311	1	0.0020	1.105	1.036	1.178
>19.1	0.054	0.036	2.295	1	0.1300	1.056	0.984	1.132
Associate degree (ref: ≤ 6.6)			9.346	3	0.0250			
>6.6 and ≤ 8.8	-0.033	0.027	1.521	1	0.2170	0.967	0.917	1.02
>8.8 and ≤ 11.3	-0.085	0.031	7.444	1	0.0060	0.918	0.864	0.976
>11.3	-0.033	0.037	0.811	1	0.3680	0.967	0.9	1.04
Bachelor Degree (ref: ≤13.2)			9.1	3	0.0280			
>13.2 and ≤17.8	0.03	0.028	1.122	1	0.2890	1.030	0.975	1.089
>17.8 and ≤23.1	-0.052	0.036	2.13	1	0.1440	0.949	0.885	1.018
>23.1	-0.017	0.05	0.123	1	0.7260	0.983	0.891	1.083
Unemployment rate 16 yr +(ref: ≤5.5)			4.195	3	0.2410			
>5.5 and ≤ 6.9	0.011	0.025	0.192	1	0.6620	1.011	0.962	1.063
>6.9 and ≤ 8.9	-0.005	0.029	0.024	1	0.8760	0.995	0.94	1.054
>8.9	0.049	0.033	2.169	1	0.1410	1.050	0.984	1.12
No Vehicle OHU% (ref:>33.9)			2.038	3	0.5650			
≤ 5.1	-0.061	0.047	1.702	1	0.1920	0.941	0.858	1.031
>5.1 and ≤ 9.9	-0.06	0.044	1.927	1	0.1650	0.941	0.864	1.025
>9.9 and ≤ 33.9	-0.034	0.036	0.864	1	0.3530	0.967	0.901	1.038
Median Household Income (ref: ≤ 46305)			17.996	3	0.0000			
>46305 and ≤ 60526	-0.098	0.03	10.568	1	0.0010	0.907	0.855	0.962
>60526 and ≤ 82738	-0.158	0.038	17.315	1	0.0000	0.854	0.792	0.92
>82738	-0.137	0.047	8.338	1	0.0040	0.872	0.795	0.957
All Families below poverty level (ref:>13.5)			7.43	3	0.0590			
≤ 3.7	0.121	0.049	6.043	1	0.0140	1.129	1.025	1.244
>3.7 and ≤7.1	0.111	0.043	6.705	1	0.0100	1.118	1.027	1.216
>7.1 and ≤ 13.5	0.076	0.033	5.431	1	0.0200	1.079	1.012	1.15
Below Poverty age 65 and above (ref:>13.2)			11.169	3	0.0110			
≤ 5.1	0.141	0.043	10.86	1	0.0010	1.151	1.059	1.252
>5.1 and ≤ 8.1	0.09	0.039	5.288	1	0.0210	1.095	1.013	1.182
>8.1 and ≤ 13.2	0.068	0.034	4.061	1	0.0440	1.071	1.002	1.144

Variables in the Equation RQ1-Model 1	*B*	*S.E.*	Wald	*df*	*p*	*OR*	95% C.I. Lower	Upper
GINI index of inequality (ref:> 0.515)			0.773	3	0.8560			
<0.3	0.079	0.144	0.299	1	0.5850	1.082	0.815	1.436
>0.3 and ≤ 0.415	0.021	0.042	0.242	1	0.6230	1.021	0.94	1.108
> 0.415 and ≤ 0.515	0.026	0.035	0.558	1	0.4550	1.026	0.959	1.099
constant	-4.206	0.131	1029	1	0.0000	0.015		

Note. Dependent Variable: AL=Anastomotic Leak, *OR* = Odds Ratio, CI = confidence interval, $*p < 0.05$.

Reporting results from the binomial logistic regression RQ1-Model-1-Dependent Variable: AL

Binomial logistic regression was performed to evaluate the effects of predictor variables entered in the RQ1-Model-1 shown on Table 4: age in years, sex, principal diagnosis, surgical approach, surgical_procedure_site, anastomosis distal end, diverting stoma, the severity of illness risk (APRSOI), admission type, race, health insurance, annual hospital volume, limited English all households, less than 9th grade, high school GED, some college no degree , associate degree, bachelor degree, unemployment rate 16 yr +, median household income, all families below poverty level, below poverty age 65 and above, GINI index of inequality, no vehicle OHU % on the likelihood of the postsurgical outcome AL (Table 4). The logistic regression model was statistically significant, $\chi 2 = 9111.991$, $p = 0.0000$ (see Appendix C, Table C3). The model explained 12.4% (Nagelkerke) of the variance in the analyses, and Hosmer and Lemeshow Test was not significant p=0.356 indicating that the model was well fit (see Appendix C, Tables C4 and C5). The null hypothesis was rejected. Overall, the model accurately classified 86.7% of 130 731cases included. The sensitivity is low 0.1%, and specificity is very high, 100 % (see Appendix C, Table C6). The significant SDOH variables *p-value*, odds ratio, and the 95% Confidence Interval for the odds, in Table 4. The SDOH race, hospital case volume, language proficiency, education, income, and poverty were significantly associated independent factors with the likelihood of the increase or decrease of AL occurrence after large intestinal surgery. The significant SDOH associated with increase or decrease of AL occurrence are reported in Tables 5 and 6. Significant covariates associated with the increase or decrease of AL are listed in Table 7.

Table 5

Significant SDOH RQ1-Model-1 associated with increase of AL occurrence after large intestinal surgery

Variable type/level	RQ1-Model-1	*p*	*OR*	95% C.I.	
	SDOH associated with AL increase			Lower	Upper
SDOH Patient					
Social /Community Context	Race (ref: White)	0.0490			
	Black or African American	0.0220	1.071	1.01	1.135
Hospital Facility	Annual Hospital Volume, cases (ref: ≤ 52)	0.0000			
	≥53 and ≤ 123	0.000	1.127	1.074	1.183
	>123 and ≤ 201	0.000	1.214	1.157	1.274
	>201	0.003	1.084	1.028	1.142
SDOH Zip code					
Education	Some College No degree % (ref: ≤ 14.3)	0.0030			
	>14.3 and ≤ 17.1	0.0020	1.090	1.032	1.152
	>17.1 and ≤ 19.1	0.0020	1.105	1.036	1.178
	Bachelor Degree (ref: ≤13.2)	0.0280			
Poverty	All Families below poverty level % (ref:>13.5)	0.0590			
	≤ 3.7	0.0140	1.129	1.025	1.244
	>3.7 and ≤7.1	0.0100	1.118	1.027	1.216
	>7.1 and ≤ 13.5	0.0200	1.079	1.012	1.15
	Below Poverty age 65 and above (ref:>13.2)	0.0110			
	≤ 5.1	0.0010	1.151	1.059	1.252
	>5.1 and ≤ 8.1	0.0210	1.095	1.013	1.182
	>8.1 and ≤ 13.2	0.0440	1.071	1.002	1.144

Note. Dependent Variable: AL=Anastomotic Leak, *OR* = Odds Ratio, CI = confidence interval, *$p<0.05$

Table 6

Significant SDOH in RQ1-Model-1 associated with decrease of AL

Variable Type/level	RQ1-Model-1	*p*	*OR*	95% C.I.	
SDOH Zip code	SDOH associated with AL decrease			Lower	Upper
Language Proficiency	Limited English All Households % (ref: >8.2)	0.0950			
	>2.8 and ≤ 8.2	0.0180	0.925	0.867	0.987
Education	High School GED % (ref: ≤ 22.9)	0.0010			
	>22.9 and ≤ 29.0	0.0170	0.928	0.873	0.987
	>29.0 and ≤ 33.5	0.0250	0.921	0.857	0.99
	>33.5	0.0000	0.850	0.782	0.924
	Associate degree (ref: ≤ 6.6)	0.0250			
	>8.8 and ≤ 11.3	0.0060	0.918	0.864	0.976
Income	Median Household Income (ref: ≤ 46305)	0.0000			
	>46305 and ≤ 60526	0.0010	0.907	0.855	0.962
	>60526 and ≤ 82738	0.0000	0.854	0.792	0.92
	>82738	0.0040	0.872	0.795	0.957

Note. Dependent Variable: AL=Anastomotic Leak, *OR*=Odds Ratio, CI=confidence interval,

*p<0.0

Table 7

Covariates in RQ1-Model-1 associated with increase or decrease of AL occurrence after large intestinal surgery

Variable type/Level	RQ1-Model-1	*p*	*OR*	95% C.I.	
	Covariates associated with AL increase			Lower	Upper
Biological Patient level	Age in years (ref: 77 and above)	0.000			
	up to 53	0.000	1.400	1.316	1.489
	54 to 65	0.000	1.220	1.152	1.292
	66 to 76	0.000	1.129	1.077	1.184
	Sex Male	0.000	1.324	1.281	1.369
Clinical Patient level	Principal Diagnosis (ref: Diverticulitis)	0.000			
	Neoplasms	0.002	1.083	1.029	1.139
	Surgical Approach (ref: Laparoscopic)	0.000			
	Open	0.000	1.219	1.166	1.274
	Other	0.000	1.212	1.106	1.329
	Surgical Procedure Site (ref: Colon resection)	0.000			
	Total colectomy	0.000	1.218	1.104	1.343
	Anastomosis Distal End (ref: Anal)	0.000			
	Colon	0.000	1.594	1.326	1.916
	Rectal	0.002	1.329	1.109	1.593
	Diverting Stoma - Yes	0.025	1.057	1.007	1.109
	APRSOI risk (ref: Minor)	0.000			
	Moderate	0.000	2.917	2.755	3.087
	Major	0.000	7.567	7.122	8.041
	Extreme	0.000	11.634	10.846	12.479
	Admission Type-Elective	0.000	1.345	1.290	1.404
	Covariates associated with AL decrease				
Clinical Patient level	Principal Diagnosis (ref: Diverticulitis)	0.000			
	Other (not IBD, Neoplasm or Diverticulitis)	0.007	0.929	0.881	0.980

Note. Dependent Variable: AL=Anastomotic Leak, *OR* = Odds Ratio, CI=confidence interval, $*p < 0.05$.

The null hypothesis for Research Question 1(RQ1) was rejected as RQ1-Model-1 (including single measure SDOH on individual and contextual levels) demonstrated a significant association of the SDOH in Table 5 and Table 6 with the increase or decrease of AL occurrence respectively.

RQ1-Model-2a

In RQ1-Model-2a single measurement patient level and composite SDOH- SVI Overall Themes evaluation on contextual level (ZIP code and County code areas) were included with dependent variable: AL. Based on the bivariate analyses, all independent variables with significance 0.05 or below were initially included in RQ1-Model-2a. A multicollinearity test was performed, and no adjustments were needed to meet the cut-off marks for the Tolerance factor less than 0.2 and VIF 5 (see Appendix C, Table C7). In Appendix C, Figure C2 presents the independent variable that were included for multivariable analysis in the final RQ1-Model-2a after the multicollinearity test (see Appendix C, Figure C2).

Table 8

Binomial logistic regression results RQ1-Model-2a. Dependent variable AL

Variables in the Equation RQ1-Model-2a	*B*	*S.E.*	*Wald*	*df*	*p*	*OR*	95% C.I.	
							Lower	Upper
Age in years (ref: 77 and above)			111.577	3	0.000			
up to 53	0.332	0.031	111.336	1	0.000	1.394	1.311	1.483
54 to 65	0.196	0.029	45.272	1	0.000	1.216	1.149	1.287
66 to 76	0.121	0.024	24.676	1	0.000	1.128	1.076	1.183
Sex Male	0.281	0.017	269.292	1	0.000	1.324	1.28	1.369
Principal Diagnosis (ref: Diverticulitis)			42.898	3	0.000			
IBD	0.005	0.045	0.013	1	0.908	1.005	0.92	1.099
Neoplasms	0.071	0.026	7.392	1	0.007	1.073	1.02	1.13
Other	-0.079	0.027	8.448	1	0.004	0.924	0.876	0.975
Surgical Procedure Site (ref: Colon resection)			19.209	3	0.000			
Other	-0.053	0.05	1.103	1	0.294	0.949	0.859	1.047
Rectal resection	0.038	0.047	0.678	1	0.410	1.039	0.948	1.139
Total colectomy	0.198	0.05	15.706	1	0.000	1.219	1.105	1.344
Surgical Approach (ref: Laparoscopic)			78.582	2	0.000			
Open	0.198	0.023	77.53	1	0.000	1.219	1.167	1.275
Other	0.194	0.047	17.314	1	0.000	1.214	1.108	1.33
Anastomosis Distal End (ref: Anal)			81.9	2	0.000			
Colon	0.47	0.094	25.096	1	0.000	1.600	1.331	1.922
Rectal	0.287	0.092	9.637	1	0.002	1.332	1.112	1.597
Diverting Stoma - Yes	0.053	0.025	4.685	1	0.030	1.055	1.005	1.107
APRSOI risk (ref: Minor)			5808.05	3	0.000			
Moderate	1.069	0.029	1357.69	1	0.000	2.912	2.751	3.083
Major	2.024	0.031	4270	1	0.000	7.565	7.119	8.038
Extreme	2.456	0.036	4714.9	1	0.000	11.653	10.86	12.5
Admission Type-Elective	0.297	0.022	189.012	1	0.000	1.345	1.29	1.403
Race (ref: White)			7.711	3	0.052			
Asian	-0.097	0.06	2.663	1	0.103	0.907	0.807	1.02
Black or African American	0.052	0.029	3.346	1	0.067	1.054	0.996	1.114
Other	0.037	0.03	1.518	1	0.218	1.037	0.979	1.099
Health Insurance (ref: Medicaid)			8.986	4	0.061			
Medicare	-0.038	0.043	0.775	1	0.379	0.963	0.886	1.047
Other	0.138	0.148	0.861	1	0.353	1.148	0.858	1.535
Private/Commercial	0.003	0.039	0.008	1	0.929	1.003	0.93	1.083
Self-Pay	0.106	0.063	2.861	1	0.091	1.112	0.983	1.256

Table 8 continued

Variables in the Equation RQ1-Model-2a	*B*	*S.E.*	*Wald*	*df*	*p*	*OR*	95% C.I.	
							Lower	Upper
≥53 and ≤ 123	0.127	0.025	26.229	1	0.000	1.135	1.081	1.192
>123 and ≤ 201	0.208	0.025	71.576	1	0.000	1.231	1.173	1.292
>201	0.106	0.027	15.871	1	0.000	1.112	1.055	1.171
T0z_Overal SVI Themes Summary score (ref: ≤.1909)			0.835	3	0.841			
>.1909 and ≤ .3929	-0.018	0.025	0.523	1	0.470	0.982	0.936	1.031
>.3929 and ≤ .6590	-0.022	0.026	0.726	1	0.394	0.978	0.93	1.029
> 0.6590	-0.018	0.03	0.334	1	0.563	0.983	0.926	1.043
T0ct Overall SVI Themes Summary score (ref: ≤ .1639)			17.885	3	0.000			
>.1639 and ≤ 5410	0.023	0.025	0.825	1	0.364	1.023	0.974	1.076
>.5410 and ≤ .7213	0.099	0.026	14.389	1	0.000	1.104	1.049	1.162
>0.7213	0.085	0.029	8.606	1	0.003	1.088	1.028	1.152
Flags_TOTALz_SVI Themes Sum Flags3 (ref: =0 flags)			12.608	2	0.002			
1	0.059	0.021	7.611	1	0.006	1.061	1.017	1.107
≥ 2	0.082	0.026	9.784	1	0.002	1.086	1.031	1.143
Flags_TOTALct_SVI Themes Sum Flags3 (ref: ≥ 2 flags)			5.011	2	0.082			
0	-0.026	0.021	1.431	1	0.232	0.975	0.935	1.016
1	-0.067	0.031	4.603	1	0.032	0.935	0.879	0.994
Constant	-4.298	0.114	1422.83	1	0.000	0.014		

Note. Dependent Variable: AL=Anastomotic Leak, *OR*=Odds Ratio, CI=confidence interval, *$p<0.05$

Reporting results from the binomial logistic regression RQ1-Model-2a-Dependent Variable: AL

Binomial logistic regression was performed to evaluate the effects of predictor variables entered in the RQ1-Model-2a shown on Table 8: age in years, sex, principal diagnosis, surgical approach, surgical_procedure_site, anastomosis distal end, diverting stoma, APRSOI severity of illness risk, admission type, race, health insurance, annual hospital volume, SVI Overall rank on zip code and county levels, and extreme SVI (variable called “flagged Overall Themes SVI on zip code and county levels on the likelihood of the postsurgical outcome AL. Before performing logistic regression, a multicollinearity test was performed, with cut-off points for tolerance less than 0.2 and VIF equal or less than 5 as shown in Appendix C, on Table C7. The logistic regression model was statistically significant, $\chi2$ =9054.913, p = 0.0000 (see Appendix C, Table C8) The model explained 12.3 % (Nagelkerke) of the variance in the analyses, and Hosmer and Lemeshow Test was not significant p=0.307 indicating that the model was well fit as shown in Appendix C, on Tables C9 and C10 respectively (see Tables C9 and C10). The null hypothesis was rejected. Overall, the model accurately classified 86.7% of 130 731cases included. The sensitivity is very low, 0.1% and specificity very high, 100 % (see Appendix C). The SDOH Overall Social Vulnerability at the county level, Extreme Social Vulnerability (flagged overall themes) at zip code and county code levels were significantly associated independent factors with the likelihood of the increase or decrease of AL occurrence after large intestinal surgery. The significant SDOH variables *p-value*, odds ratio, and the 95% Confidence Interval for the odds are listed in Table 8. The null hypothesis for Research Question 1was rejected as RQ1-Model-2a (including single measure SDOH on individual and contextual levels) demonstrated a significant association of the SDOH in Table 9. Table 10 displays the covariates related to the increase or decrease of AL occurrence, respectively.

Table 9

SDOH in RQ1-Model-2a associated with increase or decrease of AL occurrence after large intestinal surgery

Variable type/level	RQ1-Model-2a	*p*	*OR*	95% C.I.	
	Composite SVI SDOH associated with AL increase			Lower	Upper
Patient Level	Annual Hospital Volume, cases (ref: :≤ 52)	0.000			
	≥53 and ≤ 123	0.000	1.135	1.081	1.192
	>123 and ≤ 201	0.000	1.231	1.173	1.292
	>201	0.000	1.112	1.055	1.171
SDOH Zip code	Flags**_TOTALz_SVI* Themes Sum Flags (ref: =0)	0.002			
	1	0.006	1.061	1.017	1.107
	≥ 2	0.002	1.086	1.031	1.143
SDOH County code	T0ct Overall SVI Themes Summary score (ref: ≤ .1639)	0.000			
	>.5410 and ≤ .7213	0.000	1.104	1.049	1.162
	>0.7213	0.003	1.088	1.028	1.152
	Composite SVI SDOH associated with AL decrease				
	Flags_TOTALct_Themes Sum Flags3 (ref: ≥ 2 flags)	0.082			
	1	0.032	0.935	0.879	0.994

Note. Dependent Variable: AL=Anastomotic leak, *SVI-Social Vulnerability/ **Flags SVI = Extreme Vulnerability, *OR*=Odds Ratio, CI=confidence interval, *$p<0.05$

Table 10

Covariates in RQ1-Model-2a associated with increase or decrease of AL occurrence after large intestinal surgery

Variable type/Level	RQ1-Model-2a	*p*	*OR*	95% C.I.	
	Covariates associated with AL increase			Lower	Upper
Biological Patient level	Age in years (ref: 77 and above)	0.000			
	up to 53	0.000	1.394	1.311	1.483
	54 to 65	0.000	1.216	1.149	1.287
	66 to 76	0.000	1.128	1.076	1.183
	Sex Male	0.000	1.324	1.280	1.369
Clinical Patient level	Principal Diagnosis (ref: Diverticulitis)	0.000			
	Neoplasms	0.007	1.073	1.020	1.130
	Surgical Procedure Site (ref: Colon resection)	0.000			
	Total colectomy	0.000	1.219	1.105	1.344
	Surgical Approach (ref: Laparoscopic)	0.000			
	Open	0.000	1.219	1.167	1.275
	Other	0.000	1.214	1.108	1.330
	Anastomosis Distal End (ref: Anal)	0.000			
	Colon	0.000	1.600	1.331	1.922
	Rectal	0.002	1.332	1.112	1.597
	Diverting Stoma - Yes	0.030	1.055	1.005	1.107
	APRSOI risk (ref: Minor)	0.000			
	Moderate	0.000	2.912	2.751	3.083
	Major	0.000	7.565	7.119	8.038
	Extreme	0.000	11.653	10.860	12.500
	Admission Type-Elective	0.000	1.345	1.290	1.403
	Covariates associated with AL decrease				
Clinical Patient level	Principal Diagnosis (ref: Diverticulitis)	0.000			
	Other (not IBD, Neoplasm or Diverticulitis)	0.004	0.924	0.876	0.975

Note. Dependent Variable: AL=Anastomotic Leak, *SVI-Social Vulnerability/ **Flags SVI = Extreme Vulnerability, *OR*=Odds Ratio, CI=confidence interval, *$p<0.05$

RQ1-Model-2b

RQ1-Model-2b Evaluation of Social Vulnerability Themes

In RQ1-Model-2b single measurement patient level and composite SVI SDOH- the County level, were included in the analysis with dependent variable: AL. A multicollinearity test was performed, and no adjustments were needed to meet the cut-off marks for the Tolerance factor less than 0.2 and VIF 5 (Table C12). The independent variable that were included in the final RQ1-Model-2b after the multicollinearity test are presented in Appendix C (see Appendix C, Figure C3).

Reporting results from the Logistic regression RQ1-Model-2b - Dependent Variable: AL

Table 11

Binomial logistic regression results RQ1-Model-2b. Dependent variable AL

Variables in the Equation RQ1-Model-2b	*B*	*S.E.*	*Wald*	*df*	*p*	*OR*	95% CI	
							Lower	Upper
Age in years (ref: 77 and above)			110.723	3	0.000			
up to 53	0.332	0.032	110.55	1	0.000	1.394	1.31	1.483
54 to 65	0.198	0.029	46.395	1	0.000	1.220	1.152	1.291
66 to 76	0.123	0.024	25.492	1	0.000	1.131	1.078	1.186
Sex Male	0.282	0.017	271.68	1	0.000	1.326	1.282	1.371
Principal Diagnosis (ref: Diverticulitis)			45.925	3	0.000			
IBD	0.006	0.046	0.02	1	0.889	1.006	0.92	1.1
Neoplasms	0.076	0.026	8.392	1	0.004	1.079	1.025	1.135
Other	-0.08	0.027	8.57	1	0.003	0.923	0.875	0.974
Surgical Procedure Site (ref: Colon resection)			19.565	3	0.000			
Other	-0.05	0.05	0.99	1	0.320	0.951	0.862	1.05
Rectal resection	0.036	0.047	0.595	1	0.441	1.037	0.946	1.136
Total colectomy	0.202	0.05	16.33	1	0.000	1.224	1.11	1.35
Surgical Approach (ref: Laparoscopic)			83.431	2	0.000			
Open	0.205	0.023	82.04	1	0.000	1.227	1.174	1.283
Other	0.206	0.047	19.403	1	0.000	1.228	1.121	1.346
Anastomosis Distal End (ref: Anal)			80.818	2	0.000			
Colon	0.468	0.094	24.866	1	0.000	1.597	1.328	1.919
Rectal	0.286	0.092	9.57	1	0.002	1.331	1.111	1.596
Diverting Stoma - Yes	0.053	0.025	4.635	1	0.031	1.054	1.005	1.107
APRSOI risk (ref: Minor)			5788.26	3	0.000			
Moderate	1.068	0.029	1352.63	1	0.000	2.909	2.748	3.079
Major	2.023	0.031	4256.08	1	0.000	7.558	7.112	8.031
Extreme	2.454	0.036	4696.86	1	0.000	11.63	10.84	12.48
Admission Type-Elective	0.291	0.022	180.08	1	0.000	1.337	1.282	1.395
Race (ref: White)			5.597	3	0.133			
Asian	-0.064	0.061	1.127	1	0.288	0.938	0.833	1.056
Black or African American	0.058	0.03	3.769	1	0.052	1.059	0.999	1.123
Other	0.005	0.031	0.026	1	0.872	1.005	0.946	1.068
Health Insurance (ref: Medicaid)			9.848	4	0.043			
Medicare	-0.037	0.043	0.739	1	0.390	0.964	0.886	1.048
Other	0.13	0.149	0.763	1	0.382	1.139	0.851	1.525
Private/Commercial	0.001	0.039	0.001	1	0.974	1.001	0.927	1.081
Self-Pay	0.12	0.063	3.68	1	0.055	1.128	0.997	1.276
Annual Hospital Volume, cases (ref: ≤ 52)			76.572	3	0.000			
≥53 and ≤ 123	0.129	0.056	5.330	1	0.021	1.138	1.020	1.270
>123 and ≤ 201	0.238	0.053	20.301	1	0.000	1.269	1.144	1.407
>201	0.349	0.051	46.816	1	0.000	1.418	1.283	1.567

Variables in the Equation RQ1-Model-2b	*B*	*S.E.*	*Wald*	*df*	*p*	*OR*	95% C I Lower	Upper
T1z_Socioeconomic Status (ref: ≤ .1756)			2.247	3	0.523			
>.1756 and ≤.3799	0.01	0.026	0.161	1	0.689	1.010	0.96	1.063
>.3799 and ≤.6453	-0.029	0.031	0.853	1	0.356	0.972	0.915	1.033
>.6453	-0.026	0.039	0.458	1	0.499	0.974	0.903	1.051
T2z_Houshold Composition and Disability (ref:≤ .2863)			6.382	3	0.094			
>.2863 and ≤.5045	-0.042	0.026	2.64	1	0.104	0.959	0.911	1.009
>.5045 and ≤ .7467	-0.042	0.028	2.35	1	0.125	0.959	0.908	1.012
>.7467	0.008	0.031	0.065	1	0.799	1.008	0.949	1.07
T3z_Minority Status and Language (ref: ≤ .1820)			3.163	3	0.367			
>.1820 and ≤ .3850	-0.047	0.027	3.142	1	0.076	0.954	0.906	1.005
>.3850 and ≤ .6561	-0.026	0.03	0.748	1	0.387	0.975	0.919	1.033
>.6561	-0.029	0.041	0.491	1	0.484	0.972	0.897	1.053
T4z_Housing and Transportation (ref: ≤.2400)			1.033	3	0.793			
>.2400 and ≤ .4420	-0.01	0.025	0.156	1	0.693	0.990	0.942	1.04
>.4420 and ≤ .7240	0.001	0.027	0.001	1	0.975	1.001	0.948	1.056
>.7240	0.02	0.032	0.377	1	0.539	1.020	0.958	1.086
T1ct Socioeconomic Status (ref: ≤ .1475)			4.943	3	0.176			
>.1475 and ≤ 0.3934	-0.018	0.052	0.117	1	0.732	0.982	0.886	1.089
>.3934 and ≤ 0.7377	-0.075	0.057	1.712	1	0.191	0.928	0.829	1.038
>.7377	-0.151	0.085	3.185	1	0.074	0.860	0.729	1.015
T2ct Household Composition and Disability (ref: ≤ .0984)			42.127	3	0.000			
>.0984 and ≤ .3115	-0.007	0.032	0.047	1	0.828	0.993	0.933	1.057
>.3115 and ≤ .4754	-0.071	0.051	1.93	1	0.165	0.932	0.843	1.029
>0.4754	0.156	0.05	9.509	1	0.002	1.168	1.058	1.29
T4ct Housing and Transportation (ref: ≤ .2787)			19.8	3	0.000			
>.2787 and ≤ .6230	0.027	0.036	0.544	1	0.461	1.027	0.957	1.102
>.6230 and ≤ .7869	0.016	0.054	0.088	1	0.766	1.016	0.915	1.129
>.7869	0.202	0.057	12.457	1	0.000	1.224	1.094	1.37
Flags_T1z_Socioeconomic Status (ref:0)			2.281	4	0.684			
1	0.028	0.042	0.448	1	0.503	1.028	0.948	1.116
2	0.023	0.053	0.19	1	0.663	1.024	0.922	1.137
3	-0.015	0.079	0.036	1	0.849	0.985	0.844	1.15
4	-0.092	0.089	1.085	1	0.297	0.912	0.766	1.085
Flags_T2z_Household Composition & Disability (ref:0)			0.876	3	0.831			
1	-0.013	0.024	0.279	1	0.597	0.987	0.941	1.035
2	-0.039	0.046	0.725	1	0.395	0.962	0.879	1.052
3	-0.037	0.085	0.188	1	0.664	0.964	0.815	1.139
Flags_T3z_ Minority Status and Language (ref:0)			3.991	2	0.136			
1	0.073	0.037	3.99	1	0.046	1.076	1.001	1.156
2	0.044	0.085	0.27	1	0.603	1.045	0.885	1.235

Variables in the Equation RQ1-Model-2b	*B*	*S.E.*	*Wald*	*df*	*p*	*OR*	95% C I Lower	Upper
1	0.001	0.024	0.002	1	0.969	1.001	0.955	1.049
2	-0.061	0.046	1.81	1	0.179	0.940	0.86	1.028
3	-0.06	0.084	0.514	1	0.473	0.942	0.799	1.11
4	-0.277	0.256	1.167	1	0.280	0.758	0.459	1.253
Flags_T1ct Socioeconomic Status (ref: 4)			24.356	4	0.000			
0	-0.061	0.103	0.357	1	0.550	0.940	0.769	1.15
1	-0.117	0.102	1.304	1	0.254	0.890	0.728	1.087
2	0.027	0.075	0.131	1	0.718	1.028	0.886	1.192
3	-0.545	0.132	16.94	1	0.000	0.580	0.447	0.752
Flags_T2ct Household Composition and Disability (ref:0)			2.522	2	0.283			
1	-0.059	0.037	2.516	1	0.113	0.943	0.877	1.014
2	-0.006	0.088	0.004	1	0.949	0.994	0.836	1.182
Flags_T4ct Housing and Transportation (ref:0)			35.39	3	0.000			
1	0.206	0.037	30.15	1	0.000	1.228	1.141	1.322
2	-0.021	0.06	0.124	1	0.725	0.979	0.871	1.1
3	0.115	0.061	3.61	1	0.057	1.122	0.996	1.264
Constant	-4.197	0.158	701.885	1	0.000	0.015		

Note. Dependent Variable: AL=Anastomotic Leak, *OR*=Odds Ratio, CI=confidence interval, *$p<0.05$

Reporting results from the binomial logistic regression RQ1-Model-2b-Dependent Variable: AL

Binomial logistic regression was performed to evaluate the effects of predictor variables entered in the RQ1-Model-2b as shown in Table 11: age 4gr, sex, principal diagnosis, surgical approach, surgical_procedure_site, anastomosis distal end, diverting stoma, APRSOI Severity of Illness risk, admission type, race, health insurance, annual hospital volume, SVI_THEME1zip Socioeconomic Status, SVI_THEME2zip_2016 Household Composition and Disability, SVI_THEME3zip Minority Status and Language, SVI_THEME4zip Housing and Transportation, THEME1_ct Socioeconomic Status, THEME2_ct Household Composition and Disability, T4ct Housing and Transportation, Flags_T1z_Socioeconomic Status, Flags_T2z_Household

Composition & Disability, Flags_T3z_ Minority Status and Language, Flags_T4z_Housing and Transportation, Flags_T1ct Socioeconomic Status, Flags_T2ct Household Composition and Disability, and Flags_T4ct Housing and Transportation on the likelihood of the postsurgical outcome AL. The logistic regression model was statistically significant, $\chi2$ =9243.176, p = 0.0000 (see Appendix C, Table C13). The model explained 12.6% (Nagelkerke) of the variance in the analyses, and Hosmer and Lemeshow Test was not significant p=0.872 indicating that the model was well fit, presented in Appendix C (see Appendix C, Tables C14 and C15) The null hypothesis was rejected. Overall, the model accurately classified 86.7% of 130 731cases included. The sensitivity is very low, 0.1% and specificity very high, 100 %, shown on Table C16 Of the predictor variables, 3 SDOH factors were on patient-level single measurements, and 14 SDOH were composite variables presenting social vulnerability on contextual levels (zip code and county code). Overall, five composite SDOH are independent factors associated with the likelihood of the occurrence of postoperative complication Anastomotic Leak. The *p-value*, odds ratio, and the 95% Confidence Interval for the odds for this RQ1-Model-2b are listed in Table 11, and those associated with increase or decrease of AL occurrence are listed in Table 12. Significant covariates associated with an increase or decrease of AL occurrence are listed in Table 13. The null hypothesis for Research Question 1 was rejected as RQ1-Model-2b demonstrated that SDOH listed in Table 12 are significantly associated with the outcome AL and increase or decrease AL occurrence.

Table 12

SDOH in RQ1-Model-2b associated in increase or decrease of AL occurrence after large intestinal surgery

Variable type/Level	RQ1-Model-2b	*p*	*OR*	95% CI	
				Lower	Upper
	Annual Hospital Volume, cases (ref: ≤ 52)	0.000			
	≥53 and ≤ 123	0.021	1.138	1.020	1.270
	>123 and ≤ 201	0.000	1.269	1.144	1.407
	>201	0.000	1.418	1.283	1.567
	Composite SDOH from SVI THEMES associated with AL increase				
SDOH Zip code	Flags_T3z_ Minority Status and Language (ref:0)	0.136			
	1	0.046	1.076	1.001	1.156
SDOH County code	T2ct Household Composition and Disability (ref: ≤ .0984)	0.000			
	>0.4754	0.002	1.168	1.058	1.29
	T4ct Housing and Transportation (ref: ≤ .2787)	0.000			
	>.7869	0.000	1.224	1.094	1.37
	Flags_T4ct Housing and Transportation (ref:0)	0.000			
	1	0.000	1.228	1.141	1.322
	Composite SDOH from SVI THEMES associated with AL decrease				
	Flags_T1ct Socioeconomic Status (ref: 4)	0.000			
	3	0.000	0.580	0.447	0.752

Note. SDOH=Social Determinants of Health, SVI=Social Vulnerability, Flags SVI = Extreme Vulnerability, Dependent Variable: AL=Anastomotic Leak, *OR*=Odds Ratio, CI=confidence interval, *$p<0.05$

Table 13

Covariates in RQ1-Model-2b associated with increase or decrease of AL occurrence after large intestinal surgery

Variable type/Level	RQ1-Model-2b	*p*	*OR*	95% C.I.	
	Covariates associated with AL increase			Lower	Upper
Biological Patient level	Age in years (ref: 77 and above)	0.000			
	up to 53	0.000	1.394	1.310	1.483
	54 to 65	0.000	1.220	1.152	1.291
	66 to 76	0.000	1.131	1.078	1.186
	Sex Male	0.000	1.326	1.282	1.371
	Principal Diagnosis (ref: Diverticulitis)	0.000			
	Neoplasms	0.004	1.079	1.025	1.135
	Surgical Procedure Site (ref: Colon resection)	0.000			
	Total colectomy	0.000	1.224	1.110	1.350
	Surgical Approach (ref: Laparoscopic)	0.000			
	Open	0.000	1.227	1.174	1.283
	Other	0.000	1.228	1.121	1.346
	Anastomosis Distal End (ref: Anal)	0.000			
	Colon	0.000	1.597	1.328	1.919
	Rectal	0.002	1.331	1.111	1.596
	Diverting Stoma - Yes	0.031	1.054	1.005	1.107
	APRSOI risk (ref: Minor)	0.000			
	Moderate	0.000	2.909	2.748	3.079
	Major	0.000	7.558	7.112	8.031
	Extreme	0.000	11.630	10.840	12.480
	Admission Type-Elective	0.000	1.337	1.282	1.395
	Covariates associated with AL decrease				
Clinical Patient level	Principal Diagnosis (ref: Diverticulitis)	0.000			
	Other	0.003	0.923	0.875	0.974

Note. SDOH=Social Determinants of Health, SVI=Social Vulnerability, Flags SVI = Extreme Vulnerability, Dependent Variable: AL=Anastomotic Leak, *OR*=Odds Ratio, CI=95% confidence interval, *$p<0.05$

Research Question 2

Research Question and Hypothesis

Research Question 2 (RQ2): Is there an association between the SDOH and the SSI within 30 days after colorectal surgery in and out of the hospital in adult patients?

Null Hypothesis ($H_0$2): SDOH are not associated with SSI occurrence within 30 days after large intestinal resection in and out of the hospital in adult patients.

Alternative Hypothesis ($H_1$2): SDOH are associated with SSI occurrence within 30 days after large intestinal resection in and out of the hospital in adult patients.

The outcome or dependent variable was “surgical site infection” (SSI) after colorectal surgery measured as a binary outcome “yes" or "no" within 30 days after surgery and in or out of the hospital. “SSI” in this study included the following surgical site infectious complications within 30 days of the surgery such as: wound infection, abdominal abscess, pelvic abscess, retroperitoneal abscess, and AL. The definitions of each of the infectious complication are listed in the Appendix A and the identification ICD 9 and ICD 10 codes in Appendix B, Table B2.

Descriptive and Bivariate Analyzes

Table 14

Descriptive and Bivariate Statistics of the RQ2 SSI and SPARCS data patient variables (N=130731)

Variable	SSI_NO N (%)	SSI_YES N (%)	Total	Chi-square test χ^2	*p*	*Cramer's V*
Total	109298(83.6)	21433(16.4)	130731			
Age in years				95.71	.000*	0.027
< 65	55132 (50.4)	10028 (46.8)	65160			
≥65	54166 (49.6)	11405 (53.2)	65571			
Age 4gr				107.5	.000*	0.029
18 to 53	28506 (26.1)	5286 (24.7)	33792			
54 to 65	29247 (26.8)	5267 (24.6)	34514			
66 to 76	26567 (24.3)	5410 (25.2)	31977			
77 and above	24978 (22.9)	5470 (25.5)	30448			
Sex				242.8	.000*	0.043
Male	49395 (45.2)	10930 (51.0)	60325			
Female	59903 (54.8)	10503 (49.0)	70406			
Race				80.39	.000*	0.025
Asian	2875 (2.6)	471 (2.2)	3346			
Black or African American	12088 (11.1)	2756 (12.9)	14844			
Other	11167 (10.2)	2324 (10.8)	13491			
White	83168 (76.1)	15882 (74.1)	99050			
Race minority				38.73	.000*	0.017
Not minority	83168 (76.1)	15882 (74.1)	99050			
Minority (all except white)	26130 (23.9)	5551 (25.9)	31681			
Principal Diagnosis				389.8	.000*	0.055
Diverticulitis	26495 (24.2)	4684 (21.9)	31179			
IBD	4315 (3.9)	1109 (5.2)	5424			
Neoplasms	52413 (48.0)	9364 (43.7)	61777			
Other	26075 (23.9)	6276 (29.3)	32351			
APRSOI Severity of Illness risk				9050	.000*	0.263
minor	37582 (34.4)	2416 (11.3)	39998			
moderate	41817 (38.3)	6615 (30.9)	48432			
major	19575 (17.9)	6952 (32.4)	26527			
extreme	10324 (9.4)	5450 (25.4)	15774			

Table 14 continued

Variable	SSI_NO N (%)	SSI_YES N (%)	Total	Chi-square test χ^2	p	Cramer's V
Admission Type				1290	.000*	0.099
Elective	69389 (63.5)	10807 (50.4)	80196			
Emergency	39909 (36.5)	10626 (49.6)	50535			
Surgical_Procedure_Site				281.2	.000*	0.046
Colon resection	89565 (81.9)	17419 (81.3)	106984			
Other	5478 (5.0)	1297 (6.1)	6775			
Rectal resection	11678 (10.7)	1868 (8.7)	13546			
Total colectomy	2577 (2.4)	849 (4.0)	3426			
Surgical Approach				1079	.000*	0.091
laparoscopic	33084 (30.3)	4172 (19.5)	37256			
open	63153 (57.8)	14677 (68.5)	77830			
other	13061 (11.9)	2584 (12.1)	15645			
Anastomosis distal end				98.28	.000*	0.027
anal	1929 (1.8)	196 (0.9)	2125			
colon	53464 (48.9)	10905 (50.9)	64369			
rectal	53905 (49.3)	10332 (48.2)	64237			
Diverting Stoma				1274	.000*	0.099
no	95093 (87.0)	16633 (77.6)	111726			
yes	14205 (13.0)	4800 (22.4)	19005			
Health Insurance				207.2	.000*	0.04
Medicaid	5383 (4.9)	1243 (5.8)	6626			
Medicare	45929 (42.0)	9853 (46.0)	55782			
Other	345 (0.3)	78 (0.4)	423			
Private/Commercial	54886 (50.2)	9630 (44.9)	64516			
Self-Pay	2755 (2.5)	629 (2.9)	3384			
Annual Hospital Volume4				29.4	.000*	0.015
≤ 52	27629 (25.3)	5393 (25.2)	33022			
≥53 and ≤ 122.7	27930 (25.6)	5545 (25.9)	33475			
≥123 and ≤ 200.34	27769 (25.4)	5722 (26.7)	33491			
≥201	25970 (23.8)	4773 (22.3)	30743			

Note: * The Chi-square statistic is significant at the .05 level, Cramer's V– values are presented

Table 15

Descriptive and Bivariate Statistics RQ2 SSI and Social Vulnerability Index Composite Themes on Zip code and County code (N=130731)

				Chi-square test		
Variable SVI COMPOSITE	SSI_NO *N* (%)	SSI_YES *N* (%)	Total	χ^2	*p*	*Cramer's V*
Total	109298(83.6)	21433(16.4)	130731			
ZIP CODE LEVEL						
T1z_Socioeconomic Status				86.193	.000*	0.026
≤ .1756	27577 (25.2)	5110 (23.8)	32687			
>.1756 and ≤.3799	27541 (25.2)	5153 (24.0)	32694			
>.3799 and ≤.6453	27391 (25.1)	5288 (24.7)	32679			
>.6453	26789 (24.5)	5882 (27.4)	32671			
T2z_Houshold Composition and Disability				38.334	.000*	0.017
≤ .2863	27409 (25.1)	5418 (25.3)	32827			
>.2863 and ≤.5045	27478 (25.1)	5106 (23.8)	32584			
>.5045 and ≤ .7467	27412 (25.1)	5235 (24.4)	32647			
>.7467	26999 (24.7)	5674 (26.5)	32673			
T3z_Minority Status and Language				53.349	.000*	0.02
≤ .1820	27448 (25.1)	5253 (24.5)	32701			
>.1820 and ≤ .3850	27714 (25.4)	5098 (23.8)	32812			
>.3850 and ≤ .6561	27233 (24.9)	5346 (24.9)	32579			
>.6561	26903 (24.6)	5736 (26.8)	32639			
T4z_Housing and Transportation				37.686	.000*	0.017
≤.2400	27604 (25.3)	5210 (24.3)	32814			
>.2400 and ≤ .4420	27509 (25.2)	5249 (24.5)	32758			
>.4420 and ≤ .7240	27242 (24.9)	5273 (24.6)	32515			
>.7240	26943 (24.7)	5701 (26.6)	32644			
T0z_Overal Themes Summary score				81.257	.000*	0.025
≤.1909	27597 (25.2)	5094 (23.8)	32691			
>.1909 and ≤ .3929	27603 (25.3)	5168 (24.1)	32771			
>.3929 and ≤ .6590	27284 (25.0)	5314 (24.8)	32598			
> 0.6590	26814 (24.5)	5857 (27.3)	32671			
Variable				Chi-square test		

Variable SVI Composite	SSI_NO *N* (%)	SSI_YES *N* (%)	Total	χ^2	*p*	*Cramer's V*
Flags_T1z_Socioeconomic Status				79.786	.000*	0.025
0	96157 (88.0)	18395 (85.8)	114552			
1	6690 (6.1)	1505 (7.0)	8195			
2	3641 (3.3)	845 (3.9)	4486			
3	1429 (1.3)	343 (1.6)	1772			
4	1381 (1.3)	345 (1.6)	1726			
Flags_T2z_Household Composition & Disability				20.125	.000*	0.012
0	82283 (75.3)	15883 (74.1)	98166			
1	20646 (18.9)	4169 (19.5)	24815			
2	5009 (4.6)	1061 (5.0)	6070			
3	1360 (1.2)	320 (1.5)	1680			
Flags_T3z_ Minority Status and Language				57.991	.000*	0.021
0	97223 (89)	18679 (87.2)	115902			
1	10685 (9.8)	2444 (11.4)	13129			
2	1390 (1.3)	310 (1.4)	1700			
Flags_T4z_Housing and Transportation				38.223	.000*	0.017
0	73347 (67.1)	14022 (65.4)	87369			
1	26525 (24.3)	5321 (24.8)	31846			
2	8053 (7.4)	1759 (8.2)	9812			
3	1254 (1.1)	304 (1.4)	1558			
4	119 (0.1)	27 (0.1)	146			
Flags_TOTALz_Themes Sum Flags3				85.308	.000*	0.026
0	54019 (49.4)	10046 (46.9)	64065			
1	29146 (26.7)	5646 (26.3)	34792			
≥ 2	26133 (23.9)	5741 (26.8)	31874			
COUNTY LEVEL						
T1ct Socioeconomic Status				70.015	.000*	0.023
≤ .1475	27893 (25.5)	4958 (23.1)	32851			
>.1475 and ≤ 0.3934	31405 (28.7)	6198 (28.9)	37603			
>.3934 and ≤ 0.7377	28971 (26.5)	5781 (27)	34752			
>.7377	21029 (19.2)	4496 (21)	25525			

Variable SVI COMPOSITE	SSI_NO N (%)	SSI_YES N (%)	Total	Chi-square test χ^2	p	Cramer's V
T2ct Household Composition and Disability				57.63	.000*	0.021
≤ .0984	30355 (27.8)	5958 (27.8)	36313			
>.0984 and ≤ .3115	29042 (26.6)	5264 (24.6)	34306			
>.3115 and ≤ .4754	23809 (21.8)	4663 (21.8)	28472			
>0.4754	26092 (23.9)	5548 (25.9)	31640			
T3ct Minority Status and Language				25.715	.000*	0.014
≤ .7213	36124 (33.1)	6937 (32.4)	43061			
>.7213 and ≤ .8525	22110 (20.2)	4118 (19.2)	26228			
>.8525 and ≤ .9508	25765 (23.6)	5142 (24.0)	30907			
>.9508	25299 (23.1)	5236 (24.4)	30535			
T4ct Housing and Transportation				140.79	.000*	0.033
≤ .2787	28839 (26.4)	5201 (24.3)	34040			
>.2787 and ≤ .6230	27344 (25.0)	5274 (24.6)	32618			
>.6230 and ≤ .7869	32265 (29.5)	6145 (28.7)	38410			
>.7869	20850 (19.1)	4813 (22.5)	25663			
T0ct Overall Themes Summary score				77.293	.000*	0.024
≤ .1639	27893 (25.5)	4958 (23.1)	32851			
>.1639 and ≤ 5410	27687 (25.3)	5421 (25.3)	33108			
>.5410 and ≤ .7213	29297 (26.8)	5807 (27.1)	35104			
>0.7213	24421 (22.3)	5247 (24.5)	29668			
Flags_T1ct Socioeconomic Status				123.25	.000*	0.031
0	77596 (71.0)	14964 (69.8)	92560			
1	14378 (13.2)	2736 (12.8)	17114			
2	11276 (10.3)	2210 (10.3)	13486			
3	1206 (1.1)	203 (0.9)	1409			
4	4842 (4.4)	1320 (6.2)	6162			
Flags_T2ct Household Composition and Disability				50.395	.000*	0.02
0	83420 (76.3)	16064 (74.9)	99484			
1	10273 (9.4)	1914 (8.9)	12187			
2	15605 (14.3)	3455 (16.1)	19060			

Variable SVI COMPOSITE	SSI_NO *N* (%)	SSI_YES *N* (%)	Total	Chi-square test χ^2	*p*	*Cramer's V*
Flags_T3ct Minority Status and Language				20.97	.000*	0.013
0	58234 (53.3)	11055 (51.6)	69289			
1	4366 (4.0)	875 (4.1)	5241			
2	46698 (42.7)	9503 (44.3)	56201			
Flags_T4ct Housing and Transportation				94.378	.000*	0.027
0	59799 (54.7)	10962 (51.1)	70761			
1	8844 (8.1)	1845 (8.6)	10689			
2	3513 (3.2)	704 (3.3)	4217			
3	37142 (34.0)	7922 (37.0)	45064			
Flags_TOTALct_Themes Sum Flags3				27.556	0.00	0.015
0	40756 (37.3)	7652 (35.7)	48408			
1	10969 (10)	2072 (9.7)	13041			
≥ 2	57573 (52.7)	11709 (54.6)	69282			

Note: * The Chi-square statistic is significant at the .05 level, *Cramer's V* – values are presented

Table 16

Descriptive and Bivariate Statistics of the RQ2 SSI and U.S. Census ACS (American Community Survey) single measurements on Zip code level (N=130 731)

Variable ACS Individual measures	SSI_NO *N* (%)	SSI_YES *N* (%)	Total	Chi-square test χ^2	*p*	*Cramer's V*
Total	109298(83.6)	21433(16.4)	130731			
Metro Nonmetro area				0.22	0.639	
metro area	99352 (90.9)	19461 (90.8)	118813			
non metro area	9946 (9.1)	1972 (9.2)	11918			
ZIP Code Level						
US Native				33.59	.000*	0.016
≤ 69.5484	27077 (24.8)	5636 (26.3)	32713			
>69.5484 and ≤ 87.1795	27224 (24.9)	5451 (25.4)	32675			
>87.1795 and ≤ 94.8691	27538 (25.2)	5182 (24.2)	32720			
>94.8691	27459 (25.1)	5164 (24.1)	32623			
Foreign Born				33.74	.000*	0.016
≤ 5.1308	27492 (25.2)	5168 (24.1)	32660			
>5.1308 and ≤12.8205	27521 (25.2)	5180 (24.2)	32701			
>12.8205 and ≤ 30.4515	27205 (24.9)	5448 (25.4)	32653			
>30.4515	27080 (24.8)	5637 (26.3)	32717			
Language Proficiency						
Speak English well				47.76	.000*	0.019
≤ 84.5	27038 (24.7)	5747 (26.8)	32785			
>84.5 and ≤ 94.3	28060 (25.7)	5436 (25.4)	33496			
>94.3 and ≤ 97.7	26754 (24.5)	5184 (24.2)	31938			
>97.7	27446 (25.1)	5066 (23.6)	32512			
Speak English less than well				46.16	.000*	0.019
≤ 2.3	28485 (26.1)	5269 (24.6)	33754			
>2.3 and ≤ 5.7	26792 (24.5)	5179 (24.2)	31971			
>5.7 and ≤15.6	27197 (24.9)	5289 (24.7)	32486			
>15.6	26824 (24.5)	5696 (26.6)	32520			
Speak Other than English				36.5	.000*	0.017
≤ 7.6	27801 (25.4)	5245 (24.5)	33046			
>7.6 and ≤ 17.8	27285 (25.0)	5131 (23.9)	32416			
17.800001 thru 36.800000=3	27228 (24.9)	5391 (25.2)	32619			
>36.8	26984 (24.7)	5666 (26.4)	32650			

Table 16 continued				Chi-square test		
Variable ACS Individual measures	SSI_NO *N* (%)	SSI_YES *N* (%)	Total	χ^2	*p*	*Cramer's V*
Limited English All Households				47.73	.000*	0.019
≤ .7	27768 (25.4)	5233 (24.4)	33001			
>.7and ≤ 2.8	27777 (25.4)	5317 (24.8)	33094			
>2.8 and ≤ 8.2	27192 (24.9)	5201 (24.3)	32393			
>8.2	26561 (24.3)	5682 (26.5)	32243			
Education Level						
Less than 9th grade				71.63	.000*	0.023
≤ 2.3	29157 (26.7)	5369 (25.1)	34526			
>2.3 and ≤ 3.9	27110 (24.8)	5049 (23.6)	32159			
>3.9 and ≤ 7.7	26640 (24.4)	5336 (24.9)	31976			
>7.7	26391 (24.1)	5679 (26.5)	32070			
Has 9th to 12th grade no Diploma				68.88	.000*	0.023
≤4.3	27712 (25.4)	5087 (23.7)	32799			
>4.3 and ≤ 6.8	28179 (25.8)	5291 (24.7)	33470			
>6.8 and ≤ 10.1	27045 (24.7)	5379 (25.1)	32424			
>10.1	26362 (24.1)	5676 (26.5)	32038			
High School GED				3.835	0.28	
≤ 22.9	27394 (25.1)	5343 (24.9)	32737			
>22.9 and ≤ 29.0	28382 (26.0)	5538 (25.8)	33920			
>29.0 and ≤ 33.5	26358 (24.1)	5299 (24.7)	31657			
>33.5	27164 (24.9)	5253 (24.5)	32417			
Some College No degree				10.84	.013*	0.009
≤ 14.3	27450 (25.1)	5268 (24.6)	32718			
>14.3 and ≤ 17.1	28101 (25.7)	5652 (26.4)	33753			
>17.1 and ≤ 19.1	26922 (24.6)	5400 (25.2)	32322			
>19.1	26825 (24.5)	5113 (23.9)	31938			
Associate degree				38.62	.000*	0.017
≤ 6.6	27425 (25.1)	5711 (26.6)	33136			
>6.6 and ≤ 8.8	27147 (24.8)	5470 (25.5)	32617			
>8.8 and ≤ 11.3	28009 (25.6)	5268 (24.6)	33277			
>11.3	26717 (24.4)	4984 (23.3)	31701			
Bachelor Degree				26.92	.000*	0.014
≤13.2	27615 (25.3)	5643 (26.3)	33258			
>13.2 and ≤17.8	26900 (24.6)	5460 (25.5)	32360			
>17.8 and ≤23.1	27575 (25.2)	5173 (24.1)	32748			
>23.1	27208 (24.9)	5157 (24.1)	32365			

Table 16 continued

Variable ACS Individual measures	SSI_NO N N(%)	SSI_YES N (%)	Total	Chi-square test χ^2	p	Cramer's V
Graduate/Professional degree				27.22	.000*	0.014
≤ 8.0	27528 (25.2)	5648 (26.4)	33176			
>8.0 and ≤ 11.9	27390 (25.1)	5517 (25.7)	32907			
>11.9 and ≤ 18.4	27151 (24.8)	5048 (23.6)	32199			
>18.4	27229 (24.9)	5220 (24.4)	32449			
High School or Higher				82.01	.000*	0.025
≤ 82.6	27122 (24.8)	5887 (27.5)	33009			
>82.6 and ≤ 89.0	27305 (25.0)	5397 (25.2)	32702			
>89.0 and ≤ 93.1	27374 (25.0)	5152 (24.0)	32526			
>93.1	27497 (25.2)	4997 (23.3)	32494			
Bachelor or Higher degree				28.36	.000*	0.015
≤ 21.3	27339 (25.0)	5599 (26.1)	32938			
>21.3 and ≤ 29.5	27229 (24.9)	5519 (25.8)	32748			
>29.5 and ≤ 41.6	27336 (25.0)	5098 (23.8)	32434			
>41.6	27394 (25.1)	5217 (24.3)	32611			
Employment Status Employed Population Ratio 16 yr +				33.73	.000*	0.016
≤ 55.1	27180 (24.9)	5673 (26.5)	32853			
>55.1 and ≤ 59.4	27544 (25.2)	5484 (25.6)	33028			
>59.4 and ≤ 62.9	27659 (25.3)	5187 (24.2)	32846			
>62.9	26915 (24.6)	5089 (23.7)	32004			
Unemployment rate 16 yr +				105.7	.000*	0.028
≤5.5	28407 (26.0)	5188 (24.2)	33595			
>5.5 and ≤ 6.9	27713 (25.4)	5273 (24.6)	32986			
>6.9 and ≤ 8.9	26681 (24.4)	5082 (23.7)	31763			
>8.9	26497 (24.2)	5890 (27.5)	32387			
Income in the last 12 months/USD Median Household Income				90.85	.000*	0.026
≤ 46305	26797 (24.5)	5906 (27.6)	32703			
>46305 and ≤ 60526	27461 (25.1)	5274 (24.6)	32735			
>60526 and ≤ 82738	27514 (25.2)	5118 (23.9)	32632			
>82738	27526 (25.2)	5135 (24.0)	32661			
Median Family Income				83.41	.000*	0.025
≤ 56703	26834 (24.6)	5872 (27.4)	32706			
>56703 and ≤ 72903	27353 (25.0)	5321 (24.8)	32674			
>72903 and ≤ 98250	27584 (25.2)	5134 (24.0)	32718			
>98250	27527 (25.2)	5106 (23.8)	32633			

Table 16 continued				Chi-square test		
Variable ACS Individual measures	SSI_NO *N*(%)	SSI_YES *N* (%)	Total	χ^2	*p*	*Cramer's V*
Per Capita Income				65.09	.000*	0.022
≤ 23536	26973 (24.7)	5833 (27.2)	32806			
>23536 and ≤ 29398	27298 (25.0)	5297 (24.7)	32595			
>29398 and ≤37944	27581 (25.2)	5147 (24.0)	32728			
>37944	27446 (25.1)	5156 (24.1)	32602			
Poverty Status in the last 12 months % All Families below poverty level				61.08	.000*	0.022
≤ 3.7	28251 (25.8)	5233 (24.4)	33484			
>3.7 and ≤7.1	26887 (24.6)	5058 (23.6)	31945			
>7.1 and ≤ 13.5	27445 (25.1)	5403 (25.2)	32848			
>13.5	26715 (24.4)	5739 (26.8)	32454			
People below poverty level				85.35	.000*	0.026
≤ 5.9	27659 (25.3)	5086 (23.7)	32745			
>5.9 and ≤ 10.4	27770 (25.4)	5226 (24.4)	32996			
>10.4 and ≤ 18.2	27176 (24.9)	5270 (24.6)	32446			
>18.2	26693 (24.4)	5851 (27.3)	32544			
Below Poverty age 18 to 64				81.33	.000*	0.025
≤ 5.8	28676 (26.2)	5230 (24.4)	33906			
>5.8 and ≤9.8	26563 (24.3)	5063 (23.6)	31626			
>9.8 and ≤ 16.7	27364 (25.0)	5317 (24.8)	32681			
>16.7	26695 (24.4)	5823 (27.2)	32518			
Below Poverty age 65 and above				57.46	.000*	0.021
≤ 5.1	28059 (25.7)	5219 (24.4)	33278			
>5.1 and ≤ 8.1	27668 (25.3)	5214 (24.3)	32882			
>8.1 and ≤ 13.2	26680 (24.4)	5232 (24.4)	31912			
>13.2	26891 (24.6)	5768 (26.9)	32659			
GINI index of inequality				27.11	.000*	0.014
≤.3945	27483 (25.1)	5201 (24.3)	32684			
>.3945 and ≤ .4318	27505 (25.2)	5204 (24.3)	32709			
>.4318 and ≤ .4706	27248 (24.9)	5408 (25.2)	32656			
>.4706	27062 (24.8)	5620 (26.2)	32682			
Health Insurance % Public Health Insurance alone				81.38	.000*	0.025
≤ 11.50	27824 (25.5)	5041 (23.5)	32865			
>11.50 and ≤ 17.20	27753 (25.4)	5237 (24.4)	32990			
>17.20 and ≤ 26.40	27015 (24.7)	5369 (25.1)	32384			
>26.40	26706 (24.4)	5786 (27.0)	32492			

Table 16 continued				Chi-square test		
Variable ACS Individual measures	SSI_NO N *N*(%)	SSI_YES *N* (%)	Total	χ^2	*p*	*Cramer's V*
Medicare only				4.136	0.247	
≤ 3.4	27309 (25.0)	5488 (25.6)	32797			
>3.4 and ≤ 4.2	28387 (26.0)	5528 (25.8)	33915			
>4.2 and ≤ 5.1	29104 (26.6)	5694 (26.6)	34798			
>5.1	24498 (22.4)	4723 (22.0)	29221			
Medicaid only				81.21	.000*	0.025
≤ 7.0	28185 (25.8)	5189 (24.2)	33374			
>7.0 and ≤ 12.2	26977 (24.7)	5024 (23.4)	32001			
>12.2 and ≤ 21.6	27463 (25.1)	5412 (25.3)	32875			
>21.6	26673 (24.4)	5808 (27.1)	32481			
Private insurance alone				70.58	.000*	0.023
≤ 46.3	27204 (24.9)	5889 (27.5)	33093			
>46.3 and ≤ 56.7	27690 (25.3)	5383 (25.1)	33073			
>56.7 and ≤ 65.6	27017 (24.7)	5135 (24.0)	32152			
>65.6	27387 (25.1)	5026 (23.4)	32413			
No Vehicle OHU%				81.75	.000*	0.025
≤ 5.1	27799 (25.4)	5113 (23.9)	32912			
>5.1 and ≤ 9.9	27730 (25.4)	5103 (23.8)	32833			
>9.9 and ≤ 33.9	26943 (24.7)	5431 (25.3)	32374			
>33.9	26826 (24.5)	5786 (27.0)	32612			
GINI 2 categories					0.012	0.911
≤0.3	393 (0.4)	76 (0.4)	469			
>0.3	108905 (99.6)	21357 (99.6)	130262			
GINI 4 categories				18.34	.000*	0.012
≤0.3	393 (0.4)	76 (0.4)	469			
> 0.3 and ≤ 0.415	42115 (38.5)	7937 (37)	50052			
> 0.415 and ≤ 0.515	56903 (52.1)	11385 (53.1)	68288			
> 0.515	9887 (9.0)	2035 (9.5)	11922			
All Families below poverty >20%				78.03	.000*	0.024
≤ 20% of all families below poverty	96094 (87.9)	18377 (85.7)	114471			
> 20% of all families below poverty	13204 (12.1)	3056 (14.3)	16260			
People below poverty level >20%				81.2	.000*	0.025
≤ 20% of all people	87329 (79.9)	16542 (77.2)	103871			
> 20% of all people	21969 (20.1)	4891 (22.8)	26860			

Note: * The Chi-square statistic is significant at the .05 level, Cramer's V – values are presented

Interpretation of Descriptive Analyses and χ^2 test RQ2

The results from the descriptive and bivariate statistics of the Research Question 2 related to SSI evaluated as a dichotomous outcome- SSI _Yes and SSI_No are presented on Tables 14, 15, and 16. The total sample size was *N*=130 731. The descriptive statistics are presented as numbers and percentages. The Chi-square test was performed between SSI and the independent variables listed on each table and the χ^2 and *p* values listed. The expected frequency of the cells was greater than 10 for all cells. *P* values were considered significant if less than 0.05. Statistically, a significant association was observed between SSI and multiple independent variables (Tables 14, 15, and 16). Considering these results, the null hypothesis was rejected and the alternative hypothesis. The effect size for χ^2, Cramer's *V* was performed, and considering the degree of freedom, small, medium, and large association are observed (Kim HY, 2017). Cramer's *V* values were listed in tables 1 through 3 only for the significant Chi-square statistics. Based on the univariate analyses, variables with a significance of 0.05 and less were included in the multivariable analysis.

Testing the Assumptions for Binomial Logistic Regression RQ2

Assumption #1: The dependent variable should be measured on a dichotomous scale. The dependent variable for Research question 2 is Surgical Site Infection (SSI) is measured as dichotomous variables SSI _Yes and SSI_No, which meet Assumption 1. The independent variables are continuous (interval or ratio) and categorical (nominal) with two to five categories, which meet Assumption#2. The dependent variable is dichotomous and has two mutually exclusive and exhaustive categories which meet Assumption #3. Assumption #4 is related to the sample size, and it recommends a minimum of 15 and up to 50 cases per independent variable. Before multicollinearity test, for RQ2- Model 1, 32 independent variables were included thus 32x50=1600 (Laerd Statistics, 2018). The other way to calculate the sample size for logistic regression is to use proportions formula $N=10\ K/P$ where N=total sample, K= independent variables, and P = the positive outcome for SSI, which is 16.4% (21 433). Using this formula, the sample size required is: N=10x 32/0.164=320/0.164=1952 patients. According to Peduzzi et al. (1996), 10 events per variable are needed and recommended, which will make 21433/32=670 events per variables, which is more than 10 (Peduzzi et al.,1996). The sample size in this study is N=130731 which provides a sufficient number of cases per each independent variable, thus meet Assumption #4. Since these four assumptions are met, a binomial logistic regression would be an appropriate statistical test to analyze the research question. Assumption 5: Assumption 5 requires a linear relationship between the continuous independent variables in the model and the logit transformation of the outcome dependent variable. To test linearity, for all continuous independent variables that may be used in the logistic regression model, a natural log transformation was created using SPSS. The created Ln (natural log transformation) variable is a continuous variable. Subsequently, the Box-Tidwell test would be performed to test for linearity. Linearity needs to be tested only for the independent continuous variables. This assumption does not need to test linearity for the categorical variables. In the evaluation of the research question, only categorical variables were used in this analysis; therefore, this assumption is met. Assumption 6 is related to multicollinearity, which occurs when there is a correlation between the predictor or the independent variables. To examine multicollinearity, the Tolerance and the VIF (Variance Inflation Factor) values were evaluated for the independent variables for each model. The cut-off point for tolerance was set for less than 0.2 and VIF less than 5. Because this evaluation test 3 models to evaluate the SDOH association to the dependent variable, the collinearity for each set of independent variables included in each model were tested and presented in Appendix D before binomial logistic regression is performed. The multicollinearity test, and the subsequent multicollinearity evaluation after correction showing collinearity below the cut-off point for VIF 5 for RQ2-Model-1 are shown in Appendix D (see Appendix D, Tables D1 and D2) As this evaluation uses categorical variables, Assumption 7 about outliers is met.

Binomial Logistic Regression RQ2, Dependent Variable: SSI

RQ2-Model-1.

In the RQ2-Model-1 individual patient level and single measurement ACS SDOH independent variables at the Zip code level were included in the analysis with dependent variable: SSI. The independent variables initially included in RQ2-Model-1 based on the bivariate analyses, were tested for multicollinearity and adjustments were made to meet the cut-off marks for the Tolerance factor less than 0.2 and VIF 5 (see Appendix D, Tables D1 and D2). The independent variables included in the final RQ2-Model-1 after the multicollinearity evaluation are shown in Appendix D.

Results from SPSS analysis of RQ2-Model-1

Table 17

Binomial logistic regression RQ2-Model-1, Dependent variable: SSI

Variables in the Equation RQ2-Model-1	*B*	*S.E.*	*Wald*	*df*	*p*	*OR*	95% C.I.	
							Lower	Upper
Age in years ≥65	-0.152	0.022	46.870	1	0.000	0.859	0.822	0.897
Sex Male	0.221	0.016	198.582	1	0.000	1.248	1.210	1.287
Principal Diagnosis (ref: Diverticulitis)			28.620	3	0.000			
IBD	0.018	0.042	0.189	1	0.664	1.018	0.938	1.106
Neoplasms	0.013	0.024	0.296	1	0.586	1.013	0.967	1.061
Other	-0.092	0.025	13.581	1	0.000	0.912	0.868	0.958
Surgical Procedure Site (ref: Colon resection)			16.102	3	0.001			
Other	-0.005	0.046	0.011	1	0.917	0.995	0.909	1.090
Rectal resection	0.019	0.043	0.196	1	0.658	1.019	0.937	1.109
Total colectomy	0.184	0.047	15.412	1	0.000	1.202	1.097	1.318
Surgical Approach (ref: Laparoscopic)			194.844	2	0.000			
Open	0.291	0.021	193.988	1	0.000	1.338	1.284	1.394
Other	0.259	0.043	35.976	1	0.000	1.295	1.190	1.409
Anastomosis Distal End (ref: Anal)			68.036	2	0.000			
Colon	0.419	0.084	24.666	1	0.000	1.520	1.289	1.793
Rectal	0.269	0.083	10.517	1	0.001	1.309	1.112	1.541
Diverting Stoma - Yes	0.032	0.023	1.928	1	0.165	1.032	0.987	1.080
APRSOI risk (ref: Minor)			6215.957	3	0.000			
Moderate	0.940	0.025	1384.180	1	0.000	2.560	2.436	2.690
Major	1.834	0.027	4480.562	1	0.000	6.260	5.933	6.606
Extreme	2.290	0.032	5115.094	1	0.000	9.879	9.278	10.519
Admission Type-Elective	0.260	0.020	170.968	1	0.000	1.297	1.247	1.348
Race (ref: White)			13.646	3	0.003			
Asian	-0.010	0.054	0.036	1	0.850	0.990	0.890	1.101
Black or African American	0.073	0.027	7.014	1	0.008	1.075	1.019	1.135
Other	0.086	0.028	9.523	1	0.002	1.090	1.032	1.151
Health Insurance (ref: Medicaid)			21.437	4	0.000			
Medicare	-0.082	0.039	4.288	1	0.038	0.922	0.853	0.996
Other	0.189	0.135	1.953	1	0.162	1.208	0.927	1.576
Private/Commercial	-0.027	0.036	0.547	1	0.460	0.974	0.907	1.045
Self-Pay	0.117	0.057	4.181	1	0.041	1.125	1.005	1.259

Table 17 continued

Variables in the Equation RQ2-Model-1	*B*	*S.E.*	*Wald*	*df*	*p*	*OR*	95% C.I. Lower	 Upper
Annual Hospital Volume, cases (ref: ≥201)			70.741	3	0.000			
≤ 52	-0.114	0.025	21.531	1	0.000	0.892	0.850	0.936
≥53 and ≤ 122.7	0.008	0.023	0.130	1	0.719	1.008	0.963	1.056
≥123 and ≤ 200.34	0.076	0.023	11.045	1	0.001	1.079	1.032	1.128
Limited English All Households (ref: >8.2)			11.061	3	0.011			
≤ .7	-0.015	0.037	0.161	1	0.688	0.985	0.917	1.059
>.7and ≤ 2.8	-0.026	0.036	0.502	1	0.479	0.975	0.907	1.047
>2.8 and ≤ 8.2	-0.081	0.030	7.416	1	0.006	0.922	0.869	0.977
Less than 9th grade (ref: ≤ 2.3)			5.098	3	0.165			
>2.3 and ≤ 3.9	-0.022	0.025	0.742	1	0.389	0.978	0.931	1.028
>3.9 and ≤ 7.7	0.036	0.031	1.338	1	0.247	1.037	0.975	1.103
>7.7	0.030	0.044	0.469	1	0.494	1.031	0.945	1.124
Has 9th to 12th grade no Diploma (ref: ≤4.3)			1.568	3	0.667			
>4.3 and ≤ 6.8	0.005	0.029	0.028	1	0.868	1.005	0.949	1.065
>6.8 and ≤ 10.1	-0.008	0.038	0.046	1	0.830	0.992	0.921	1.068
>10.1	-0.038	0.046	0.695	1	0.405	0.963	0.880	1.053
Some College No degree (ref: ≤ 14.3)			13.545	3	0.004			
>14.3 and ≤ 17.1	0.070	0.026	7.294	1	0.007	1.072	1.019	1.128
>17.1 and ≤ 19.1	0.083	0.029	7.938	1	0.005	1.086	1.025	1.150
>19.1	0.030	0.033	0.854	1	0.355	1.031	0.967	1.099
Associate degree (ref: ≤ 6.6)			8.318	3	0.040			
>6.6 and ≤ 8.8	-0.023	0.025	0.836	1	0.361	0.978	0.931	1.026
>8.8 and ≤ 11.3	-0.077	0.029	7.275	1	0.007	0.926	0.875	0.979
>11.3	-0.074	0.035	4.606	1	0.032	0.929	0.868	0.994
Bachelor Degree (ref: ≤13.2)			9.273	3	0.026			
>13.2 and ≤17.8	0.053	0.025	4.503	1	0.034	1.054	1.004	1.107
>17.8 and ≤23.1	-0.007	0.030	0.055	1	0.815	0.993	0.936	1.053
>23.1	0.039	0.042	0.885	1	0.347	1.040	0.958	1.128
Employed Population Ratio 16 yr +(ref: ≤ 55.1)			4.515	3	0.211			
>55.1 and ≤ 59.4	0.034	0.024	3.955	1	0.047	1.049	1.001	1.101
>59.4 and ≤ 62.9	-0.015	0.028	0.664	1	0.415	1.023	0.969	1.080
>62.9	0.019	0.030	1.849	1	0.174	1.042	0.982	1.105
Unemployment rate 16 yr +(ref: ≤5.5)			15.248	3	0.002			
>5.5 and ≤ 6.9	0.020	0.024	0.056	1	0.813	1.006	0.960	1.054
>6.9 and ≤ 8.9	0.015	0.027	0.106	1	0.744	0.991	0.939	1.046
>8.9	0.070	0.031	7.532	1	0.006	1.089	1.025	1.157
Median Household Income (ref: ≤ 46305)			24.832	3	0.000			
>46305 and ≤ 60526	-0.126	0.030	17.892	1	0.000	0.882	0.832	0.935
>60526 and ≤ 82738	-0.177	0.038	21.711	1	0.000	0.838	0.778	0.903
>82738	-0.145	0.049	8.826	1	0.003	0.865	0.786	0.952

Variables in the Equation RQ2-Model-1	*B*	*S.E.*	*Wald*	*df*	*p*	*OR*	95% C.I. Lower	Upper
All Families below poverty level (ref:>13.5)			15.179	3	0.002			
≤ 3.7	0.156	0.047	10.951	1	0.001	1.169	1.066	1.281
>3.7 and ≤7.1	0.147	0.042	12.510	1	0.000	1.158	1.068	1.257
>7.1 and ≤ 13.5	0.114	0.031	13.207	1	0.000	1.121	1.054	1.193
Below Poverty age 65 and above (ref: ≤ 5.1)			3.481	3	0.323			
>5.1 and ≤ 8.1	-0.022	0.025	0.827	1	0.363	0.978	0.932	1.026
>8.1 and ≤ 13.2	-0.033	0.029	1.336	1	0.248	0.967	0.915	1.023
>13.2	-0.074	0.040	3.467	1	0.063	0.929	0.859	1.004
No Vehicle OHU% (ref: ≤ 5.1)			8.829	3	0.032			
>5.1 and ≤ 9.9	-0.010	0.025	0.173	1	0.677	0.990	0.942	1.040
>9.9 and ≤ 33.9	0.032	0.032	0.959	1	0.327	1.032	0.969	1.100
>33.9	0.108	0.043	6.393	1	0.011	1.114	1.024	1.210
Private insurance alone (ref: ≤ 46.3			0.795	3	0.851			
>46.3 and ≤ 56.7	-0.025	0.031	0.635	1	0.426	0.976	0.918	1.037
>56.7 and ≤ 65.6	-0.023	0.039	0.350	1	0.554	0.977	0.905	1.055
>65.6	-0.034	0.047	0.540	1	0.462	0.966	0.881	1.059
GINI index of inequality (ref: ≤.3945)			1.571	3	0.666			
>.3945 and ≤ .4318	-0.026	0.024	1.116	1	0.291	0.975	0.929	1.022
>.4318 and ≤ .4706	-0.013	0.028	0.203	1	0.652	0.987	0.934	1.044
>.4706	0.000	0.033	0.000	1	0.993	1.000	0.937	1.068
Constant	-3.523	0.125	788.863	1	0.000	0.030		

Note. Dependent Variable: SSI=Surgical Site Infection, *OR*=Odds Ratio, CI=confidence interval, **p*<0.05

Reporting results from the binomial logistic regression RQ2-Model-1 Dependent Variable: Surgical Site Infectious Complications (SSI)

Binomial logistic regression was performed to evaluate the effects of the predictor variables entered in the RQ2-Model-1 shown on Table 17 and Appendix D, Figure D1: age in years, sex, principal diagnosis, surgical approach, anastomosis distal end, diverting stoma, admission type, APRSOI-severity of illness risk, race, health insurance, annual hospital volume4, limited English All Households, less than 9th grade, has 9th to 12th grade no diploma, some college no degree, associate degree, bachelor degree, employed population ratio 16 yr +, unemployment rate 16 yr +, median household income, all families below poverty level, below poverty age 65 and above, GINI index of inequality, private insurance alone, and no vehicle OHU% on the likelihood of the postsurgical outcome SSI. The logistic regression model was statistically significant, $\chi 2$ =10028.091, p = .000 (Table D3). The model explained 12.5 % (Nagelkerke) of the variance in SSI, and Hosmer and Lemeshow Test was not significant p=0.979 indicating that the model was well fit as shown in Appendix D, Tables D4 and D5. The model accurately classified 83.6 % of 130 731cases included. The sensitivity is 3%, and the specificity is 100%, displayed in Table D6. The significant SDOH variables *p-value*, odds ratio, and the 95% Confidence Interval for the odds, in Table 17. Significant covariates and SDOH in RQ2-Model-1 associated with increased or decreased SSI occurrence after colorectal surgery are presented in Tables 18 and 19.

Table 18

Covariates in RQ2-Model-1 associated with increase of SSI occurrence after large intestinal surgery

Variable Category/Level	RQ2-Model-1	*p*	*OR*	95% C.I.	
	Covariates associated with SSI increase			Lower	Upper
Biological Patient level	Sex Male	0.000	1.248	1.210	1.287
Clinical Patient level	Surgical Procedure Site (ref: Colon resection)	0.001			
Covariates	Total colectomy	0.000	1.202	1.097	1.318
	Surgical Approach (ref: Laparoscopic)	0.000			
	Open	0.000	1.338	1.284	1.394
	Other	0.000	1.295	1.190	1.409
	Anastomosis Distal End (ref: Anal)	0.000			
	Colon	0.000	1.520	1.289	1.793
	Rectal	0.001	1.309	1.112	1.541
	APRSOI risk (ref: Minor)	0.000			
	Moderate	0.000	2.560	2.436	2.690
	Major	0.000	6.260	5.933	6.606
	Extreme	0.000	9.879	9.278	10.519
	Admission Type-Elective	0.000	1.297	1.247	1.348

Note. Dependent Variable: SSI=Surgical Site Infection, *OR*=Odds Ratio, CI=confidence interval, *p<0.0

Table 19 *SDOH in RQ2-Model-1 associated with increase or decrease of SSI occurrence after large intestinal surgery*

Variable Category/Level	RQ2-Model-1	*p*	*OR*	95% C.I. Upper	Lower
	SDOH associated with SSI increase				
SDOH Patient level	Race (ref: White)	0.003			
Social Context	Black or African American	0.008	1.075	1.019	1.135
	Other	0.002	1.090	1.032	1.151
	Health Insurance (ref: Medicaid)	0.000			
	Self-Pay	0.041	1.125	1.005	1.259
	Annual Hospital Volume, cases (ref: ≥201)	0.000			
	≥123 and ≤ 200.34	0.001	1.079	1.032	1.128
SDOH Zip code	Some College No degree (ref: ≤ 14.3)	0.004			
Education	>14.3 and ≤ 17.1	0.007	1.072	1.019	1.128
	>17.1 and ≤ 19.1	0.005	1.086	1.025	1.150
	Bachelor Degree (ref: ≤13.2)	0.026			
	>13.2 and ≤17.8	0.034	1.054	1.004	1.107
Employment Status	Employed Population Ratio 16 yr +(ref: ≤ 55.1)	0.211			
	>55.1 and ≤ 59.4	0.047	1.049	1.001	1.101
	Unemployment rate 16 yr +(ref: ≤5.5)	0.002			
	>8.9	0.006	1.089	1.025	1.157
Poverty	All Families below poverty level (ref:>13.5)	0.002			
	≤ 3.7	0.001	1.169	1.066	1.281
	>3.7 and ≤7.1	0.000	1.158	1.068	1.257
	>7.1 and ≤ 13.5	0.000	1.121	1.054	1.193
Economic stability	No Vehicle OHU% (ref: ≤ 5.1)	0.032			
	>33.9	0.011	1.114	1.024	1.210
	SDOH associated with SSI decrease				
Language Proficiency	Limited English All Households (ref: >8.2)	0.011			
	>2.8 and ≤ 8.2	0.006	0.922	0.869	0.977
Education	Associate degree (ref: ≤ 6.6)	0.040			
	>8.8 and ≤ 11.3	0.007	0.926	0.875	0.979
	>11.3	0.032	0.929	0.868	0.994
Income	Median Household Income (ref: ≤ 46305)	0.000			
	>46305 and ≤ 60526	0.000	0.882	0.832	0.935
	>60526 and ≤ 82738	0.000	0.838	0.778	0.903
	>82738	0.003	0.865	0.786	0.952
Healthcare access	Health Insurance (ref: Medicaid)	0.000			
	Medicare	0.038	0.922	0.853	0.996

Note. Dependent Variable: SSI= Surgical Site Infection, *OR*=Odds Ratio, CI=confidence interval, *$p<0.05$

The null hypothesis for Research Question 2 (RQ2) was rejected as RQ2-Model-1 (including single measure SDOH on individual and contextual levels) demonstrated a significant association of the SDOH in Table 19 with the increase or decrease of SSI occurrence after large intestinal surgery.

RQ2-Model-2a

RQ2-Model-2a included single measurement patient level and composite SDOH- SVI Overall Themes evaluation on contextual level (ZIP code and County code areas) with the SSI occurrence. Dependent Variable: SSI. The independent SDOH variables initially included in RQ2-Model-2a based on the bivariate analyses were tested for multicollinearity and no adjustments were needed to meet the cut-off marks for the Tolerance factor less than 0.2 and VIF 5 (Appendix D, Table D7). The final variables included in RQ2-Model-2a after multicollinearity test are listed in Figure D2 (see Appendix D).

Results from SPSS analysis of RQ2 Model 2a

Table 20

Binomial logistic regression results RQ2-Model-2a. Dependent variable SSI.

Variables in the Equation *RQ2-Model-2a*	*B*	*S.E.*	*Wald*	*df*	*p*	*OR*	95% C.I Lower	Upper
Age in years (ref: 77 and above)			116.006	3	0.000			
up to 53	0.310	0.029	113.355	1	0.000	1.364	1.288	1.444
54 to 65	0.207	0.027	59.118	1	0.000	1.229	1.166	1.296
66 to 76	0.144	0.022	41.185	1	0.000	1.155	1.105	1.207
Sex Male	0.212	0.016	180.254	1	0.000	1.236	1.198	1.274
Principal Diagnosis (ref: Diverticulitis)			36.597	3	0.000			
IBD	-0.014	0.042	0.116	1	0.734	0.986	0.907	1.071
Neoplasms	0.028	0.024	1.412	1	0.235	1.029	0.982	1.078
Other	-0.097	0.025	14.993	1	0.000	0.908	0.864	0.953
Surgical Procedure Site (ref: Colon resection)			15.995	3	0.001			
Other	-0.008	0.046	0.033	1	0.855	0.992	0.905	1.086
Rectal resection	0.014	0.043	0.105	1	0.746	1.014	0.932	1.103
Total colectomy	0.182	0.047	15.136	1	0.000	1.200	1.095	1.315
Surgical Approach (ref: Laparoscopic)			206.200	2	0.000			
Open	0.299	0.021	205.173	1	0.000	1.348	1.294	1.404
Other	0.266	0.043	38.164	1	0.000	1.305	1.199	1.420
Anastomosis Distal End (ref: Anal)			71.992	2	0.000			
Colon	0.424	0.084	25.235	1	0.000	1.528	1.295	1.803
Rectal	0.270	0.083	10.500	1	0.001	1.310	1.112	1.542
Diverting Stoma – Yes	0.032	0.023	1.894	1	0.169	1.032	0.987	1.079
APRSOI risk (ref: Minor)			6303.339	3	0.000			
Moderate	0.945	0.025	1398.815	1	0.000	2.573	2.449	2.704
Major	1.850	0.027	4542.012	1	0.000	6.357	6.024	6.708
Extreme	2.318	0.032	5195.232	1	0.000	10.154	9.534	10.815
Admission Type-Elective	0.251	0.020	159.079	1	0.000	1.286	1.236	1.337
Race (ref: White)			9.690	3	0.021			
Asian	-0.047	0.054	0.766	1	0.381	0.954	0.859	1.060
Black or African American	0.052	0.026	3.846	1	0.050	1.053	1.000	1.109
Other	0.067	0.027	6.089	1	0.014	1.069	1.014	1.128

Table 20 continued

Variables in the Equation *RQ2-Model-2a*	*B*	*S.E.*	*Wald*	*df*	*p*	*OR*	95%C.I. Lower	Upper
Health Insurance (ref: Medicaid)			17.027	4	0.002			
Medicare	-0.048	0.039	1.487	1	0.223	0.953	0.883	1.030
Other	0.188	0.135	1.929	1	0.165	1.207	0.926	1.573
Private/Commercial	-0.010	0.036	0.079	1	0.779	0.990	0.923	1.062
Self-Pay	0.139	0.057	5.901	1	0.015	1.150	1.027	1.286
Annual Hospital Volume, cases (ref: ≤ 52)			81.205	3	0.000			
≥53 and ≤ 122.7	0.126	0.023	30.404	1	0.000	1.134	1.084	1.186
≥123 and ≤ 200.34	0.203	0.023	80.158	1	0.000	1.225	1.172	1.281
≥201	0.127	0.024	26.988	1	0.000	1.135	1.082	1.191
T0z_Overal SVI Themes Summary score (ref: ≤.1909)			0.513	3	0.916			
>.1909 and ≤ .3929	-0.015	0.023	0.449	1	0.503	0.985	0.942	1.030
>.3929 and ≤ .6590	-0.014	0.024	0.320	1	0.572	0.987	0.941	1.034
> 0.6590	-0.011	0.028	0.157	1	0.692	0.989	0.936	1.045
T0ct Overall SVI Themes Summary score (ref: ≤ .1639)			27.173	3	0.000			
>.1639 and ≤ 5410	0.047	0.023	3.928	1	0.047	1.048	1.001	1.097
>.5410 and ≤ .7213	0.111	0.024	20.927	1	0.000	1.117	1.065	1.171
>0.7213	0.117	0.027	19.349	1	0.000	1.124	1.067	1.184
Flags_TOTALz_SVI Themes Sum Flags3 (ref: =0 flags)			21.243	2	0.000			
1	0.044	0.020	4.865	1	0.027	1.045	1.005	1.086
≥ 2	0.111	0.024	21.026	1	0.000	1.117	1.065	1.171
Flags_TOTALct_SVI Themes Sum Flags3 (ref: ≥ 2 flags)			11.440	2	0.003			
0	-0.028	0.030	0.829	1	0.363	0.973	0.917	1.032
1	0.052	0.020	6.943	1	0.008	1.053	1.013	1.095
Constant	-4.036	0.103	1536.914	1	0.000	0.018		

Note. Dependent Variable: SSI=Surgical Site Infection, *OR*=Odds Ratio, CI=confidence interval, *$p<0.05$

Reporting results RQ2-Model-2a, Dependent Variable: SSI

Binomial logistic regression was performed to evaluate the effects of predictor variables entered in the RQ2-Model-2a shown in Table 20: age in years, sex, principal diagnosis, surgical approach, surgical_procedure_site, anastomosis distal end, diverting stoma, APRSOI severity of illness risk, admission type, race, health insurance, annual hospital volume, SVI Overall rank on zip code and county levels, and extreme SVI (variable called "flagged Overall Themes SVI on zip code and county levels on the likelihood of the postsurgical outcome SSI (Table 20). The logistic regression model was statistically significant, $\chi 2$ =10065.94, p = 0.000 (see Appendix D, Table D8). The model explained 12.6 % (Nagelkerke) of the variance in the analyses, and Hosmer and Lemeshow Test was not significant p=0.216 indicating that the model was well fit, shown in Appendix D, Tables D9 and D10 respectively. The null hypothesis was rejected. Overall, the model accurately classified 83.6% of 130 731cases included. The sensitivity is very low, 0.3% and specificity is very high, 100 %, presented in Table D11. The SDOH Overall Social Vulnerability at the county level, High Social Vulnerability (flagged overall themes) at zip code and county code levels are significantly associated independent factors with the likelihood of the increase or decrease of SSIoccurrence after colorectal surgery. The significant SDOH variables *p-value*, odds ratio, and the 95% Confidence Interval for the odds, are displayed in Table 20. The significant covariates associated with increase of SSI occurrence after large intestinal surgery are listed on Table 21. The null hypothesis for Research Question 2 is rejected as RQ2-Model-2a demonstrated a significant association of the SDOH with the increase or decrease of SSI occurrence as shown in Table 22.

Table 21

Covariates in RQ2-Model-2a associated with increase or decrease of SSI occurrence after large intestinal surgery

Variable Type/Level	Variables in Equation RQ2-Model-2a	*p*	*OR*	95% C.I. Lower	Upper
	Covariates associated with SSI increase				
Biological Patient level	Sex Male	0.000	1.236	1.198	1.274
	Surgical Procedure Site (ref: Colon resection)	0.001			
	Total colectomy	0.000	1.200	1.095	1.315
	Surgical Approach (ref: Laparoscopic)	0.000			
	Open	0.000	1.348	1.294	1.404
	Other	0.000	1.305	1.199	1.420
	Anastomosis Distal End (ref: Anal)	0.000			
	Colon	0.000	1.528	1.295	1.803
	Rectal	0.001	1.310	1.112	1.542
	APRSOI risk (ref: Minor)	0.000			
	Moderate	0.000	2.573	2.449	2.704
	Major	0.000	6.357	6.024	6.708
	Extreme	0.000	10.154	9.534	10.815
	Covariates associated with SSI decrease				
Clinical Patient level	Principal Diagnosis (ref: Diverticulitis)	0.000			
Covariates	Other	0.000	0.908	0.864	0.953

Note. Dependent Variable: SSI=Surgical Site Infection, *OR*=Odds Ratio, CI=confidence interval, *$p<0.05$

Table 22 *SDOH in RQ2-Model-2a associated with increase of SSI occurrence after large intestinal surgery*

Variable Type/Level	RQ2-Model-2a	*p*	*OR*	95% C.I. Lower	Upper
SDOH Zip Code	SDOH associated with SSI increase				
Social Context	Race (ref: White)	0.021			
	Black or African American	0.050	1.053	1.000	1.109
	Other	0.014	1.069	1.014	1.128
Health Care Access	Health Insurance (ref: Medicaid)	0.002			
	Self-Pay	0.015	1.150	1.027	1.286
Hospital Facility Used	Annual Hospital Volume, cases (ref: ≤ 52)	0.000			
	≥53 and ≤ 122.7	0.000	1.134	1.084	1.186
	≥123 and ≤ 200.34	0.000	1.225	1.172	1.281
	≥201	0.000	1.135	1.082	1.191
	Composite SVI SDOH associated with SSI increase				
Extreme Social Vulnerability	Flags_TOTALz_SVI Themes Sum Flags3 (ref: =0 flags)	0.000			
	1	0.027	1.045	1.005	1.086
	≥ 2	0.000	1.117	1.065	1.171
SDOH County Code					
Social Vulnerability	T0ct Overall SVI Themes Summary score (ref: ≤ .1639)	0.000			
	>.1639 and ≤ 5410	0.047	1.048	1.001	1.097
	>.5410 and ≤ .7213	0.000	1.117	1.065	1.171
	>0.7213	0.000	1.124	1.067	1.184
Extreme Social Vulnerability	Flags_TOTALct_SVI Themes Sum Flags3 (ref: ≥ 2 flags)	0.003			
	1	0.008	1.053	1.013	1.095

Note. Dependent Variable: SSI =Surgical Site Infection, *OR*=Odds Ratio, CI=confidence interval, **p*<0.05

RQ2-Model-2b

The RQ2-Model-2b included Social Vulnerability Themes as independent SDOH variables at the Zip code and County level with Dependent Variable: SSI. The independent SDOH variables included in RQ2-Model-2b based on the bivariate analyses are listed in Appendix D, Figure D3. The Social Vulnerability Themes composition are listed in Table B4. Multicollinearity test was performed, and adjustments were made to meet the cut-off marks for Tolerance factor less than 0.2 and VIF 5 (Appendix D, Table D12 and Table D13). The final variables included in RQ2-Model-2b are listed on Figure D3 (see Appendix D, Figure D3).

Results from SPSS analysis of RQ2-Model-2b

Table 23

Binomial logistic regression results RQ2-Model-2b. Dependent variable SSI

Variables in the Equation RQ2_Model_2b	*B*	*S.E.*	*Wald*	*df*	*p*	*OR*	95% C.I. Lower	Upper
Age in years (ref: 77 and above)			115.793	3	0.000			
up to 53	0.311	0.029	113.184	1	0.000	1.365	1.289	1.445
54 to 65	0.209	0.027	60.512	1	0.000	1.233	1.170	1.300
66 to 76	0.143	0.022	40.718	1	0.000	1.154	1.104	1.206
Sex Male	0.213	0.016	182.963	1	0.000	1.238	1.200	1.277
Principal Diagnosis (ref: Diverticulitis)			38.417	3	0.000			
IBD	-0.014	0.042	0.104	1	0.747	0.986	0.908	1.072
Neoplasms	0.030	0.024	1.603	1	0.205	1.031	0.984	1.080
Other	-0.098	0.025	15.443	1	0.000	0.906	0.863	0.952
Surgical Procedure Site (ref: Colon resection)			16.608	3	0.001			
Other	-0.007	0.047	0.021	1	0.884	0.993	0.907	1.088
Rectal resection	0.014	0.043	0.111	1	0.739	1.014	0.932	1.104
Total colectomy	0.186	0.047	15.771	1	0.000	1.205	1.099	1.321
Surgical Approach (ref: Laparoscopic)			215.227	2	0.000			
Open	0.305	0.021	213.895	1	0.000	1.357	1.303	1.414
Other	0.277	0.043	41.358	1	0.000	1.320	1.213	1.436
Anastomosis Distal End (ref: Anal)			71.915	2	0.000			
Colon	0.428	0.084	25.732	1	0.000	1.535	1.301	1.811
Rectal	0.274	0.083	10.867	1	0.001	1.316	1.118	1.549
Diverting Stoma – Yes	0.029	0.023	1.599	1	0.206	1.029	0.984	1.077
Admission Type-Elective	0.247	0.020	152.421	1	0.000	1.280	1.231	1.331
APRSOI risk (ref: Minor)			6279.391	3	0.000			
Moderate	0.942	0.025	1389.106	1	0.000	2.566	2.442	2.696
Major	1.847	0.027	4521.013	1	0.000	6.340	6.008	6.690
Extreme	2.314	0.032	5173.208	1	0.000	10.117	9.498	10.775
Race (ref: White)			5.001	3	0.172			
Asian	-0.023	0.055	0.179	1	0.672	0.977	0.878	1.087
Black or African American	0.055	0.027	4.095	1	0.043	1.056	1.002	1.114
Other	0.031	0.028	1.246	1	0.264	1.032	0.977	1.090

Variables in the Equation RQ2_Model_2b	*B*	*S.E.*	*Wald*	*df*	*p*	*OR*	95% C.I. Lower	Upper
Medicare	-0.046	0.039	1.385	1	0.239	0.955	0.884	1.031
Other	0.191	0.136	1.982	1	0.159	1.210	0.928	1.578
Private/Commercial	-0.016	0.036	0.199	1	0.656	0.984	0.917	1.056
Self-Pay	0.138	0.058	5.710	1	0.017	1.147	1.025	1.285
Annual Hospital Volume, cases (ref: ≥201)			79.228	3	0.000			
≤ 52	0.136	0.024	33.279	1	0.000	1.146	1.094	1.200
≥53 and ≤ 122.7	0.208	0.024	77.256	1	0.000	1.231	1.175	1.289
≥123 and ≤ 200.34	0.139	0.025	29.891	1	0.000	1.149	1.093	1.207
T1z_Socioeconomic Status (ref: ≤ .1756)			0.478	3	0.924			
>.1756 and ≤.3799	0.012	0.024	0.248	1	0.618	1.012	0.965	1.061
>.3799 and ≤.6453	0.019	0.028	0.457	1	0.499	1.019	0.964	1.078
>.6453	0.018	0.035	0.247	1	0.619	1.018	0.950	1.090
T2z_Houshold Composition and Disability (ref: ≤ .2863)			3.079	3	0.380			
>.2863 and ≤.5045	-0.021	0.023	0.828	1	0.363	0.979	0.935	1.025
>.5045 and ≤ .7467	-0.031	0.025	1.566	1	0.211	0.970	0.924	1.018
>.7467	0.004	0.027	0.023	1	0.879	1.004	0.953	1.058
T3z_Minority Status and Language (ref: ≤ .1820)			4.503	3	0.212			
>.1820 and ≤ .3850	-0.051	0.025	4.166	1	0.041	0.950	0.904	0.998
>.3850 and ≤ .6561	-0.049	0.030	2.744	1	0.098	0.952	0.898	1.009
>.6561	-0.047	0.040	1.342	1	0.247	0.954	0.882	1.033
T4z_Housing and Transportation (ref: ≤.2400)			0.755	3	0.860			
>.2400 and ≤ .4420	-0.015	0.023	0.428	1	0.513	0.985	0.941	1.031
>.4420 and ≤ .7240	-0.004	0.025	0.029	1	0.866	0.996	0.949	1.045
>.7240	-0.019	0.028	0.445	1	0.505	0.981	0.929	1.037
T1ct Socioeconomic Status (ref: ≤ .1475)			3.441	3	0.328			
>.1475 and ≤ 0.3934	0.045	0.043	1.070	1	0.301	1.046	0.961	1.139
>.3934 and ≤ 0.7377	-0.001	0.050	0.001	1	0.980	0.999	0.905	1.102
>.7377	-0.033	0.074	0.192	1	0.661	0.968	0.837	1.120
T2ct Household Composition and Disability (ref: ≤ .0984)			14.473	3	0.002			

Variables in the Equation RQ2_Model_2b	*B*	*S.E.*	*Wald*	*df*	*p*	*OR*	95% C.I. Lower	Upper
>.0984 and ≤ .3115	-0.082	0.037	4.891	1	0.027	0.921	0.856	0.991
>.3115 and ≤ .4754	-0.079	0.049	2.598	1	0.107	0.924	0.840	1.017
>0.4754	0.036	0.042	0.731	1	0.393	1.037	0.954	1.127
T3ct Minority Status and Language (ref: ≤ .7213)			3.790	3	0.285			
>.7213 and ≤ .8525	-0.024	0.038	0.412	1	0.521	0.976	0.906	1.051
>.8525 and ≤ .9508	0.025	0.043	0.340	1	0.560	1.025	0.943	1.115
>.9508	0.094	0.070	1.779	1	0.182	1.099	0.957	1.261
T4ct Housing and Transportation (ref: ≤ .2787)			35.732	3	0.000			
>.2787 and ≤ .6230	0.004	0.033	0.013	1	0.910	1.004	0.940	1.072
>.6230 and ≤ .7869	0.032	0.048	0.436	1	0.509	1.032	0.940	1.134
>.7869	0.235	0.049	22.866	1	0.000	1.264	1.149	1.392
Flags_T1z_Socioeconomic Status (ref:0)			4.742	4	0.315			
1	0.076	0.037	4.318	1	0.038	1.079	1.004	1.159
2	0.027	0.046	0.339	1	0.561	1.027	0.938	1.125
3	0.022	0.069	0.099	1	0.752	1.022	0.893	1.169
4	-0.019	0.073	0.069	1	0.793	0.981	0.850	1.133
Flags_T1ct Socioeconomic Status (ref: 4)			23.553	4	0.000			
0	-0.081	0.054	2.243	1	0.134	0.922	0.830	1.025
1	0.027	0.092	0.088	1	0.767	1.028	0.858	1.231
2	-0.340	0.102	11.173	1	0.001	0.711	0.583	0.869
3	0.050	0.119	0.178	1	0.673	1.051	0.833	1.327
Constant	-3.620	0.107	1136.406	1	0.000	0.027		

Note. Dependent Variable: SSI=Surgical Site Infection, *OR*=Odds Ratio, CI=confidence interval, **p*<0.05

Reporting results from the binomial logistic regression RQ2-Model 2b, Dependent Variable: SSI

Binomial logistic regression was performed to evaluate the effects of predictor variables entered in the RQ2-Model-2b shown in Table 23: age in years, sex, principal diagnosis, surgical approach, surgical_procedure_site, anastomosis distal end, diverting stoma, APRSOI severity of illness risk, admission type, race, health insurance, annual hospital volume, T1ct Socioeconomic Status, T2ct Household Composition and Disability, T3ct Minority Status and Language, T4ct Housing and Transportation, Flags_T1z_Socioeconomic Status, Flags_T2z_Household Composition & Disability, Flags_T3z_ Minority Status and Language, and Flags_T4z_Housing and Transportation, and Flags_T1ct_Socioeconomic Status on zip code and county levels on the likelihood of the postsurgical outcome Surgical Site Infection . The logistic regression model was statistically significant, $\chi2$ =10194.47, $p = 0.000$ as shown in Appendix D, Table D14. The model explained 12.7 % (Nagelkerke) of the variance in the analyses, and Hosmer and Lemeshow Test was not significant p=0.824 indicating that the model was well fit (see Appendix D, Table D15 and 16). The null hypothesis was rejected. Overall, as shown in Table D17 the model accurately classified 83.6% of 130 731cases included. The sensitivity is very low, 0.5% and specificity very high, 99.5 %. The significant SDOH variables *p-value*, odds ratio, and the 95% Confidence Interval for the odds, in Table 23. Covariates in RQ2-Model-2b associated with increase of SSI occurrence after large intestinal surgery are listed in Table 24.

Table 24

Covariates in RQ2-Model-2b associated with increase of SSI occurrence after large intestinal surgery

Variable Type/Level	RQ2_Model_2b	*p*	*OR*	95% C.I.	
	Covariates associated with SSI increase			Lower	Upper
Biological Patient level		0.000			
	Age in years (ref: 77 and above)				
	up to 53	0.000	1.365	1.289	1.445
	54 to 65	0.000	1.233	1.170	1.300
	66 to 76	0.000	1.154	1.104	1.206
	Sex Male	0.000	1.238	1.200	1.277
Clinical Patient level	Surgical Procedure Site (ref: Colon resection)	0.001			
Covariates	Total colectomy	0.000	1.205	1.099	1.321
	Surgical Approach (ref: Laparoscopic)	0.000			
	Open	0.000	1.357	1.303	1.414
	Other	0.000	1.320	1.213	1.436
	Anastomosis Distal End (ref: Anal)	0.000			
	Colon	0.000	1.535	1.301	1.811
	Rectal	0.001	1.316	1.118	1.549
	Admission Type-Elective	0.000	1.280	1.231	1.331
	APRSOI risk (ref: Minor)	0.000			
	Moderate	0.000	2.566	2.442	2.696
	Major	0.000	6.340	6.008	6.690
	Extreme	0.000	10.117	9.498	10.775

Note. Dependent Variable: SSI=Surgical Site Infection, *OR*=Odds Ratio, CI=confidence interval, *$p<0.05$

Table 25

SDOH in RQ2-Model-2b associated with increase or decrease of SSI occurrence after large intestinal surgery

Variable Type/Level	RQ2_Model_2b	*p*	*OR*	95% C.I.	
				Lower	Upper
SDOH Zip code	SDOH associated with SSI increase				
Social Context	Race (ref: White)	0.172			
	Black or African American	0.043	1.056	1.002	1.114
Health Care Access	Health Insurance (ref: Medicaid)	0.003			
	Self-Pay	0.017	1.147	1.025	1.285
Hospital Facility Used	Annual Hospital Volume, cases (ref: ≥201)	0.000			
	≤ 52	0.000	1.146	1.094	1.200
	≥53 and ≤ 122.7	0.000	1.231	1.175	1.289
	≥123 and ≤ 200.34	0.000	1.149	1.093	1.207
	Composite SVI SDOH associated with SSI increase				
SDOH Zip code	Flags_T1z_Socioeconomic Status (ref:0)	0.315			
	1	0.038	1.079	1.004	1.159
SDOH County code	T4ct Housing and Transportation (ref: ≤ .2787)	0.000			
	>.7869	0.000	1.264	1.149	1.392
	Composite SVI SDOH associated with SSI decrease				
SDOH Zip code	T3z_Minority Status and Language (ref: ≤ .1820)	0.212			
	>.1820 and ≤ .3850	0.041	0.950	0.904	0.998
SDOH County code	T2ct Household Composition and Disability (ref: ≤ .0984)	0.002			
	>.0984 and ≤ .3115	0.027	0.921	0.856	0.991
	Flags_T1ct Socioeconomic Status (ref: 4)	0.000			
	2	0.001	0.711	0.583	0.869

Note. Dependent Variable: SSI =Surgical Site Infection, *OR*=Odds Ratio, CI=confidence interval, **p*<0.05

The null hypothesis for Research Question 2 is rejected as RQ2-Model-2b demonstrated a significant association of the SDOH (Table 25) with the increase or decrease of SSI occurrence after large intestinal surgery.

Research Question 3

Research Question and Hypothesis

Research Question 3 (RQ3): Is there an association between SDOH and overall surgical complications (infectious and noninfectious) occurrence within 30 days after colorectal surgery in and out of the hospital an adult population?

Null Hypothesis ($H_0 3$): SDOH are not associated with overall surgical complications occurrence within 30 days after large intestinal resection in and out of the hospital in adult patients.

Alternative Hypothesis ($H_1 3$): SDOH are associated with overall surgical complications occurrence within 30 days after large intestinal resection in and out of the hospital in adult patients.

The outcome or dependent variable was “overall surgical complications” (COMPL) after colorectal surgery measured as a binary outcome "yes" or "no" within 30 days after surgery and in or out of the hospital.

Descriptive and Bivariate Analyzes

Table 26

Descriptive and Bivariate Statistics RQ3, COMPL and SPARCS data variables (N=130731)

Independent variables SPARCS	COMPL_NO N (%)	COMPL_YES N (%)	Total	Chi-square test χ^2	*p*	*Cramer's V*
	93203(71.3)	37528(28.7)	130731			
Age in years				1474.07	.000*	0.106
< 65	49595(53.2)	15565(41.5)	65160			
≥65	43608(46.8)	21963(58.5)	65571			
Age in years				1895.14	.000*	0.120
up to 53	25893(27.8)	7899(21.0)	33792			
54 to 65	25989(27.8)	8525(22.7)	34514			
66 to 76	22241(23.9)	9736(30.4)	31977			
77 and above	19080(20.5)	11368(37.3)	30448			
Sex				120.73	.000*	0.030
Male	42112(45.2)	18213(48.5)	60325			
Female	51091(54.8)	19315(51.5)	70406			
Race				151.75	.000*	0.034
Asian	2556(2.7)	790(2.1)	3346			
Black or African American	10034(10.8)	4810(12.8)	14844			
Other	9566(10.3)	3925(10.5)	13491			
White	71047(76.2)	28003(74.6)	99050			
Race minority				37.74	.000*	0.017
Not minority	71047(76.2)	28003(74.6)	99050			
Minority (all except white)	22156(23.8)	9525(25.4)	31681			
Principal Diagnosis				1345.82	.000*	0.101
Diverticulitis	23704(25.4)	7475(19.9)	31179			
IBD	3675(3.9)	1749(4.7)	5424			
Neoplasms	45163(48.5)	16614(44.3)	61777			
Other	20661(22.2)	11690(31.2)	32351			
Admission Type				3829.77	.000*	0.171
Elective	62104(66.6)	18092(48.2)	80196			
Emergency	31099(33.4)	19436(51.8)	50535			
Surgical Approach				2157.09	.000*	0.128
laparoscopic	29889(32.1)	7367(19.6)	37256			
open	52138(55.9)	25692(68.5)	77830			
other	11176(12)	4469(11.9)	15645			

Table 26 continued				Chi-square test		
Independent variables SPARCS	COMPL_NO N (%)	COMPL_YES N (%)	Total	χ^2	*p*	*Cramer's V*
Surgical_Procedure_Site						
Colon resection	76547(71.5)	30437(28.5)	106984	690.416	.000	0.073
Other	4441(65.5)	2334(34.5)	6775			
Rectal resection	10316(76.2)	3230(23.8)	13546			
Total colectomy	1899(54.4)	1527(46.6)	3426			
Anastomosis distal end				180.42	.000*	0.037
anal	1695(1.8)	430(1.1)	2125			
colon	44971(48.3)	19398(51.7)	64369			
rectal	46537(49.9)	17700(47.2)	64237			
Diverting Stoma				2876.82	.000*	0.148
no	82746(88.8)	28980(77.2)	111726			
yes	10457(11.2)	8548(22.8)	19005			
Health insurance				1534.63	.000*	0.108
Medicaid	4610(4.9)	2016(5.4)	6626			
Medicare	36758(39.4)	19024(50.7)	55782			
Other	307(0.3)	116(0.3)	423			
Private/Commercial	49101(52.7)	15415(41.1)	64516			
Self-Pay	2427(2.6)	957(2.6)	3384			
Annual Hospital Volume4				83.55	.000*	0.025
≤ 52.31	23361(25.1)	9661(25.7)	33022			
≥53 and ≤ 122.7	23573(25.3)	9902(26.4)	33475			
≥123 and ≤ 200.34	23723(25.5)	9768(26.0)	33491			
≥201	22546(24.2)	8197(21.8)	30743			
APRSOI Severity of Illness risk				20762.4	.000	.399
minor	35958(38.6)	4040(10.)	39998			
moderate	37137(39.9)	11295(301)	48432			
major	14434(15.5)	12093(32.2)	26527			
extreme	5674(6.1)	10100(7.7)	15774			

Note: * The Chi-square statistic is significant at the .05 level. *Cramer's V* – values are presented

Table 27

Descriptive and Bivariate Statistics RQ3, COMPL and SVI THEMES (Social Vulnerability Index) on Zip code and County code (N=130731)

Variables Composite	SVI	COMPL_NO *N* (%)	COMPL_YES *N* (%)	Total	Chi-square test χ^2	*p*	*Cramer's V*
ZIP CODE LEVEL							
T1z_Socioeconomic Status					109.530	.000	0.029
≤ .1756		23658(25.4)	9029(24.1)	32687			
>.1756 and ≤.3799		23679(25.4)	9015(24.0)	32694			
>.3799 and ≤.6453		23258(25.0)	9421(25.1)	32679			
>.6453		22608(24.3)	10063(26.8)	32671			
T2z_Houshold Composition and Disability					43.573	.000	0.018
≤ .2863		23434(25.1)	9393(25.0)	32827			
>.2863 and ≤.5045		23519(25.2)	9065(24.2)	32584			
>.5045 and ≤ .7467		23395(25.1)	9252(24.7)	32647			
>.7467		22855(24.5)	9818(26.2)	32673			
T3z_Minority Status and Language					69.007	.000	0.023
≤ .1820		23454(25.2)	9247(24.6)	32701			
>.1820 and ≤ .3850		23787(25.5)	9025(24.0)	32812			
>.3850 and ≤ .6561		23228(24.9)	9351(24.9)	32579			
>.6561		22734(24.4)	9905(26.4)	32639			
T4z_Housing and Transportation					50.382	.000	0.020
≤.2400		23633(25.4)	9181(24.5)	32814			
>.2400 and ≤ .4420		23571(25.3)	9187(24.5)	32758			
>.4420 and ≤ .7240		23208(24.9)	9307(24.8)	32515			
>.7240		22791(24.5)	9853(26.3)	32644			
T0z_Overal Themes Summary score					97.278	.000	0.027
≤.1909		23654(25.4)	9037(24.1)	32691			
>.1909 and ≤ .3929		23702(25.4)	9069(24.2)	32771			
>.3929 and ≤ .6590		23198(24.9)	9400(25.0)	32598			
> 0.6590		22649(24.3)	10022(26.7)	32671			

					Chi-square test		
Variables Composite	SVI	COMPL_NO *N* (%)	COMPL_YES *N* (%)	Total	χ^2	*p*	*Cramer's V*
F_T1z Socioeconomic Status					58.414	.000	0.021
	0	82047(88)	32505(86.6)	114552			
	1	5732(6.2)	2463(6.6)	8195			
	2	3053(3.3)	1433(3.8)	4486			
	3	1188(1.3)	584(1.6)	1772			
	4	1183(1.3)	543(1.4)	1726			
F_T2z_Household Composition & Disability					20.858	.000	0.013
	0	70242(75.4)	27924(74.4)	98166			
	1	17583(18.9)	7232(19.3)	24815			
	2	4233(4.5)	1837(4.9)	6070			
	3	1145(1.2)	535(1.4)	1680			
F_T3z_ Minority Status and Language					51.852	.000	0.020
	0	82997(89.0)	32905(87.7)	115902			
	1	9011(9.7)	4118(11.0)	13129			
	2	1195(1.3)	505(1.3)	1700			
F_T4z_Housing and Transportation					59.644	.000	0.021
	0	62715(67.3)	24654(65.7)	87369			
	1	22605(24.3)	9241(24.6)	31846			
	2	6744(7.2)	3068(8.2)	9812			
	3	1042(1.1)	516(1.4)	1558			
	4	97(0.1)	49(0.1)	146			
F_TOTALz_Themes Sum Flags					97.760	.000	0.027
	0	46262(49.6)	17803(47.4)	64065			
	1	24894(26.7)	9898(26.4)	34792			
	≥ 2	22047(23.7)	9827(26.2)	31874			
T1_ct Socioeconomic Status					81.800	.000	0.025
≤ .1475		23978(25.7)	8873(23.6)	32851			
>.1475 and ≤ 0.3934		26804(28.8)	10799(28.8)	37603			
>.3934 and ≤ 0.7377		24638(26.4)	10114(27.0)	34752			
>.7377		17783(19.1)	7742(20.6)	25525			

Variables Composite	SVI	COMPL_NO N (%)	COMPL_YES N (%)	Total	Chi-square test χ^2	p	*Cramer's V*
T2_ct Household Composition and Disability							
≤ .0984		25897(27.8)	10416(27.8)	36313			
>.0984 and ≤ .3115		24939(26.8)	9367(25.0)	34306			
>.3115 and ≤ .4754		20251(21.7)	8221(21.9)	28472			
>0.4754		22116(23.7)	9524(25.4)	31640			
T3_ct Minority Status and Language					35.878	.000	0.017
≤ .7213		30842(33.1)	12219(32.6)	43061			
>.7213 and ≤ .8525		18979(20.4)	7249(19.3)	26228			
>.8525 and ≤ .9508		21945(23.5)	8962(23.9)	30907			
>.9508		21437(23.0)	9098(24.2)	30535			
T4_ct Housing and Transportation					115.303	.000	0.030
≤ .2787		24685(26.5)	9355(24.9)	34040			
>.2787 and ≤ .6230		23346(25.0)	9272(24.7)	32618			
>.6230 and ≤ .7869		27547(29.6)	10863(28.9)	38410			
>.7869		17625(18.9)	8038(21.4)	25663			
T0_ct Overall Themes Summary score					77.467	.000	0.024
≤ .1639		23978(25.7)	8873(23.6)	32851			
>.1639 and ≤ 5410		23600(25.3)	9508(25.3)	33108			
>.5410 and ≤ .7213		24891(26.7)	10213(27.2)	35104			
>0.7213		20734(22.2)	8934(23.8)	29668			
F_T1_ct Socioeconomic Status					109.967	.000	0.029
	0	66252(71.1)	26308(70.1)	92560			
	1	12288(13.2)	4826(12.9)	17114			
	2	9606(10.3)	3880(10.3)	13486			
	3	1024(1.1)	385(1.0)	1409			
	4	4033(4.3)	2129(5.7)	6162			
F_T2_ct Household Composition and Disability					52.342	.000	0.020
	0	71247(76.4)	28237(75.2)	99484			
	1	8781(9.4)	3406(9.1)	12187			
	2	13175(14.1)	5885(15.7)	19060			

Variables	SVI Composite	COMPL_NO *N* (%)	COMPL_YES N (%)	Total	Chi-square test $\chi 2$	*p*	Cramer's *V*
F_T3_ct Minority Status and Language					26.944	.000	0.014
	0	49821(53.5)	19468(51.9)	69289			
	1	3714(4.0)	1527(4.1)	5241			
	2	39668(42.6)	16533(44.1)	56201			
F_T4_ct Housing and Transportation					116.981	.000	0.030
	0	51306(55.0)	19455(51.8)	70761			
	1	7414(8.0)	3275(8.7)	10689			
	2	3011(3.2)	1206(3.2)	4217			
	3	31472(33.8)	13592(36.2)	45064			
F_TOTALct_Themes Sum Flags					28.780	.000	0.015
	0	34880(37.4)	13528(36)	48408			
	1	9365(10.0)	3676(9.8)	13041			
	≥2	48958(52.5)	20324(54.2)	69282			

Note. * The Chi-square statistic is significant at the .05 level. *Cramer's V* – values are presented

Table 28

Descriptive and Bivariate Statistics RQ3 COMPL and U.S. Census ACS (American Community Survey) single measurements on Zip code level (N=130 731)

Variables ACS Individual measures	COMPL_NO *N* (%)	COMPL_YES *N* (%)	Total	Chi-square test χ^2	*p*	*Cramer's V*
ZIP Code Level						
Metro Nonmetro area				0.017	NS	.000
metro area	84700 (90.9)	34113 (90.9)	118813			
non metro area	8503 (9.1)	3415 (9.1)	11918			
US Native %				45.412	.000	.019
≤ 69.5484	22916 (24.6)	9797 (26.1)	32713			
>69.5484 and ≤ 87.1795	23201 (24.9)	9474 (25.2)	32675			
>87.1795 and ≤ 94.8691	23626 (25.3)	9094 (24.2)	32720			
>94.8691	23460 (25.2)	9163 (24.4)	32623			
Foreign Born%				44.907	.000	.019
≤ 5.1308	23488 (25.2)	9172 (24.4)	32660			
>5.1308 and ≤12.8205	23607 (25.3)	9094 (24.2)	32701			
>12.8205 and ≤ 30.4515	23189 (24.9)	9464 (25.2)	32653			
>30.4515	22919 (24.6)	9798 (26.1)	32717			
Language Proficiency%						
Speak English well				51.843	.000	.020
≤ 84.5	22888 (24.6)	9897 (26.4)	32785			
>84.5 and ≤ 94.3	23950 (25.7)	9546 (25.4)	33496			
>94.3 and ≤ 97.7	22879 (24.5)	9059 (24.1)	31938			
>97.7	23486 (25.2)	9026 (24.1)	32512			
Speak English less than well				53.135	.000	.020
≤ 2.3	24392 (26.2)	9362 (24.9)	33754			
>2.3 and ≤ 5.7	22909 (24.6)	9062 (24.1)	31971			
>5.7 and ≤15.6	23202 (24.9)	9284 (24.7)	32486			
>15.6	22700 (24.4)	9820 (26.2)	32520			
Speak Other than English				43.316	.000	.018
≤ 7.6	23797 (25.5)	9249 (24.6)	33046			
>7.6 and ≤ 17.8	23370 (25.1)	9046 (24.1)	32416			
>17.8 and ≤ 36.8	23153 (24.8)	9466 (25.2)	32619			
>36.8	22883 (24.6)	9767 (26.0)	32650			

Table 28 continued				Chi-square test		
Variables ACS Individual measures	COMPL_NO *N* (%)	COMPL_YES *N* (%)	Total	χ^2	*p*	*Cramer's V*
Limited English All Households				57.413	.000	.021
>.7and ≤ 2.8	23759 (25.5)	9335 (24.9)	33094			
>2.8 and ≤ 8.2	23240 (24.9)	9153 (24.4)	32393			
>8.2	22455 (24.1)	9788 (26.1)	32243			
Education Level%						
Less than 9th grade				88.584	.000	.026
≤ 2.3	25054 (26.9)	9472 (25.2)	34526			
>2.3 and ≤ 3.9	23207 (24.9)	8952 (23.9)	32159			
>3.9 and ≤ 7.7	22619 (24.3)	9357 (24.9)	31976			
>7.7	22323 (24.0)	9747 (26.0)	32070			
Has 9th to 12th grade but no Diploma				95.784	.000	.027
≤4.3	23759 (25.5)	9040 (24.1)	32799			
>4.3 and ≤ 6.8	24232 (26.0)	9238 (24.6)	33470			
>6.8 and ≤ 10.1	22946 (24.6)	9478 (25.3)	32424			
>10.1	22266 (23.9)	9772 (26.0)	32038			
High School GED				5.165	NS	.006
≤ 22.9	23458 (25.2)	9279 (24.7)	32737			
>22.9 and ≤ 29.0	24168 (25.9)	9752 (26.0)	33920			
>29.0 and ≤ 33.5	22433 (24.1)	9224 (24.6)	31657			
>33.5	23144 (24.8)	9273 (24.7)	32417			
Some College No degree				6.424	NS	.007
≤ 14.3	23390 (25.1)	9328 (24.9)	32718			
>14.3 and ≤ 17.1	23936 (25.7)	9817 (26.2)	33753			
>17.1 and ≤ 19.1	22974 (24.6)	9348 (24.9)	32322			
>19.1	22903 (24.6)	9035 (24.1)	31938			
Associate degree				51.050	.000	.020
≤ 6.6	23258 (25.0)	9878 (26.3)	33136			
>6.6 and ≤ 8.8	23067 (24.7)	9550 (25.4)	32617			
>8.8 and ≤ 11.3	23906 (25.6)	9371 (25.0)	33277			
>11.3	22972 (24.6)	8729 (23.3)	31701			
Bachelor Degree				29.525	.000	.015
≤13.2	23393 (25.1)	9865 (26.3)	33258			
>13.2 and ≤17.8	22971 (24.6)	9389 (25.0)	32360			
>17.8 and ≤23.1	23539 (25.3)	9209 (24.5)	32748			
>23.1	23300 (25.0)	9065 (24.2)	32365			
Graduate or Professional degree						
≤ 8.0	23372 (25.1)	9804 (26.1)	33176	30.619	.000	.015
>8.0 and ≤ 11.9	23299 (25.0)	9608 (25.6)	32907			
>11.9 and ≤ 18.4	23212 (24.9)	8987 (23.9)	32199			
>18.4	23320 (25.0)	9129 (24.3)	32449			

Table 28 continued				Chi-square test		
Variables ACS Individual measures	COMPL_NO *N* (%)	COMPL_YES *N* (%)	Total	χ^2	*p*	*Cramer's V*
High School or Higher				112.699	.000	.029
≤ 82.6	22873 (24.5)	10136 (27)	33009			
>82.6 and ≤ 89.0	23196 (24.9)	9506 (25.3)	32702			
>89.0 and ≤ 93.1	23539 (25.3)	8987 (23.9)	32526			
>93.1	23595 (25.3)	8899 (23.7)	32494			
Bachelor or Higher degree				30.913	.000	.015
≤ 21.3	23158 (24.8)	9780 (26.1)	32938			
>21.3 and ≤ 29.5	23245 (24.9)	9503 (25.3)	32748			
>29.5 and ≤ 41.6	23343 (25.0)	9091 (24.2)	32434			
>41.6	23457 (25.2)	9154 (24.4)	32611			
Employment Status						
Employed Population Ratio 16 yr +				65.244	.000	.022
≤ 55.1	22925 (24.6)	9928 (26.5)	32853			
>55.1 and ≤ 59.4	23446 (25.2)	9582 (25.5)	33028			
>59.4 and ≤ 62.9	23731 (25.5)	9115 (24.3)	32846			
>62.9	23101 (24.8)	8903 (23.7)	32004			
Unemployment rate 16 yr +				116.330	.000	.030
≤5.5	24441 (26.2)	9154 (24.4)	33595			
>5.5 and ≤ 6.9	23705 (25.4)	9281 (24.7)	32986			
>6.9 and ≤ 8.9	22677 (24.3)	9086 (24.2)	31763			
>8.9	22380 (24.0)	10007 (26.7)	32387			
Income in the last 12 months/USD						
Median Household Income				98.590	.000	.027
≤ 46305	22655 (24.3)	10048 (26.8)	32703			
>46305 and ≤ 60526	23335 (25.0)	9400 (25.0)	32735			
>60526 and ≤ 82738	23553 (25.3)	9079 (24.2)	32632			
>82738	23660 (25.4)	9001 (24.0)	32661			
Median Family Income				100.315	.000	.028
≤ 56703	22632 (24.3)	10074 (26.8)	32706			
>56703 and ≤ 72903	23356 (25.1)	9318 (24.8)	32674			
>72903 and ≤ 98250	23598 (25.3)	9120 (24.3)	32718			
>98250	23617 (25.3)	9016 (24.0)	32633			
Per Capita Income				82.272	.000	.025
≤ 23536	22769 (24.4)	10037 (26.7)	32806			
>23536 and ≤ 29398	23283 (25.0)	9312 (24.8)	32595			
>29398 and ≤37944	23605 (25.3)	9123 (24.3)	32728			
>37944	23546 (25.3)	9056 (24.1)	32602			

Table 28 continued				Chi-square test		
Variables ACS Individual measures	COMPL_NO *N* (%)	COMPL_YES *N* (%)	Total	χ^2	*p*	*Cramer's V*
Poverty Status in the last 12 months %						
All Families below poverty level				82.951	.000	.025
≤ 3.7	24317 (26.1)	9167 (24.4)	33484			
>3.7 and ≤7.1	22998 (24.7)	8947 (23.8)	31945			
>7.1 and ≤ 13.5	23291 (25.0)	9557 (25.5)	32848			
>13.5	22597 (24.2)	9857 (26.3)	32454			
People below poverty level				111.446	.000	.029
≤ 5.9	23853 (25.6)	8892 (23.7)	32745			
>5.9 and ≤ 10.4	23747 (25.5)	9249 (24.6)	32996			
>10.4 and ≤ 18.2	23058 (24.7)	9388 (25.0)	32446			
>18.2	22545 (24.2)	9999 (26.6)	32544			
Below Poverty age 18 to 64				114.764	.000	.030
≤ 5.8	24723 (26.5)	9183 (24.5)	33906			
>5.8 and ≤9.8	22716 (24.4)	8910 (23.7)	31626			
>9.8 and ≤ 16.7	23245 (24.9)	9436 (25.1)	32681			
>16.7	22519 (24.2)	9999 (26.6)	32518			
Below Poverty age 65 and above				92.087	.000	.027
≤ 5.1	24098 (25.9)	9180 (24.5)	33278			
>5.1 and ≤ 8.1	23657 (25.4)	9225 (24.6)	32882			
>8.1 and ≤ 13.2	22819 (24.5)	9093 (24.2)	31912			
>13.2	22629 (24.3)	10030(26.7)	32659			
GINI index of inequality				55.206	.000	.021
≤.3945	23610 (25.3)	9074 (24.2)	32684			
>.3945 and ≤ .4318	23492 (25.2)	9217 (24.6)	32709			
>.4318 and ≤ .4706	23295 (25.0)	9361 (24.9)	32656			
>.4706	22806 (24.5)	9876 (26.3)	32682			
Health Insurance %						
Public Health Insurance alone				95.540	.000	.027
≤ 11.50	23929 (25.7)	8936 (23.8)	32865			
>11.50 and ≤ 17.20	23690 (25.4)	9300 (24.8)	32990			
>17.20 and ≤ 26.40	23016 (24.7)	9368 (25.0)	32384			
>26.40	22568 (24.2)	9924 (26.4)	32492			
Medicare only				1.919	NS	.004
≤ 3.4	23367 (25.1)	9430 (25.1)	32797			
>3.4 and ≤ 4.2	24100 (25.9)	9815 (26.2)	33915			
>4.2 and ≤ 5.1	24829 (26.6)	9969 (26.6)	34798			
>5.1	20907 (22.4)	8314 (22.2)	29221			

Table 28 continued				Chi-square test		
Variables ACS Individual measures	COMPL_NO *N* (%)	COMPL_YES *N* (%)	Total	χ^2	*p*	*Cramer's V*
Medicaid only				91.105	.000	.026
≤ 7.0	24206 (26)	9168 (24.4)	33374			
>7.0 and ≤ 12.2	23066 (24.7)	8935 (23.8)	32001			
>12.2 and ≤ 21.6	23385 (25.1)	9490 (25.3)	32875			
>21.6	22546 (24.2)	9935 (26.5)	32481			
Private insurance alone				96.214	.000	.027
≤ 46.3	22928 (24.6)	10165 (27.1)	33093			
>46.3 and ≤ 56.7	23666 (25.4)	9407 (25.1)	33073			
>56.7 and ≤ 65.6	23089 (24.8)	9063 (24.1)	32152			
>65.6	23520 (25.2)	8893 (23.7)	32413			
No Vehicle OHU%				126.950	.000	.031
≤ 5.1	23931 (25.7)	8981 (23.9)	32912			
>5.1 and ≤ 9.9	23834 (25.6)	8999 (24.0)	32833			
>9.9 and ≤ 33.9	22795 (24.5)	9579 (25.5)	32374			
>33.9	22643 (24.3)	9969 (26.6)	32612			

Note. * The Chi-square statistic is significant at the .05 level, Cramer's V – values are presented

Interpretation of Descriptive Analyses and *χ2* Test RQ3

On Tables 26, 27 and 28 were presented the results from the descriptive and bivariate statistics of the Research Question 3 related to all complications (COMPL) evaluated as a dichotomous outcome- "COMPL_Yes" and "COMPL _No." The total sample size was *N*=130 731. The descriptive statistics were presented as numbers and percentages. The Chi-square test was performed between the outcome COMPL and the independent variables listed on each table and the results of *χ2* and *p* values listed on each table. The expected frequency of the cells was greater than 10 for all cells, and the *p*-value was considered significant if less than 0.05. Statistically, a significant association was observed between the outcome COMPL and multiple independent variables (Tables 25, 26, and 27). Considering these results, the null hypothesis was rejected, and the alternative hypothesis accepted. The effect size for *X*2, Cramer's *V* was performed, and considering the degree of freedom, small, medium, and large association are observed (Kim HY, 2017). Cramer's *V* value is listed in Tables 25, 26 and 27 only for the significant Chi-square statistics. Based on the bivariate analyses, variables with a significance of 0.05 and less will be included in the multivariable analysis.

Testing the Assumptions for Binomial Logistic Regression RQ3

Assumption #1: The dependent variable should be measured on a dichotomous scale. The dependent variable for Research question 3 is overall surgical complications (COMPL) and is measured as dichotomous variables "COMPL_Yes" and "COMPL _No," which meet Assumption 1. The independent variables are continuous (interval or ratio) and categorical (nominal) with two to five categories, which meet Assumption#2. The dependent variable is dichotomous and has two mutually exclusive and exhaustive categories which meet Assumption 3. Assumption #4 is related to the sample size, and it recommends a minimum of 15 and up to 50 cases per independent variable. With 34 independent variables before multicollinearity test, the sample size needed is at least 34x50=1700 cases and the current study sample is sufficient (Laerd Statistics, 2018). Using Peduzzi recommendation (1996), the sample size should be *N*=10x34/0.287=340/.287=1185. Also, Peduzzi recommends at least 10 events (COMPL) per event, which is calculate by dividing the total positive complications on independent variables, thus 37528/ 34= 110 4 cases (Peduzzi et al., 1996). The sample size in this study is *N*=130731which provides a sufficient number of cases per each independent variable, thus meet Assumption #4. Since these four assumptions are met, a binomial logistic regression would be an appropriate statistical test to analyze the research question. Assumption 5: Assumption 5 requires a linear relationship between the continuous independent variables in the model and the logit transformation of the outcome dependent variable. To test linearity, for all continuous independent variables used in the logistic regression model, a natural log transformation has to be created using SPSS. This assumption does not need to test linearity for the categorical variables, and the analyses for RQ3 included only categorical variables; therefore, this assumption is met. Assumption 6: Assumption 6 is related to multicollinearity, which occurs when there is a correlation between the predictor or the independent variables. The Tolerance and the VIF (Variance Inflation Factor) values were evaluated for the independent variables to examine for multicollinearity. The cut-off point for tolerance was set for less than 0.2 and VIF 5, at which point multicollinearity was accepted as problematic. Multicollinearity was tested for each model and presented in the regression model results. The evaluation of multicollinearity for RQ3-Model-1 and the subsequent evaluation after correction showing collinearity below the cut-off point for VIF 5 is shown in Appendix E (see Appendix E, Table E1 and E2) As this evaluation uses categorical variables, Assumption 7 about outliers is met.

Binomial Logistic Regression RQ3, Dependent Variable: COMPL

RQ3-Model-1.

In RQ3-Model-1 single measurement patient level and ACS SDOH independent variables at the Zip code level were included for analysis with Dependent Variable: COMPL. The independent SDOH variables initially included in RQ3-Model-1 based on the bivariate analyses were tested for multicollinearity, and adjustments were made to meet the cut-off marks for the Tolerance factor less than 0.2 and VIF 5 (Appendix E The independent variable that were included in the final RQ3-Model-1 after the multicollinearity evaluation are presented in Appendix E (see Appendix E, Figure E1).

Results from SPSS analysis of RQ3-Model-1

Table 29

Binomial logistic regression RQ3-Model-1, Dependent variable: COMPL

Variables in the Equation	*B*	*S.E.*	*Wald*	*df*	*p*	*OR*	95%CI	
RQ3-Model-1							Lower	Upper
Age in years ≥65	0.05	0.02	7.38	1	0.007	1.054	1.015	1.094
Sex Male	0.16	0.01	143.54	1	0.000	1.176	1.145	1.208
Principal Diagnosis (ref: Diverticulitis)			39.52	3	0.000			
IBD	0.06	0.04	2.61	1	0.106	1.062	0.987	1.142
Neoplasms	0.12	0.02	36.32	1	0.000	1.131	1.087	1.178
Other	0.05	0.02	6.18	1	0.013	1.055	1.011	1.101
Surgical Procedure Site (ref: Colon resection)			65.34	3	0.000			
Other	0.07	0.04	2.79	1	0.095	1.069	0.988	1.156
Rectal resection	0.06	0.04	2.61	1	0.106	1.061	0.987	1.140
Total colectomy	0.34	0.04	64.90	1	0.000	1.410	1.297	1.533
Surgical Approach (ref: Laparoscopic)			210.72	2	0.000			
Open	0.25	0.02	210.71	1	0.000	1.287	1.244	1.331
Other	0.19	0.04	26.22	1	0.000	1.207	1.123	1.297
Anastomosis Distal End (ref: Anal)			77.90	2	0.000			
Colon	0.17	0.06	6.65	1	0.010	1.181	1.041	1.340
Rectal	0.01	0.06	0.04	1	0.834	1.013	0.895	1.147
Diverting Stoma - Yes	-0.02	0.02	1.05	1	0.306	0.979	0.941	1.019
APRSOI risk (ref: Minor)			12242.72	3	0.000			
Moderate	1.02	0.02	2526.10	1	0.000	2.760	2.653	2.871
Major	2.06	0.02	8255.82	1	0.000	7.846	7.505	8.202
Extreme	2.82	0.03	10207.14	1	0.000	16.825	15.928	17.772
Admission Type-Elective	0.199	0.17	135.83	1	0.000	1.220	1.180	1.261
Race (ref: White)			35.54	3	0.000			
Asian	-0.06	0.05	1.68	1	0.196	0.942	0.860	1.031
Black or African American	0.12	0.02	24.21	1	0.000	1.124	1.073	1.178
Other	0.09	0.02	14.19	1	0.000	1.096	1.045	1.149
Health Insurance (ref: Medicaid)			4.82	4	0.306			
Medicare	-0.01	0.04	0.09	1	0.759	0.989	0.924	1.059
Other	0.05	0.12	0.20	1	0.656	1.056	0.831	1.341
Private/Commercial	-0.04	0.03	1.87	1	0.171	0.957	0.900	1.019
Self-Pay	-0.02	0.05	0.10	1	0.752	0.984	0.889	1.088
Annual Hospital Volume, cases (ref: ≥201)			79.97	3	0.000			
≤ 52	-0.09	0.02	19.89	1	0.000	0.910	0.874	0.949
≥53 and ≤ 122.7	0.05	0.02	5.26	1	0.022	1.047	1.007	1.089
≥123 and ≤ 200.34	0.07	0.02	11.71	1	0.001	1.070	1.029	1.112

Table 29 continued

Variables in the Equation	*B*	*S.E.*	*Wald*	*df*	*p*	*OR*	95%CI	
RQ3-Model-1							Lower	Upper
Limited English All Households (ref: >8.2)			15.34	3	0.002			
≤ .7	0.02	0.03	0.22	1	0.643	1.015	0.953	1.081
>.7and ≤ 2.8	-0.02	0.03	0.26	1	0.613	0.984	0.925	1.047
>2.8 and ≤ 8.2	-0.07	0.03	6.74	1	0.009	0.934	0.888	0.983
Less than 9th grade (ref: ≤ 2.3)			4.47	3	0.215			
>2.3 and ≤ 3.9	-0.02	0.02	0.57	1	0.452	0.984	0.944	1.026
>3.9 and ≤ 7.7	0.02	0.03	0.84	1	0.359	1.024	0.973	1.077
>7.7	-0.01	0.04	0.12	1	0.732	0.987	0.918	1.062
High School GED (ref: ≤ 22.9)			3.23	3	0.358			
>22.9 and ≤ 29.0	0.00	0.03	0.00	1	0.983	0.999	0.952	1.049
>29.0 and ≤ 33.5	-0.01	0.03	0.05	1	0.829	0.994	0.938	1.053
>33.5	-0.04	0.04	1.61	1	0.204	0.957	0.894	1.024
Associate degree (ref: ≤ 6.6)			10.09	3	0.018			
>6.6 and ≤ 8.8	-0.01	0.02	0.16	1	0.685	0.991	0.950	1.034
>8.8 and ≤ 11.3	-0.06	0.03	5.34	1	0.021	0.944	0.899	0.991
>11.3	-0.08	0.03	7.28	1	0.007	0.923	0.870	0.978
Bachelor Degree (ref: ≤13.2)			1.74	3	0.629			
>13.2 and ≤17.8	0.00	0.02	0.02	1	0.897	1.003	0.959	1.049
>17.8 and ≤23.1	-0.03	0.03	0.86	1	0.353	0.973	0.920	1.030
>23.1	-0.03	0.04	0.49	1	0.485	0.973	0.902	1.050
Employed Population Ratio 16 yr +(ref: ≤ 55.1)			7.41	3	0.060			
>55.1 and ≤ 59.4	0.03	0.02	2.68	1	0.102	1.035	0.993	1.078
>59.4 and ≤ 62.9	-0.02	0.02	0.40	1	0.529	0.985	0.939	1.033
>62.9	0.02	0.03	0.52	1	0.472	1.019	0.968	1.073
Unemployment rate 16 yr +(ref: ≤5.5)			9.03	3	0.029			
>5.5 and ≤ 6.9	0.02	0.02	0.93	1	0.336	1.020	0.980	1.061
>6.9 and ≤ 8.9	0.02	0.02	0.42	1	0.519	1.015	0.970	1.062
>8.9	0.07	0.03	7.09	1	0.008	1.073	1.019	1.130
Median Household Income (ref: ≤ 46305)			10.32	3	0.016			
>46305 and ≤ 60526	-0.05	0.03	3.64	1	0.056	0.953	0.907	1.001
>60526 and ≤ 82738	-0.10	0.03	9.82	1	0.002	0.904	0.849	0.963
>82738	-0.11	0.04	7.65	1	0.006	0.892	0.823	0.967
All Families below poverty level (ref:>13.5)			29.19	3	0.000			
≤ 3.7	0.15	0.04	13.40	1	0.000	1.160	1.071	1.256
>3.7 and ≤7.1	0.17	0.04	21.77	1	0.000	1.182	1.102	1.269
>7.1 and ≤ 13.5	0.14	0.03	26.88	1	0.000	1.152	1.092	1.215
Below Poverty age 65 and above (ref:>13.2)			6.21	3	0.102			
≤ 5.1	0.06	0.03	3.29	1	0.070	1.063	0.995	1.137
>5.1 and ≤ 8.1	0.04	0.03	1.47	1	0.226	1.039	0.977	1.104
>8.1 and ≤ 13.2	0.00	0.03	0.00	1	0.950	1.002	0.950	1.056
GINI index of inequality (ref: >.4706)			6.25	3	0.100			

Table 29 continued

Variables in the Equation	*B*	*S.E.*	*Wald*	*df*	*p*	*OR*	95%CI	
RQ3-Model-1							Lower	Upper
≤.3945	-0.01	0.03	0.16	1	0.690	0.988	0.933	1.047
>.3945 and ≤ .4318	-0.03	0.03	1.08	1	0.298	0.974	0.926	1.024
>.4318 and ≤ .4706	-0.05	0.02	5.09	1	0.024	0.953	0.914	0.994
Medicare only (ref: ≤ 3.4)			2.04	3	0.565			
>3.4 and ≤ 4.2	0.02	0.02	0.95	1	0.330	1.019	0.981	1.059
>4.2 and ≤ 5.1	0.00	0.02	0.00	1	0.959	1.001	0.962	1.042
>5.1	-0.01	0.02	0.20	1	0.656	0.990	0.948	1.034
Private insurance alone (ref: ≤ 46.3)			6.09	3	0.107			
>46.3 and ≤ 56.7	-0.05	0.03	4.15	1	0.042	0.948	0.900	0.998
>56.7 and ≤ 65.6	-0.03	0.03	0.55	1	0.457	0.976	0.914	1.041
>65.6	0.00	0.04	0.00	1	0.954	0.998	0.922	1.079
No Vehicle OHU% (ref: ≤ 5.1)			11.15	3	0.011			
>5.1 and ≤ 9.9	-0.01	0.02	0.22	1	0.642	0.990	0.949	1.033
>9.9 and ≤ 33.9	0.05	0.03	3.72	1	0.054	1.056	0.999	1.115
>33.9	0.10	0.04	7.06	1	0.008	1.103	1.026	1.186
Constant	-2.62	0.10	738.82	1	0.000	0.073		

Note. Dependent Variable: COMPL= Overall Surgical Complications, *OR*=Odds Ratio, CI=confidence interval, *$p<0.05$

Reporting results from the binomial logistic regression RQ3-Model 1- Dependent Variable: Overall Surgical Complication (COMPL)

Binomial logistic regression was performed to evaluate the effects of predictor variables entered in the final RQ3-Model-1 shown in Table 29: age in years, sex, principal diagnosis, surgical approach, anastomosis distal end, diverting stoma, admission type, APRSOI-severity of illness risk, race, health insurance, at time of surgery, annual hospital volume4, limited English All Households, less than 9th grade, high school GED, associate degree, bachelor degree, employed population ratio 16 yr +, unemployment rate 16 yr +, median household income, all families below poverty level, below poverty age 65 and above, GINI index of inequality, Medicare only, private insurance alone, and no vehicle OHU% on the likelihood of the postsurgical outcome overall COMPL. The logistic regression model was statistically significant, $\chi 2$ =21856.93, p = .000, shown in Appendix E, Table E3. The model explained 22.0% (Nagelkerke) of the variance in COMPL, and Hosmer and Lemeshow Test was not significant p=0.180 indicating that the model was well fit, presented in Appendix E, Tables E4 and E5 respectively. The model accurately classified 75.0% of 130 731cases included. The sensitivity is 35%, and specificity is 91.2% (Appendix E) The significant SDOH variables *p-value*, odds ratio, and the 95% Confidence Interval for the odds, in Table 29. Covariates associated with increase of the outcome COMPL are listed in Table 30. Of the 17 SDOH predictor variables, ten were statistically significant and listed in Tables 31.

Table 30
RQ3-Model-1 Covariates *associated with increase of outcome COMPL*

Variable Category/Level	RQ3-Model-1	*p*	*OR*	95%CI Lower	 Upper
	Covariates associated with COMPL increase				
Biological Patient level	Age in years ≥65	0.007	1.054	1.015	1.094
	Sex Male	0.000	1.176	1.145	1.208
Clinical Patient level	Principal Diagnosis (ref: Diverticulitis)	0.000			
Covariates	Neoplasms	0.000	1.131	1.087	1.178
	Other	0.013	1.055	1.011	1.101
	Surgical Procedure Site (ref: Colon resection)	0.000			
	Total colectomy	0.000	1.410	1.297	1.533
	Surgical Approach (ref: Laparoscopic)	0.000			
	Open	0.000	1.287	1.244	1.331
	Other	0.000	1.207	1.123	1.297
	APRSOI risk (ref: Minor)	0.000			
	Moderate	0.000	2.760	2.653	2.871
	Major	0.000	7.846	7.505	8.202
	Extreme	0.000	16.825	15.928	17.772
	Admission Type -Elective	0.000	1.120	1.180	1.261

Note. Dependent Variable: COMPL= Overall Surgical Complications, *OR*=Odds Ratio, CI=confidence interval, *$p<0.05$

Table 31

SDOH in RQ3-Model-1 associated with increase or decrease of COMPL occurrence after large intestinal surgery

Variable Category/Level	RQ3-Model-1	*p*	*OR*	95%CI Lower	 Upper
Biological Patient	Age in years ≥65	0.007	1.054	1.015	1.094
	Sex Male	0.000	1.176	1.145	1.208
SDOH Patient	SDOH associated with COMPL increase				
Social Context	Race (ref: White)	0.000			
	Black or African American	0.000	1.124	1.073	1.178
	Other (all other except Asian)	0.000	1.096	1.045	1.149
Hospital Facility	Annual Hospital Volume, cases (ref: ≥201)	0.000			
	≥53 and ≤ 122.7	0.022	1.047	1.007	1.089
	≥123 and ≤ 200.34	0.001	1.070	1.029	1.112
SDOH Zip code					
Employment Status	Unemployment rate 16 yr. +(ref: ≤5.5)	0.029			
	>8.9	0.008	1.073	1.019	1.130
Poverty	All Families below poverty level (ref:>13.5)	0.000			
	≤ 3.7	0.000	1.160	1.071	1.256
	>3.7 and ≤7.1	0.000	1.182	1.102	1.269
	>7.1 and ≤ 13.5	0.000	1.152	1.092	1.215
Economic stability	No Vehicle OHU% (ref: ≤ 5.1)	0.011			
	>33.9	0.008	1.103	1.026	1.186
	SDOH associated with COMPL decrease				
Language Proficiency	Limited English All Households (ref: >8.2)	0.002			
	>2.8 and ≤ 8.2	0.009	0.934	0.888	0.983
Education	Associate degree (ref: ≤ 6.6)	0.018			
	>8.8 and ≤ 11.3	0.021	0.944	0.899	0.991
	>11.3	0.007	0.923	0.870	0.978
Income	Median Household Income (ref: ≤ 46305)	0.016			
	>60526 and ≤ 82738	0.002	0.904	0.849	0.963
	>82738	0.006	0.892	0.823	0.967
Inequality	GINI index of inequality (ref: >.4706)	0.100			
	>.4318 and ≤ .4706	0.024	0.953	0.914	0.994
Health Care Access	Private insurance alone (ref: ≤ 46.3)	0.107			
	>46.3 and ≤ 56.7	0.042	0.948	0.900	0.998

Note. Dependent Variable: COMPL= Overall Surgical Complications, *OR*=Odds Ratio, CI=confidence interval, **p*<0.05

The null hypothesis for Research Question 3 (RQ3) was rejected as RQ3-Model-1 (including single measure SDOH on individual and contextual levels) demonstrated a significant association of the SDOH in Table 31 with the increase or decrease of the dependent variable COMPL occurrence after large intestinal surgery.

RQ3-Model-2a

In RQ3-Model-2a the association of patient level SDOH, and the composite SDOH *SVI* Overall Themes on contextual level (ZIP code and County code areas) were evaluated with overall surgical complications occurrence after large intestinal surgery Dependent Variable is COMPL (Appendix E, Figure E2). The independent SDOH variables initially included in RQ3-Model-2a based on the bivariate analyses were evaluated for multicollinearity and no adjustments were needed to meet the cut-off marks for the Tolerance factor less than 0.2 and VIF 5 (Appendix E, Table E7). The final variables included in RQ3-Model-2a after multicollinearity test are listed in Appendix E.

Results from SPSS analysis of RQ3-Model-2a

Table 32

Binomial logistic regression RQ3-Model-2a. Dependent variable COMPL

Variables in the Equation *RQ3-Model-2a*	*B*	*S.E.*	*Wald*	*df*	*p*	*OR*	95% C.I.	
							Lower	Upper
Age in years ≥65	0.052	0.019	7.347	1	0.007	1.053	1.015	1.094
Sex Male	0.162	0.014	143.253	1	0.000	1.176	1.145	1.208
Principal Diagnosis (ref: Diverticulitis)			38.500	3	0.000			
IBD	0.055	0.037	2.158	1	0.142	1.056	0.982	1.136
Neoplasms	0.120	0.020	34.513	1	0.000	1.128	1.083	1.174
Other	0.048	0.022	5.010	1	0.025	1.050	1.006	1.095
Surgical Procedure Site (ref: Colon resection)			65.676	3	0.000			
Other	0.067	0.040	2.790	1	0.095	1.069	0.988	1.156
Rectal resection	0.053	0.037	2.092	1	0.148	1.054	0.981	1.133
Total colectomy	0.344	0.043	64.981	1	0.000	1.410	1.297	1.533
Surgical Approach (ref: Laparoscopic)			220.792	2	0.000			
Open	0.257	0.017	220.740	1	0.000	1.293	1.250	1.338
Other	0.196	0.037	28.582	1	0.000	1.217	1.132	1.308
Anastomosis Distal End (ref: Anal)			78.658	2	0.000			
Colon	0.169	0.064	6.910	1	0.009	1.184	1.044	1.344
Rectal	0.016	0.063	0.064	1	0.801	1.016	0.898	1.150
Diverting Stoma - Yes	-0.022	0.021	1.127	1	0.288	0.978	0.940	1.019
APRSOI risk (ref: Minor)			12256.688	3	0.000			
Moderate	1.013	0.020	2518.263	1	0.000	2.754	2.647	2.865
Major	2.059	0.023	8258.026	1	0.000	7.837	7.497	8.193
Extreme	2.823	0.028	10216.212	1	0.000	16.824	15.928	17.771
Admission Type-Elective	0.198	0.017	135.082	1	0.000	1.219	1.179	1.260
Race (ref: White)			35.534	3	0.000			
Asian	-0.077	0.046	2.844	1	0.092	0.926	0.846	1.013
Black or African American	0.109	0.023	22.759	1	0.000	1.115	1.066	1.167
Other	0.086	0.024	13.256	1	0.000	1.089	1.040	1.141
Health Insurance (ref: Medicaid)			4.288	4	0.368			
Medicare	-0.011	0.035	0.104	1	0.747	0.989	0.924	1.058
Other	0.050	0.122	0.166	1	0.684	1.051	0.827	1.335
Private/Commercial	-0.041	0.032	1.653	1	0.199	0.960	0.902	1.022
Self-Pay	-0.004	0.052	0.006	1	0.938	0.996	0.900	1.102

Table 32 continue

Variables in the Equation *RQ3-Model-2a*	*B*	*S.E.*	*Wald*	*df*	*p*	*OR*	95% C.I.	
							Lower	Upper
Annual Hospital Volume, cases (ref: ≥201)			81.500	3	0.000			
≤ 52	-0.102	0.021	23.660	1	0.000	0.903	0.867	0.941
≥53 and ≤ 122.7	0.038	0.020	3.549	1	0.060	1.038	0.998	1.080
≥123 and ≤ 200.34	0.062	0.020	10.090	1	0.001	1.064	1.024	1.106
T0z_Overal Themes Summary score (ref: ≤.1909)			2.294	3	0.514			
>.1909 and ≤ .3929	-0.022	0.019	1.327	1	0.249	0.978	0.941	1.016
>.3929 and ≤ .6590	-0.001	0.020	0.003	1	0.956	0.999	0.960	1.040
> 0.6590	-0.022	0.024	0.843	1	0.359	0.978	0.933	1.026
T0ct Overall Themes Summary score (ref: ≤ .1639)			28.239	3	0.000			
>.1639 and ≤ 5410	0.036	0.020	3.214	1	0.073	1.037	0.997	1.078
>.5410 and ≤ .7213	0.107	0.021	27.088	1	0.000	1.113	1.069	1.159
>0.7213	0.067	0.023	8.590	1	0.003	1.069	1.022	1.118
Flags_TOTALz_Themes Sum Flags (ref:0)			23.718	2	0.000			
1	0.034	0.017	4.104	1	0.043	1.035	1.001	1.070
≥ 2	0.101	0.021	23.686	1	0.000	1.107	1.062	1.153
Flags_TOTALct_Themes Sum Flags (ref:0)			10.047	2	0.007			
1	-0.024	0.026	0.854	1	0.355	0.976	0.928	1.027
≥ 2	0.041	0.017	5.857	1	0.016	1.042	1.008	1.077
Constant	-2.886	0.078	1366.065	1	0.000	0.056		

Note. Dependent Variable: COMPL= Overall Surgical Complications, *OR*=Odds Ratio, CI=confidence interval, *p<0.05

Reporting results from the binomial logistic regression RQ3-Model 2a- Dependent Variable: COMPL

Binomial logistic regression was performed to evaluate the effects of predictor variables entered in the RQ3-Model-2a shown in Table 32: age in years, sex, principal diagnosis, surgical approach, surgical_procedure_site, anastomosis distal end, diverting stoma, APRSOI severity of illness risk, admission type, race, health insurance, annual hospital volume, SVI Overall rank on zip code and county levels, and extreme SVI (variable called "flagged Overall Themes SVI on zip code and county levels on the likelihood of the postsurgical outcome COMPL. The logistic regression model was statistically significant, $\chi 2 = 21816.047$, $p = 0.000$ shown in Appendix E, Table E8. The model explained 22 % (Nagelkerke) of the variance in the analyses, and Hosmer and Lemeshow Test was not significant p=0.128 indicating that the model was well fit (see Appendix E, Tables E9 and E10). The null hypothesis was rejected. Overall, the model accurately classified 75% of 130 731cases included as shown in Table E11. The sensitivity is 34.7%, and specificity is high 91.2 %. The SDOH Overall Social Vulnerability at the county level, Extreme Social Vulnerability (flagged overall themes) at zip code and county code levels are significantly associated independent factors with the likelihood of the increase of COMPL occurrence after large intestinal surgery. The significant SDOH variables *p-value*, odds ratio, and the 95% Confidence Interval for the odds are listed in Table 32. The null hypothesis for Research Question 3 is rejected as RQ3-Model-2a demonstrated a significant association of the SDOH with an increase of COMPL occurrence after large intestinal surgery (Table 33).

Table 33

RQ3-*Model-2a SDOH and covariates associated with increase of COMPL*

Variable category/level	RQ3-Model-2a	*p*	*OR*	95% C.I.	
	Covariates associated with COMPL increase			Lower	Upper
Biological Patient level	Age in years ≥65	0.007	1.053	1.015	1.094
	Sex Male	0.000	1.176	1.145	1.208
Clinical Patient	Principal Diagnosis (ref: Diverticulitis)	0.000			
Covariates	Neoplasms	0.000	1.128	1.083	1.174
	Other	0.025	1.050	1.006	1.095
	Surgical Procedure Site (ref: Colon resection)	0.000			
	Total colectomy	0.000	1.410	1.297	1.533
	Surgical Approach (ref: Laparoscopic)	0.000			
	Open	0.000	1.293	1.250	1.338
	Other	0.000	1.217	1.132	1.308
	Anastomosis Distal End (ref: Anal)	0.000			
	Colon	0.009	1.184	1.044	1.344
	APRSOI risk (ref: Minor)	0.000			
	Moderate	0.000	2.754	2.647	2.865
	Major	0.000	7.837	7.497	8.193
	Extreme	0.000	16.824	15.928	17.771
	Admission Type-Elective	0.000	1.219	1.179	1.260
	SDOH associated with COMPL increase				
SDOH Patient					
Social Context	Race (ref: White)	0.000			
	Black or African American	0.000	1.115	1.066	1.167
	Other	0.000	1.089	1.040	1.141
Hospital Facility	Annual Hospital Volume, cases (ref: ≥201)	0.000			
	≥53 and ≤ 122.7	0.060	1.038	0.998	1.080
	≥123 and ≤ 200.34	0.001	1.064	1.024	1.106
SDOH Zip code	Flags_TOTALz_Themes Sum Flags (ref:0)	0.000			
	1	0.043	1.035	1.001	1.070
	≥ 2	0.000	1.107	1.062	1.153
SDOH County code *Social Vulnerability*	T0ct Overall Themes Summary score (ref: ≤ .1639)	0.000			
	>.5410 and ≤ .7213	0.000	1.113	1.069	1.159
	>0.7213	0.003	1.069	1.022	1.118
Extreme Social Vulnerability	Flags_TOTALct_Themes Sum Flags (ref:0)	0.007			
	≥ 2	0.016	1.042	1.008	1.077

*N*ote. Dependent Variable: COMPL= Overall Surgical Complications, *OR*=Odds Ratio, CI=confidence interval, **p*<0.05

RQ3-Model-2b

In RQ3-Model-2b the Social Vulnerability Themes –composite contextual SDOH at zip code and county code level were included in the model for analysis with dependent variable COMPL. The themes composition is listed in Appendix B, (see Appendix B, Table B4). The independent SDOH variables initially included in RQ3-Model-2b based on the bivariate analyses were tested for multicollinearity and adjustments were made to meet the cut-off marks for Tolerance factor less than 0.2 and VIF 5 (Appendix E, Tables E12 and E13). The final variables included in RQ3-Model-2b are listed on Figure E3.

RQ3-Model-2b Logistic regression results Dependent Variable: COMPL

Table 34 *Binomial logistic regression results RQ3-Model-2b. Dependent variable COMPL*

Variables in the Equation RQ3-Model-2b	*B*	*S.E.*	*Wald*	*df*	*p*	*OR*	95% C.I. Lower	Upper
Age in years ≥65	0.048	0.019	6.279	1	0.012	1.049	1.011	1.090
Sex Male	0.164	0.014	146.416	1	0.000	1.178	1.147	1.210
Principal Diagnosis (ref: Diverticulitis)			40.774	3	0.000			
IBD	0.057	0.037	2.365	1	0.124	1.059	0.984	1.139
Neoplasms	0.124	0.020	36.453	1	0.000	1.132	1.087	1.178
Other	0.049	0.022	5.145	1	0.023	1.050	1.007	1.096
Surgical Procedure Site (ref: Colon resection)			65.941	3	0.000			
Other	0.068	0.040	2.865	1	0.091	1.070	0.989	1.158
Rectal resection	0.052	0.037	2.013	1	0.156	1.053	0.980	1.132
Total colectomy	0.344	0.043	65.158	1	0.000	1.411	1.298	1.534
Surgical Approach (ref: Laparoscopic)			229.484	2	0.000			
Open	0.263	0.017	229.365	1	0.000	1.300	1.257	1.345
Other	0.204	0.037	30.976	1	0.000	1.227	1.142	1.318
Anastomosis Distal End (ref: Anal)			77.221	2	0.000			
Colon	0.170	0.064	6.963	1	0.008	1.185	1.045	1.345
Rectal	0.018	0.063	0.081	1	0.776	1.018	0.899	1.153
Diverting Stoma – Yes	-0.024	0.021	1.336	1	0.248	0.977	0.938	1.017
APRSOI risk (ref: Minor)			12239.958	3	0.000			
Moderate	1.011	0.020	2507.772	1	0.000	2.749	2.643	2.860
Major	2.057	0.023	8230.461	1	0.000	7.821	7.481	8.176
Extreme	2.823	0.028	10209.055	1	0.000	16.828	15.931	17.775
Admission Type-Elective	0.194	0.017	129.699	1	0.000	1.215	1.175	1.256
Race (ref: White)			30.453	3	0.000			
Asian	-0.065	0.046	1.943	1	0.163	0.937	0.856	1.027
Black or African American	0.115	0.023	24.097	1	0.000	1.122	1.072	1.175
Other	0.061	0.024	6.220	1	0.013	1.062	1.013	1.114
Health Insurance (ref: Medicaid)			6.305	4	0.178			
Medicare	-0.009	0.035	0.072	1	0.789	0.991	0.925	1.061
Other	0.046	0.122	0.142	1	0.706	1.047	0.824	1.331
Private/Commercial	-0.048	0.032	2.289	1	0.130	0.953	0.895	1.014
Self-Pay	-0.010	0.052	0.038	1	0.845	0.990	0.895	1.095
Annual Hospital Volume, cases (ref: ≥201)			101.279	3	0.000			
≤ 52	-0.121	0.021	31.814	1	0.000	0.886	0.849	0.924
≥53 and ≤ 122.7	0.051	0.021	6.234	1	0.013	1.053	1.011	1.096
≥123 and ≤ 200.34	0.055	0.020	7.915	1	0.005	1.057	1.017	1.099

Variables in the Equation RQ3-Model-2b	*B*	*S.E.*	*Wald*	*df*	*p*	*OR*	95% C.I. Lower	Upper
Flags_T1z_Socioeconomic Status (ref:0)			3.543	4	0.471			
1	-0.039	0.031	1.510	1	0.219	0.962	0.905	1.023
2	0.000	0.041	0.000	1	0.993	1.000	0.922	1.085
3	0.028	0.062	0.209	1	0.647	1.029	0.912	1.161
4	-0.092	0.070	1.739	1	0.187	0.912	0.796	1.046
Flags_T2z_Household Composition & Disability(ref:0)			1.228	3	0.746			
1	-0.012	0.018	0.412	1	0.521	0.988	0.954	1.024
2	-0.032	0.035	0.815	1	0.367	0.969	0.905	1.038
3	0.016	0.068	0.056	1	0.813	1.016	0.890	1.160
Flags_T3z_ Minority Status and Language (ref:0)			8.212	2	0.016			
1	0.063	0.028	5.231	1	0.022	1.065	1.009	1.125
2	-0.075	0.068	1.219	1	0.270	0.928	0.812	1.060
Flags_T4z_Housing and Transportation (ref:0)			5.738	4	0.220			
1	0.015	0.018	0.726	1	0.394	1.015	0.980	1.052
2	0.069	0.034	4.149	1	0.042	1.072	1.003	1.146
3	0.064	0.066	0.930	1	0.335	1.066	0.936	1.214
4	-0.214	0.208	1.055	1	0.304	0.807	0.537	1.215
T1ct Socioeconomic Status (ref: ≤ .1475)			15.103	3	0.002			
>.1475 and ≤ 0.3934	0.098	0.035	7.570	1	0.006	1.103	1.028	1.182
>.3934 and ≤ 0.7377	0.062	0.042	2.142	1	0.143	1.064	0.979	1.156
>.7377	0.027	0.055	0.241	1	0.624	1.028	0.922	1.146
T2ct Household Composition and Disability (ref: ≤ .0984)		16.409	3	0.001				
>.0984 and ≤ .3115		-0.018	0.030	0.372	1	0.542	0.982	0.926
>.3115 and ≤ .4754	-0.027	0.037	0.525	1	0.469	0.974	0.906	1.047
>0.4754	0.070	0.034	4.346	1	0.037	1.073	1.004	1.146
T3ct Minority Status and Language (ref: ≤ .7213)			20.139	3	0.000			
>.7213 and ≤ .8525	0.013	0.029	0.215	1	0.643	1.013	0.958	1.072
>.8525 and ≤ .9508	0.028	0.030	0.877	1	0.349	1.028	0.970	1.090
>.9508	0.153	0.035	18.660	1	0.000	1.166	1.087	1.249
T4ct Housing and Transportation (ref: ≤ .2787)			54.390	3	0.000			
>.2787 and ≤ .6230	-0.053	0.028	3.558	1	0.059	0.949	0.898	1.002
>.6230 and ≤ .7869	-0.116	0.039	8.590	1	0.003	0.891	0.824	0.962
>.7869	0.090	0.037	5.891	1	0.015	1.094	1.017	1.176
Constant	-2.867	0.082	1213.630	1	0.000	0.057		

Note. Dependent Variable: COMPL= Overall Surgical Complications, *OR*=Odds Ratio, CI=confidence interval, *p<0.0

Reporting results from the binomial logistic regression RQ3-Model-2b, Dependent Variable: COMPL

Binomial logistic regression was performed to evaluate the effects of predictor variables entered in the RQ3-Model-2b shown in Table 34: age in years, sex, principal diagnosis, surgical approach, anastomosis distal end, diverting stoma, admission type, APRSOI severity of illness risk, race, health insurance, annual hospital volume4, T1ct Socioeconomic Status, T2ct Household Composition and Disability, T3ct Minority Status and Language, T4ct Housing and Transportation, Flags_T1z_Socioeconomic Status, Flags_T2z_Household Composition & Disability, Flags_T3z_ Minority Status and Language, and Flags_T4z_Housing and Transportation on the likelihood of the postsurgical outcome COMPL. The logistic regression model was statistically significant, $\chi 2$ =21938.77, p =.000 shown in Appendix E, Table E14. The model explained 22.1% (Nagelkerke) of the variance in COMPL, and Hosmer and Lemeshow Test was not significant p=0.109 indicating that the model was well fit, presented in Tables E15 and E16 respectively. The research hypothesis was rejected and the alternative accepted. The model accurately classified 75.0% of 130 731cases included. The sensitivity is 35.1%, and specificity is 91.1%, shown in Table E17. The significant SDOH variables *p-value*, odds ratio, and the 95% Confidence Interval for the odds are listed in Table 34. Covariates associated with increase or decrease of COMPL occurrence after large intestinal surgery are listed in Table 35. SDOH associated with increase or decrease of the COMPL after large intestinal surgery are listed in Table 36.

Table 35

Covariates in RQ3-Model-2b associated with increase or decrease of COMPL *occurrence after large intestinal surgery*

Variable category/level	RQ3-Model-2b	*p*	*OR*	95% C.I.	
	Covariates associated with COMPL increase			Lower	Upper
Biological Patient level	Age in years ≥65	0.012	1.049	1.011	1.090
	Sex Male	0.000	1.178	1.147	1.210
Clinical Patient level	Principal Diagnosis (ref: Diverticulitis)	0.000			
Covariates	Neoplasms	0.000	1.132	1.087	1.178
	Other	0.023	1.050	1.007	1.096
	Surgical Procedure Site (ref: Colon resection)	0.000			
	Total colectomy	0.000	1.411	1.298	1.534
	Surgical Approach (ref: Laparoscopic)	0.000			
	Open	0.000	1.300	1.257	1.345
	Other	0.000	1.227	1.142	1.318
	Anastomosis Distal End (ref: Anal)	0.000			
	Colon	0.008	1.185	1.045	1.345
	APRSOI risk (ref: Minor)	0.000			
	Moderate	0.000	2.749	2.643	2.860
	Major	0.000	7.821	7.481	8.176
	Extreme	0.000	16.828	15.931	17.775
	Admission Type-Elective	0.000	1.215	1.175	1.256

Note. Dependent Variable: COMPL= Overall Surgical Complications, *OR*=Odds Ratio, CI=confidence interval, *$p<0.05$

Table 36

SDOH in RQ3-Model-2b associated with increase or decrease of COMPL *occurrence after large intestinal surgery*

Variable category/level	Variables in the Equation RQ3-Model-2b	*p*	*OR*	95% C.I.	
	SDOH associated with COMPL increase			Lower	Upper
SDOH Patient	Race (ref: White)	0.000			
Social Context	Black or African American	0.000	1.122	1.072	1.175
	Other	0.013	1.062	1.013	1.114
Hospital Facility	Annual Hospital Volume, cases (ref: ≥201)	0.000			
	≥53 and ≤ 122.7	0.013	1.053	1.011	1.096
	≥123 and ≤ 200.34	0.005	1.057	1.017	1.099
SDOH Zip code	Flags_T3z_ Minority Status and Language (ref:0)	0.016			
	1	0.022	1.065	1.009	1.125
	Flags_T4z_Housing and Transportation (ref:0)	0.220			
	2	0.042	1.072	1.003	1.146
SDOH County *Social Vulnerability*	T1ct Socioeconomic Status (ref: ≤ .1475)	0.002			
	>.1475 and ≤ 0.3934	0.006	1.103	1.028	1.182
	T2ct Household Composition and Disability (ref: ≤ .0984)	0.001			
	>0.4754	0.037	1.073	1.004	1.146
	T3ct Minority Status and Language (ref: ≤ .7213)	0.000			
	>.9508	0.000	1.166	1.087	1.249
	T4ct Housing and Transportation (ref: ≤ .2787)	0.000			
	>.6230 and ≤ .7869	0.003	0.891	0.824	0.962
	>.7869	0.015	1.094	1.017	1.176

Note. Dependent Variable: COMPL= Overall Surgical Complications, *OR*=Odds Ratio, CI=confidence interval, **p*<0.05

The null hypothesis for Research Question 3 (RQ3) was rejected as RQ3-Model-2b demonstrated significant association of the SDOH with increase or decrease of all surgical COMPL occurrence after large intestinal surgery shown in Table 36.

Research Question 4

Research Question and Hypothesis

Research Question 4 (RQ4): Is there an association between the SDOH and Not SSI related (hospital acquired) infectious complications within 30 days after colorectal surgery in and out of the hospital in adult patients?

Null Hypothesis ($H_0$4): SDOH are not associated with Not SSI (hospital acquired) infectious complications occurrence within 30 days after large intestinal resection in and out of the hospital in adult patients.

Alternative Hypothesis ($H_1$4): SDOH are associated with Not SSI related (hospital acquired) infectious complications occurrence within 30 days after large intestinal resection in and out of the hospital in adult patients.

The outcome or dependent variable was “Not SSI hospital acquired infectious complications" after colorectal surgery measured as a binary outcome "yes" or "no" within 30 days after surgery and in or out of the hospital.

Descriptive and Bivariate Analyzes

Table 37

Descriptive and Bivariate Statistics of the RQ4 Not_SSI and SPARCS patient variables (N=130731)

Variable				Chi-square test		
	Not_SSI_No *N* (%)	Not_SSI_Yes *N* (%)	Total	χ^2	*p*	*Cramer's V*
Total	112655(86.2)	18076(13.8)	130731			
Age in years				1177.8	.000*	0.095
< 65	58292 (51.7)	6868 (38.0)	65160			
≥65	54363 (48.3)	11208 (62.0)	65571			
Age 4gr				1694.3	.000*	0.114
up to 53	30340 (26.9)	3452 (19.1)	33792			
54 to 65	30729 (27.3)	3785 (20.9)	34514			
66 to 76	27321 (24.3)	4656 (25.8)	31977			
77 and above	24265 (21.5)	6183 (34.2)	30448			
Sex				12.9	.000*	0.01
Male	52207 (46.3)	8118 (44.9)	60325			
Female	60448 (53.7)	9958 (55.1)	70406			
Race				87.1	.000*	0.026
Asian	2983 (2.6)	363 (2.0)	3346			
Black or African American	12478 (11.1)	2366 (13.1)	14844			
Other	11584 (10.3)	1907 (10.5)	13491			
White	85610 (76)	13440 (74.4)	99050			
Race minority				22.8	.000*	0.013
Not minority	85610 (76)	13440 (74.4)	99050			
Minority (all except white)	27045 (24)	4636 (25.6)	31681			
Principal Diagnosis				987.2	.000*	0.087
Diverticulitis	27674 (24.6)	3505 (19.4)	31179			
IBD	4629 (4.1)	795 (4.4)	5424			
Neoplasms	54120 (48.0)	7657 (42.4)	61777			
Other	26232 (23.3)	6119 (33.9)	32351			
APRSOI Severity of Illness risk				15399.4	.000*	0.343
minor	38347 (34)	1651 (9.1)	39998			
moderate	44212 (39.2)	4220 (23.3)	48432			
major	20804 (18.5)	5723 (31.7)	26527			
extreme	9292 (8.2)	6482 (35.9)	15774			

Table 37 continued

Variable				Chi-square test		
	Not_SSI_No *N* (%)	Not_SSI_Yes *N* (%)	Total	χ^2	*p*	*Cramer's V*
Admission Type				3191.8	.000*	0.156
Elective	72541 (64.4)	7655 (42.3)	80196			
Emergency	40114 (35.6)	10421 (57.7)	50535			
Surg Site				554.8	.000*	0.065
Left colectomy	45305 (40.2)	6794 (37.6)	52099			
Other	5532 (4.9)	1243 (6.9)	6775			
Rectal resection	12086 (10.7)	1460 (8.1)	13546			
Right colectomy	44328 (39.3)	7249 (40.1)	51577			
Total colectomy	2604 (2.3)	822 (4.5)	3426			
Transverse colectomy	2800 (2.5)	508 (2.8)	3308			
Surgical Procedure Site				523.6	.000*	0.063
Colon resection	92433 (82.0)	14551 (80.5)	106984			
Other	5532 (4.9)	1243 (6.9)	6775			
Rectal resection	12086 (10.7)	1460 (8.1)	13546			
Total colectomy	2604 (2.3)	822 (4.5)	3426			
Surgical Approach				1635.6	.000*	0.112
laparoscopic	34346 (30.5)	2910 (16.1)	37256			
open	64916 (57.6)	12914 (71.4)	77830			
other	13393 (11.9)	2252 (12.5)	15645			
Anastomosis distal end				90.5	.000*	0.026
anal	1955 (1.7)	170 (0.9)	2125			
colon	55074 (48.9)	9295 (51.4)	64369			
rectal	55626 (49.4)	8611 (47.6)	64237			
Diverting Stoma				2268.4	.000*	0.132
no	98373 (87.3)	13353 (73.9)	111726			
yes	14282 (12.7)	4723 (26.1)	19005			
LOSS_4gr/days				16487.6	.000*	0.338
≤ 4	38590 (34.3)	1496 (8.3)	40086			
≥5 and ≤ 6	32765 (29.1)	2447 (13.5)	35212			
≥ 7 and ≤ 9	23320 (20.7)	4000 (22.1)	27320			
≥10	17980 (16.0)	10133 (56.1)	28113			
Health Insurance				1241.9	.000*	0.097
Medicaid	5634 (5.0)	992 (5.5)	6626			
Medicare	46010 (40.8)	9772 (54.1)	55782			
Other	373 (0.3)	50 (0.3)	423			
Private/Commercial	57734 (51.2)	6782 (37.5)	64516			
Self-Pay	2904 (2.6)	480 (2.7)	3384			

Table 37 continued

Variable				Chi-square test		
	Not_SSI_No *N* (%)	Not_SSI_Yes *N* (%)	Total	χ^2	*p*	*Cramer's V*
Annual Hospital Volume4/cases				118.0	.000*	0.03
≤ 52	28039 (24.9)	4983 (27.6)	33022			
≥53 and ≤ 122.7	28683 (25.5)	4792 (26.5)	33475			
≥123 and ≤ 200.34	28953 (25.7)	4538 (25.1)	33491			
≥201	26980 (23.9)	3763 (20.8)	30743			

Note. * The Chi-square statistic is significant at the .05 level, Cramer's *V* – values are presented

Table 38

Descriptive and Bivariate Statistics of the RQ4 Not_SSI and SVI Themes (Social Vulnerability Index) on Zip code and County code (N=130731)

				Chi-square test		
Variable SVI COMPOSITE	Not_SSI_No *N* (%)	Not_SSI_Yes *N* (%)	Total	χ^2	*p*	*Cramer's V*
Total	112655(86.2)	18076(13.8)	130731			
ZIP CODE LEVEL						
T1z_Socioeconomic Status				107.1	.000*	0.029
≤ .1756	28453 (25.3)	4234 (23.4)	32687			
>.1756 and ≤.3799	28469 (25.3)	4225 (23.4)	32694			
>.3799 and ≤.6453	28069 (24.9)	4610 (25.5)	32679			
>.6453	27664 (24.6)	5007 (27.7)	32671			
T2z_Houshold Composition and Disability				23.03	.000*	0.013
≤ .2863	28310 (25.1)	4517 (25.0)	32827			
>.2863 and ≤.5045	28261 (25.1)	4323 (23.9)	32584			
>.5045 and ≤ .7467	28163 (25.0)	4484 (24.8)	32647			
>.7467	27921 (24.8)	4752 (26.3)	32673			
T3z_Minority Status and Language				104.3	.000*	0.028
≤ .1820	28439 (25.2)	4262 (23.6)	32701			
>.1820 and ≤ .3850	28572 (25.4)	4240 (23.5)	32812			
>.3850 and ≤ .6561	28015 (24.9)	4564 (25.2)	32579			
>.6561	27629 (24.5)	5010 (27.7)	32639			
T4z_Housing and Transportation				56.03	.000*	0.021
≤.2400	28486 (25.3)	4328 (23.9)	32814			
>.2400 and ≤ .4420	28418 (25.2)	4340 (24.0)	32758			
>.4420 and ≤ .7240	27992 (24.8)	4523 (25.0)	32515			
>.7240	27759 (24.6)	4885 (27.0)	32644			
T0z_Overal Themes Summary score				100.7	.000*	0.028
≤.1909	28496 (25.3)	4195 (23.2)	32691			
>.1909 and ≤ .3929	28449 (25.3)	4322 (23.9)	32771			
>.3929 and ≤ .6590	28047 (24.9)	4551 (25.2)	32598			
> 0.6590	27663 (24.6)	5008 (27.7)	32671			

Table 38 continued				Chi-square test		
Variable SVI COMPOSITE	Not_SSI_No *N* (%)	Not_SSI_Yes *N* (%)	Total	χ^2	*p*	*Cramer's V*
Flags_T1z_Socioeconomic Status				61.69	.000*	0.022
0	99021 (87.9)	15531 (85.9)	114552			
1	6940 (6.2)	1255 (6.9)	8195			
2	3785 (3.4)	701 (3.9)	4486			
3	1465 (1.3)	307 (1.7)	1772			
4	1444 (1.3)	282 (1.6)	1726			
Flags_T2z_Household Composition & Disability				32.33	.000*	0.016
0	84876 (75.3)	13290 (73.5)	98166			
1	21220 (18.8)	3595 (19.9)	24815			
2	5125 (4.5)	945 (5.2)	6070			
3	1434 (1.3)	246 (1.4)	1680			
Flags_T3z_ Minority Status and Language				58.98	.000*	0.021
0	100172 (88.9)	15730 (87.0)	115902			
1	11028 (9.8)	2101 (11.6)	13129			
2	1455 (1.3)	245 (1.4)	1700			
Flags_T4z_Housing and Transportation				25.37	.000*	0.014
0	75463 (67.0)	11906 (65.9)	87369			
1	27439 (24.4)	4407 (24.4)	31846			
2	8322 (7.4)	1490 (8.2)	9812			
3	1306 (1.2)	252 (1.4)	1558			
4	125 (0.1)	21 (0.1)	146			
Flags_TOTALz_Themes Sum Flags3				82.97	.000*	0.025
0	55583 (49.3)	8482 (46.9)	64065			
1	30089 (26.7)	4703 (26.0)	34792			
≥ 2	26983 (24.0)	4891 (27.1)	31874			
COUNTY LEVEL T1ct Socioeconomic Status				71.64	.000*	0.023
≤ .1475	28685 (25.5)	4166 (23.0)	32851			
>.1475 and ≤ 0.3934	32469 (28.8)	5134 (28.4)	37603			
>.3934 and ≤ 0.7377	29806 (26.5)	4946 (27.4)	34752			
>.7377	21695 (19.3)	3830 (21.2)	25525			

Table 38 continued				Chi-square test		
Variable SVI COMPOSITE	Not_SSI_No *N* (%)	Not_SSI_Yes *N* (%)	Total	χ^2	*p*	*Cramer's V*
T2ct Household Composition and Disability				38.32	.000*	0.017
≤ .0984	31178 (27.7)	5135 (28.4)	36313			
>.0984 and ≤ .3115	29877 (26.5)	4429 (24.5)	34306			
>.3115 and ≤ .4754	24341 (21.6)	4131 (22.9)	28472			
>0.4754	27259 (24.2)	4381 (24.2)	31640			
T3ct Minority Status and Language				85.58	.000*	0.026
≤ .7213	37339 (33.1)	5722 (31.7)	43061			
>.7213 and ≤ .8525	22859 (20.3)	3369 (18.6)	26228			
>.8525 and ≤ .9508	26584 (23.6)	4323 (23.9)	30907			
>.9508	25873 (23.0)	4662 (25.8)	30535			
T4ct Housing and Transportation				84.34	.000*	0.025
≤ .2787	29651 (26.3)	4389 (24.3)	34040			
>.2787 and ≤ .6230	28322 (25.1)	4296 (23.8)	32618			
>.6230 and ≤ .7869	32920 (29.2)	5490 (30.4)	38410			
>.7869	21762 (19.3)	3901 (21.6)	25663			
T0ct Overall Themes Summary score				61.16	.000*	0.022
≤ .1639	28685 (25.5)	4166 (23.0)	32851			
>.1639 and ≤ 5410	28495 (25.3)	4613 (25.5)	33108			
>.5410 and ≤ .7213	30201 (26.8)	4903 (27.1)	35104			
>0.7213	25274 (22.4)	4394 (24.3)	29668			
Flags_T1ct Socioeconomic Status				84.05	.000*	0.025
0	80112 (71.1)	12448 (68.9)	92560			
1	14686 (13.0)	2428 (13.4)	17114			
2	11527 (10.2)	1959 (10.8)	13486			
3	1235 (1.1)	174 (1.0)	1409			
4	5095 (4.5)	1067 (5.9)	6162			
Flags_T2ct Household Composition and Disability				68.62	.000*	0.023
0	85993 (76.3)	13491 (74.6)	99484			
1	10596 (9.4)	1591 (8.8)	12187			
2	16066 (14.3)	2994 (16.6)	19060			

Table 38 continued				Chi-square test		
Variable SVI COMPOSITE	Not_SSI_No *N* (%)	Not_SSI_Yes *N* (%)	Total	χ^2	*p*	*Cramer's V*
Flags_T3ct Minority Status and Language				63.48	.000*	0.022
0	60198 (53.4)	9091 (50.3)	69289			
1	4506 (4.0)	735 (4.1)	5241			
2	47951 (42.6)	8250 (45.6)	56201			
Flags_T4ct Housing and Transportation				114.5	.000*	0.03
0	61588 (54.7)	9173 (50.7)	70761			
1	9216 (8.2)	1473 (8.1)	10689			
2	3632 (3.2)	585 (3.2)	4217			
3	38219 (33.9)	6845 (37.9)	45064			
Flags_TOTALct_Themes Sum Flags3				42.48	.000*	0.018
0	42058 (37.3)	6350 (35.1)	48408			
1	11298 (10.0)	1743 (9.6)	13041			
≥ 2	59299 (52.6)	9983 (55.2)	69282			

Note. * The Chi-square statistic is significant at the .05 level, Cramer's *V* – values are presented

Table 39

Descriptive and Bivariate Statistics RQ4 Not_SSI and U.S. Census ACS (American Community Survey) single measurements on Zip code level (N=130 731)

				Chi-square test		
Variables ACS	Not_SSI_No *N* (%)	Not_SSI_Yes *N* (%)	Total	χ^2	*p*	*Cramer's V*
Total	112655(86.2)	18076(13.8)	130731			
Metro Nonmetro area				1.233	0.267	
metro area	102345 (90.8)	16468 (91.1)	118813			
non metro area	10310 (9.2)	1608 (8.9)	11918			
ACS zip code level						
US Native%				103.3	.000*	0.028
≤ 69.5484	27738 (24.6)	4975 (27.5)	32713			
>69.5484 and ≤ 87.1795	28026 (24.9)	4649 (25.7)	32675			
>87.1795 and ≤ 94.8691	28563 (25.4)	4157 (23.0)	32720			
>94.8691	28328 (25.1)	4295 (23.8)	32623			
Foreign Born%				103.8	.000*	0.028
≤ 5.1308	28356 (25.2)	4304 (23.8)	32660			
>5.1308 and ≤12.8205	28551 (25.3)	4150 (23.0)	32701			
>12.8205 and ≤ 30.4515	28007 (24.9)	4646 (25.7)	32653			
>30.4515	27741 (24.6)	4976 (27.5)	32717			
Language Proficiency%						
Speak English well				110	.000*	0.029
≤ 84.5	27724 (24.6)	5061 (28.0)	32785			
>84.5 and ≤ 94.3	28858 (25.6)	4638 (25.7)	33496			
>94.3 and ≤ 97.7	27734 (24.6)	4204 (23.3)	31938			
>97.7	28339 (25.2)	4173 (23.1)	32512			
Speak English less than well				114.3	.000*	0.03
≤ 2.3	29439 (26.1)	4315 (23.9)	33754			
>2.3 and ≤ 5.7	27745 (24.6)	4226 (23.4)	31971			
>5.7 and ≤15.6	27981 (24.8)	4505 (24.9)	32486			
>15.6	27490 (24.4)	5030 (27.8)	32520			
Speak Other than English				101.6	.000*	0.028
≤ 7.6	28740 (25.5)	4306 (23.8)	33046			
>7.6 and ≤ 17.8	28256 (25.1)	4160 (23.0)	32416			
17.800001 thru 36.800000=3	27976 (24.8)	4643 (25.7)	32619			
>36.8	27683 (24.6)	4967 (27.5)	32650			

Table 39 continued				Chi-square test		
Variables ACS	Not_SSI_No *N* (%)	Not_SSI_Yes *N* (%)	Total	χ^2	*p*	*Cramer's V*
Limited English All Households				120.3	.000*	0.03
≤ .7	28683 (25.5)	4318 (23.9)	33001			
>.7and ≤ 2.8	28770 (25.5)	4324 (23.9)	33094			
>2.8 and ≤ 8.2	27996 (24.9)	4397 (24.3)	32393			
>8.2	27206 (24.1)	5037 (27.9)	32243			
Education Level%						
Less than 9th grade				140.5	.000*	0.033
≤ 2.3	30244 (26.8)	4282 (23.7)	34526			
>2.3 and ≤ 3.9	27904 (24.8)	4255 (23.5)	32159			
>3.9 and ≤ 7.7	27358 (24.3)	4618 (25.5)	31976			
>7.7	27149 (24.1)	4921 (27.2)	32070			
Has 9th to 12th grade no Diploma				136.1	.000*	0.032
≤4.3	28658 (25.4)	4141 (22.9)	32799			
>4.3 and ≤ 6.8	29129 (25.9)	4341 (24.0)	33470			
>6.8 and ≤ 10.1	27770 (24.7)	4654 (25.7)	32424			
>10.1	27098 (24.1)	4940 (27.3)	32038			
High School GED				8.823	.032*	0.008
≤ 22.9	28367 (25.2)	4370 (24.2)	32737			
>22.9 and ≤ 29.0	29174 (25.9)	4746 (26.3)	33920			
>29.0 and ≤ 33.5	27201 (24.1)	4456 (24.7)	31657			
>33.5	27913 (24.8)	4504 (24.9)	32417			
Some College No degree				91.06	.000*	0.007
≤ 14.3	28075 (24.9)	4643 (25.7)	32718			
>14.3 and ≤ 17.1	29097 (25.8)	4656 (25.8)	33753			
>17.1 and ≤ 19.1	27866 (24.7)	4456 (24.7)	32322			
>19.1	27617 (24.5)	4321 (23.9)	31938			
Associate degree				91.06	.000*	0.026
≤ 6.6	28230 (25.1)	4906 (27.1)	33136			
>6.6 and ≤ 8.8	27889 (24.8)	4728 (26.2)	32617			
>8.8 and ≤ 11.3	28788 (25.6)	4489 (24.8)	33277			
>11.3	27748 (24.6)	3953 (21.9)	31701			
Bachelor Degree				33.97	.000*	0.016
≤13.2	28421 (25.2)	4837 (26.8)	33258			
>13.2 and ≤17.8	27827 (24.7)	4533 (25.1)	32360			
>17.8 and ≤23.1	28250 (25.1)	4498 (24.9)	32748			
>23.1	28157 (25.0)	4208 (23.3)	32365			

Table 39 continued				Chi-square test		
Variables ACS	Not_SSI_No *N* (%)	Not_SSI_Yes *N* (%)	Total	χ^2	*p*	*Cramer's V*
Graduate/Professional degree				54.72	.000*	0.02
≤ 8.0	28287 (25.1)	4889 (27.0)	33176			
>8.0 and ≤ 11.9	28211 (25.0)	4696 (26.0)	32907			
>11.9 and ≤ 18.4	27990 (24.8)	4209 (23.3)	32199			
>18.4	28167 (25.0)	4282 (23.7)	32449			
High School or Higher				163.5	.000*	0.035
≤ 82.6	27865 (24.7)	5144 (28.5)	33009			
>82.6 and ≤ 89.0	28048 (24.9)	4654 (25.7)	32702			
>89.0 and ≤ 93.1	28260 (25.1)	4266 (23.6)	32526			
>93.1	28482 (25.3)	4012 (22.2)	32494			
Bachelor or Higher degree				44.91	.000*	0.019
≤ 21.3	28081 (24.9)	4857 (26.9)	32938			
>21.3 and ≤ 29.5	28161 (25.0)	4587 (25.4)	32748			
>29.5 and ≤ 41.6	28044 (24.9)	4390 (24.3)	32434			
>41.6	28369 (25.2)	4242 (23.5)	32611			
Employment Status						
Employed Population Ratio 16 yr +				91.21	.000*	0.026
≤ 55.1	27910 (24.8)	4943 (27.3)	32853			
>55.1 and ≤ 59.4	28288 (25.1)	4740 (26.2)	33028			
>59.4 and ≤ 62.9	28600 (25.4)	4246 (23.5)	32846			
>62.9	27857 (24.7)	4147 (22.9)	32004			
Unemployment rate 16 yr +				119	.000*	0.03
≤5.5	29364 (26.1)	4231 (23.4)	33595			
>5.5 and ≤ 6.9	28616 (25.4)	4370 (24.2)	32986			
>6.9 and ≤ 8.9	27262 (24.2)	4501 (24.9)	31763			
>8.9	27413 (24.3)	4974 (27.5)	32387			
Income in the last 12 months/USD						
Median Household Income				100.6	.000*	0.028
≤ 46305	27700 (24.6)	5003 (27.7)	32703			
>46305 and ≤ 60526	28140 (25.0)	4595 (25.4)	32735			
>60526 and ≤ 82738	28349 (25.2)	4283 (23.7)	32632			
>82738	28466 (25.3)	4195 (23.2)	32661			
Median Family Income				103.3	.000*	0.028
≤ 56703	27676 (24.6)	5030 (27.8)	32706			
>56703 and ≤ 72903	28134 (25.0)	4540 (25.1)	32674			
>72903 and ≤ 98250	28417 (25.2)	4301 (23.8)	32718			
>98250	28428 (25.2)	4205 (23.3)	32633			

Table 39 continued				*Chi-square test*		
Variables ACS	Not_SSI_No *N* (%)	Not_SSI_Yes *N* (%)	Total	χ^2	*p*	*Cramer's V*
Per Capita Income				92	.000*	0.027
≤ 23536	27805 (24.7)	5001 (27.7)	32806			
>23536 and ≤ 29398	28029 (24.9)	4566 (25.3)	32595			
>29398 and ≤37944	28434 (25.2)	4294 (23.8)	32728			
>37944	28387 (25.2)	4215 (23.3)	32602			
Poverty Status in the last 12 months %						
All Families below poverty level				94.21	.000*	0.027
≤ 3.7	29242 (26.0)	4242 (23.5)	33484			
>3.7 and ≤7.1	27724 (24.6)	4221 (23.4)	31945			
>7.1 and ≤ 13.5	28084 (24.9)	4764 (26.4)	32848			
>13.5	27605 (24.5)	4849 (26.8)	32454			
People below poverty level				114.5	.000*	0.03
≤ 5.9	28642 (25.4)	4103 (22.7)	32745			
>5.9 and ≤ 10.4	28629 (25.4)	4367 (24.2)	32996			
>10.4 and ≤ 18.2	27782 (24.7)	4664 (25.8)	32446			
>18.2	27602 (24.5)	4942 (27.3)	32544			
Below Poverty age 18 to 64				116.1	.000*	0.03
≤ 5.8	29670 (26.3)	4236 (23.4)	33906			
>5.8 and ≤9.8	27425 (24.3)	4201 (23.2)	31626			
>9.8 and ≤ 16.7	27970 (24.8)	4711 (26.1)	32681			
>16.7	27590 (24.5)	4928 (27.3)	32518			
Below Poverty age 65 and above				135.3	.000*	0.032
≤ 5.1	29061 (25.8)	4217 (23.3)	33278			
>5.1 and ≤ 8.1	28537 (25.3)	4345 (24.0)	32882			
>8.1 and ≤ 13.2	27498 (24.4)	4414 (24.4)	31912			
>13.2	27559 (24.5)	5100 (28.2)	32659			
GINI index of inequality				46.7	.000*	0.019
≤.3945	28442 (25.2)	4242 (23.5)	32684			
>.3945 and ≤ .4318	28273 (25.1)	4436 (24.5)	32709			
>.4318 and ≤ .4706	28084 (24.9)	4572 (25.3)	32656			
>.4706	27856 (24.7)	4826 (26.7)	32682			
Health Insurance %						
Public Health Insurance alone				113.8	.000*	0.029
≤ 11.50	28732 (25.5)	4133 (22.9)	32865			
>11.50 and ≤ 17.20	28571 (25.4)	4419 (24.4)	32990			
>17.20 and ≤ 26.40	27853 (24.7)	4531 (25.1)	32384			
>26.40	27499 (24.4)	4993 (27.6)	32492			

Table 39 continued				Chi-square test		
Variables ACS	Not_SSI_No *N* (%)	Not_SSI_Yes *N* (%)	Total	χ^2	*p*	*Cramer's V*
Medicare only				4.627	0.201	0.006
≤ 3.4	28311 (25.1)	4486 (24.8)	32797			
>3.4 and ≤ 4.2	29278 (26.0)	4637 (25.7)	33915			
>4.2 and ≤ 5.1	29993 (26.6)	4805 (26.6)	34798			
>5.1	25073 (22.3)	4148 (22.9)	29221			
Medicaid only				113.4	.000*	0.029
≤ 7.0	29094 (25.8)	4280 (23.7)	33374			
>7.0 and ≤ 12.2	27810 (24.7)	4191 (23.2)	32001			
>12.2 and ≤ 21.6	28283 (25.1)	4592 (25.4)	32875			
>21.6	27468 (24.4)	5013 (27.7)	32481			
Private insurance alone				121.1	.000*	0.03
≤ 46.3	27958 (24.8)	5135 (28.4)	33093			
>46.3 and ≤ 56.7	28526 (25.3)	4547 (25.2)	33073			
>56.7 and ≤ 65.6	27878 (24.7)	4274 (23.6)	32152			
>65.6	28293 (25.1)	4120 (22.8)	32413			
No Vehicle OHU%				168.8	.000*	0.036
≤ 5.1	28751 (25.5)	4161 (23.0)	32912			
>5.1 and ≤ 9.9	28675 (25.5)	4158 (23.0)	32833			
>9.9 and ≤ 33.9	27689 (24.6)	4685 (25.9)	32374			
>33.9	27540 (24.4)	5072 (28.1)	32612			
GINI 2 categories				2.965	0.085	0.005
≤0.3	417 (0.4)	52 (0.3)	469			
>0.3	112238 (99.6)	18024 (99.7)	130262			
GINI 4 categories				30.07	.000*	0.015
≤0.3	417 (0.4)	52 (0.3)	469			
> 0.3 and ≤ 0.415	43430 (38.6)	6622 (36.6)	50052			
> 0.415 and ≤ 0.515	58630 (52.0)	9658 (53.4)	68288			
> 0.515	10178 (9.0)	1744 (9.6)	11922			
All Families below poverty >20%				73.77	.000*	0.024
≤ 20% of all families below poverty	98997 (87.9)	15474 (85.6)	114471			
> 20% of all families below poverty	13658 (12.1)	2602 (14.4)	16260			
People below poverty level >20%				56.52	.000*	0.021
≤ 20% of all people	89888 (79.8)	13983 (77.4)	103871			
> 20% of all people	22767 (20.2)	4093 (22.6)	26860			

*N*ote: * The Chi-square statistic is significant at the .05 level, Cramer's *V* – values are presented

Interpretation of Descriptive Analyses and χ2 Test RQ4est

The results from the descriptive and bivariate statistics of the Research Question 4 related to Not_SSI evaluated as a dichotomous outcome- Not_SSI_No and Not_SSI_Yes were presented on Tables 37, 38, and 3. The total sample size was *N*=130731. The descriptive statistics are presented as numbers and percentages. The Chi-square test was performed between Not_SSI and the independent variables listed on each table and the χ2 and p values listed. The expected frequency of the cells was greater than 10 for all cells. *P* values were considered significant if less than 0.05. Statistically, a significant association was observed between Not_SSI and multiple independent variables (Tables 37, 38, and 39). Considering these results, the null hypothesis was rejected, and the alternative hypothesis accept. The effect size for χ2, Cramer's V was performed, and considering the degree of freedom, small, medium, and large association is observed (Kim HY, 2017). Cramer's V value is listed in Tables 37, 38 and 39 only for the significant Chi-square statistics. Based on the univariate analyses, variables with a significance of 0.05 and less will be included in the multivariable analysis.

Testing the Assumptions for Binomial Logistic Regression RQ4

Assumption #1: The dependent variable should be measured on a dichotomous scale. The dependent variable for RQ4 is Not_SSI is measured as dichotomous variables: Not_SSI_No and Not_SSI_Yes, which meet assumption 1. The independent variables are continuous (interval or ratio) and categorical (nominal) with two to five categories, which meet Assumption#2. The dependent variable is dichotomous and has two mutually exclusive and exhaustive categories which meet Assumption #3. Assumption #4 is related to the sample size, and it recommends a minimum of 15 and up to 50 cases per independent variable. With conservative choice of 50 cases per variable *N*= 50x44=2200 patients (Laerd Statistics, 2018). As per Peduzzi recommendation (1996), the sample size is *N*=10x44/0.138=440/0.138=3188. Also, if we follow the 10 events per variable, then Not_SSI 18076/44=410 EPV which is more than 10 (Peduzzi et al.,1996). The sample size in this study is *N*=130731which provides a sufficient number of cases per each independent variable, thus meet Assumption #4. Since these four assumptions are met, a binomial logistic regression would be an appropriate statistical test to analyze the research question. Assumption 5*:* Assumption 5 requires a linear relationship between the continuous independent variables in the model and the logit transformation of the outcome dependent variable. To test linearity, for all continuous independent variables that may be used in the logistic regression model, a natural log transformation has to be created using SPSS. The created Ln (natural log transformation) variable is a continuous variable. Subsequently, the Box-Tidwell test will be performed to test for linearity. This assumption does not need to test linearity for the categorical variables. Since this analysis included only categorical variables, this assumption is met. Assumption 6 is related to multicollinearity, which occurs when there is a correlation between the predictor or the independent variables. To examine for multicollinearity, the Tolerance and the VIF (Variance Inflation Factor) values were evaluated for the independent variables. The cut-off point for tolerance was set for less than 0.2 and VIF above 5, at which point multicollinearity was accepted as problematic.

The evaluation of multicollinearity for RQ4-Model-1 and the subsequent evaluation after correction showing collinearity below the cut-off point for VIF 5, and there are no predictors with VIF above 5, were shown in Appendix F (see Appendix F, Tables F1 and F2). Multicollinearity will be evaluated for each model and presented with the results for each model. As this evaluation used categorical variables, Assumption 7 about outliers is met.

Binomial Logistic Regression RQ4, Dependent variable: Not_SSI

RQ4-Model-1.

In this model were evaluated single measurement patient and ACS independent variables at zip code level with Dependent Variable: Not_SSI. The independent SDOH variables initially included in RQ4-Model-1 based on the bivariate analysis were evaluated for multicollinearity, and adjustments were made to meet the cut-off marks for the Tolerance factor less than 0.2 and VIF 5 (Appendix F). The independent variables included in the final RQ4-Model-1 after the multicollinearity evaluation are shown in Appendix F, Figure F1.

Results from SPSS Analysis of RQ4-Model-1

Table 40

Binomial logistic regression results RQ4-Model-1, Dependent variable Not_SSI

Variables in the Equation RQ4-Model-1	*B*	*S.E.*	*Wald*	*df*	*p*	*OR*	95% C.I. Lower	Upper
Age in years (ref: ≥77			17.010	3	0.001			
up to 53	-0.028	0.032	0.771	1	0.380	0.972	0.912	1.036
54 to 65	-0.095	0.029	10.497	1	0.001	0.909	0.859	0.963
66 to 76	-0.072	0.024	9.238	1	0.002	0.931	0.888	0.975
Sex Male	-0.086	0.018	23.108	1	0.000	0.918	0.886	0.951
Principal Diagnosis (ref: Diverticulitis)			3.489	3	0.322			
IBD	-0.070	0.049	2.033	1	0.154	0.932	0.846	1.027
Neoplasms	-0.033	0.027	1.504	1	0.220	0.967	0.917	1.020
Other	-0.007	0.028	0.058	1	0.809	0.993	0.941	1.049
Surgical Procedure Site (ref: Colon resection)			15.097	3	0.002			
Other	0.050	0.051	0.954	1	0.329	1.051	0.951	1.162
Rectal resection	0.018	0.048	0.135	1	0.713	1.018	0.927	1.117
Total colectomy	0.189	0.050	14.343	1	0.000	1.209	1.096	1.333
Surgical Approach (ref: Laparoscopic)			22.180	2	0.000			
Open	0.114	0.025	20.765	1	0.000	1.121	1.067	1.177
Other	0.142	0.048	8.629	1	0.003	1.152	1.048	1.267
Anastomosis Distal End (ref: Anal)			20.066	2	0.000			
Colon	0.218	0.093	5.513	1	0.019	1.243	1.037	1.491
Rectal	0.124	0.091	1.843	1	0.175	1.132	0.946	1.355
Diverting Stoma - Yes	-0.087	0.024	12.772	1	0.000	0.916	0.874	0.961
APRSOI risk (ref: Minor)			3027.576	3	0.000			
Moderate	0.422	0.031	179.889	1	0.000	1.525	1.434	1.622
Major	1.045	0.034	938.497	1	0.000	2.844	2.660	3.040
Extreme	1.856	0.038	2368.137	1	0.000	6.400	5.939	6.897
Admission Type-Elective	0.527	0.023	526.409	1	0.000	1.694	1.619	1.772
Length of Hospital Stay /days (ref: ≤ 4)			3512.543	3	0.000			
≥ 5 and ≤ 6	0.642	0.040	259.435	1	0.000	1.900	1.758	2.055
≥ 7 and ≤ 9	1.351	0.038	1295.229	1	0.000	3.862	3.588	4.157
≥10	2.117	0.040	2822.737	1	0.000	8.307	7.683	8.982
Race (ref: White)			4.832	3	0.185			
Asian	-0.084	0.063	1.793	1	0.181	0.919	0.813	1.040
Black or African American	-0.038	0.031	1.591	1	0.207	0.962	0.906	1.022
Other	0.026	0.032	0.672	1	0.412	1.026	0.965	1.092

Variables in the Equation RQ4-Model-1	*B*	*S.E.*	*Wald*	*df*	*p*	*OR*	95% C.I. Lower	Upper
Health Insurance (ref: Medicaid)			4.965	4	0.291			
Medicare	0.018	0.044	0.177	1	0.674	1.019	0.935	1.110
Other	-0.017	0.166	0.010	1	0.920	0.983	0.710	1.361
Private/Commercial	0.005	0.041	0.015	1	0.901	1.005	0.928	1.089
Self-Pay	0.127	0.066	3.713	1	0.054	1.135	0.998	1.292
Annual Hospital Volume, cases (ref: ≤ 52)			15.908	3	0.001			
≥53 and ≤ 122.7	0.085	0.025	11.732	1	0.001	1.089	1.037	1.144
≥123 and ≤ 200.34	0.088	0.025	11.920	1	0.001	1.091	1.039	1.147
≥201	0.055	0.027	4.041	1	0.044	1.057	1.001	1.115
Limited English All Households% (ref: >8.2)			15.664	3	0.001			
≤ .7	-0.077	0.041	3.505	1	0.061	0.925	0.853	1.004
>.7and ≤ 2.8	-0.118	0.041	8.208	1	0.004	0.889	0.820	0.963
>2.8 and ≤ 8.2	-0.127	0.034	13.953	1	0.000	0.881	0.824	0.942
Less than 9th grade% (ref: ≤ 2.3)			10.090	3	0.018			
>2.3 and ≤ 3.9	0.000	0.029	0.000	1	0.992	1.000	0.945	1.057
>3.9 and ≤ 7.7	0.023	0.035	0.432	1	0.511	1.024	0.955	1.097
>7.7	-0.090	0.050	3.275	1	0.070	0.914	0.828	1.008
Has 9th to 12th grade no Diploma % (ref:>10.1)			1.462	3	0.691			
≤4.3	-0.005	0.051	0.008	1	0.928	0.995	0.900	1.101
>4.3 and ≤ 6.8	-0.021	0.041	0.258	1	0.611	0.980	0.905	1.061
>6.8 and ≤ 10.1	0.014	0.031	0.188	1	0.665	1.014	0.953	1.078
High School GED% (ref: ≤ 22.9)			1.750	3	0.626			
>22.9 and ≤ 29.0	-0.006	0.033	0.036	1	0.849	0.994	0.931	1.061
>29.0 and ≤ 33.5	-0.029	0.039	0.546	1	0.460	0.972	0.901	1.048
>33.5	-0.051	0.045	1.278	1	0.258	0.950	0.870	1.038
Some College No degree% (ref:>19.1)			2.019	3	0.568			
≤ 14.3	0.039	0.037	1.104	1	0.293	1.040	0.967	1.119
>14.3 and ≤ 17.1	0.000	0.030	0.000	1	0.987	1.000	0.944	1.060
>17.1 and ≤ 19.1	0.016	0.027	0.371	1	0.543	1.016	0.965	1.070
Associate degree% (ref: ≤ 6.6)			11.701	3	0.008			
>6.6 and ≤ 8.8	0.004	0.028	0.022	1	0.883	1.004	0.951	1.060
>8.8 and ≤ 11.3	-0.051	0.032	2.484	1	0.115	0.950	0.892	1.013
>11.3	-0.112	0.040	8.033	1	0.005	0.894	0.827	0.966

Table 40 continued

Variables in the Equation RQ4-Model-1	*B*	*S.E.*	*Wald*	*df*	*p*	*OR*	95% C.I. Lower	Upper
Bachelor Degree % (ref: ≤13.2)			6.949	3	0.074			
>13.2 and ≤17.8	0.013	0.030	0.176	1	0.675	1.013	0.955	1.074
>17.8 and ≤23.1	-0.004	0.039	0.009	1	0.924	0.996	0.922	1.076
>23.1	-0.095	0.055	2.944	1	0.086	0.909	0.816	1.014
Employed Population Ratio 16 yr + (ref:≤ 55.1)			11.649	3	0.009			
>55.1 and ≤ 59.4	0.029	0.027	1.141	1	0.285	1.029	0.976	1.085
>59.4 and ≤ 62.9	-0.062	0.031	3.854	1	0.050	0.940	0.884	1.000
>62.9	-0.009	0.034	0.073	1	0.787	0.991	0.927	1.059
Unemployment rate 16 yr + (ref:>8.9)			1.720	3	0.632			
≤5.5	-0.028	0.035	0.623	1	0.430	0.973	0.908	1.042
>5.5 and ≤ 6.9	-0.041	0.031	1.702	1	0.192	0.960	0.903	1.021
>6.9 and ≤ 8.9	-0.019	0.028	0.471	1	0.493	0.981	0.930	1.036
Median Household Income (ref:≤ 46305)			10.578	3	0.014			
>46305 and ≤ 60526	-0.045	0.033	1.848	1	0.174	0.956	0.895	1.020
>60526 and ≤ 82738	-0.126	0.043	8.726	1	0.003	0.881	0.811	0.958
>82738	-0.154	0.055	7.835	1	0.005	0.857	0.770	0.955
All Families below poverty level % (ref:>13.5)			35.207	3	0.000			
≤ 3.7	0.217	0.053	16.771	1	0.000	1.243	1.120	1.379
>3.7 and ≤7.1	0.236	0.047	25.482	1	0.000	1.266	1.155	1.387
>7.1 and ≤ 13.5	0.203	0.035	33.287	1	0.000	1.226	1.144	1.313
Below Poverty age 65 and above % (ref:>13.2)			1.227	3	0.746			
≤ 5.1	0.011	0.044	0.064	1	0.800	1.011	0.927	1.103
>5.1 and ≤ 8.1	0.015	0.041	0.131	1	0.717	1.015	0.937	1.099
>8.1 and ≤ 13.2	-0.015	0.035	0.194	1	0.660	0.985	0.920	1.054
No Vehicle OHU% (ref:>33.9)			8.347	3	0.039			
≤ 5.1	-0.092	0.048	3.702	1	0.054	0.912	0.831	1.002
>5.1 and ≤ 9.9	-0.126	0.045	7.969	1	0.005	0.882	0.808	0.962
>9.9 and ≤ 33.9	-0.073	0.037	3.944	1	0.047	0.930	0.866	0.999
Private insurance alone% (ref: ≤ 46.3)			7.576	3	0.056			
>46.3 and ≤ 56.7	-0.078	0.034	5.107	1	0.024	0.925	0.865	0.990
>56.7 and ≤ 65.6	-0.042	0.044	0.922	1	0.337	0.959	0.880	1.045
>65.6	0.000	0.053	0.000	1	0.997	1.000	0.902	1.109

Table 40 continued

Variables in the Equation RQ4-Model-1	*B*	*S.E.*	*Wald*	*df*	*p*	*OR*	95% C.I. Lower	Upper
GINI index of inequality (ref: ≤.3945)			2.154	3	0.541			
>.3945 and ≤ .4318	0.000	0.028	0.000	1	1.000	1.000	0.947	1.056
>.4318 and ≤ .4706	-0.034	0.033	1.079	1	0.299	0.966	0.906	1.031
>.4706	-0.006	0.039	0.025	1	0.875	0.994	0.921	1.073
Constant	-4.060	0.106	1471.240	1	0.000	0.017		

*N*ote. Dependent Variable: Not_SSI=Not Surgical Site Infectious Complications, *OR*=Odds Ratio, CI=confidence interval, *p<0.05

Reporting results from the binomial logistic regression RQ4-Model 1 Dependent Variable: Not_SSI

Binomial logistic regression was performed to evaluate the effects of predictor variables entered in the RQ4-Model 1 shown in Table 40: age in years, sex, principal diagnosis, surgical procedure site, surgical approach, anastomosis distal end, diverting stoma, APRSOI-the severity of Illness risk, admission type, LOSS_4gr (length of hospital stay in days), race, health insurance, annual hospital volume, limited English all households, less than 9th grade, high school GED, some college no degree, associate degree, bachelor degree, employed population ratio 16 yr +, unemployment rate 16 yr +, median household income, all families below poverty level, below poverty age 65 and above, GINI index of inequality, private insurance alone and no vehicle OHU% on the likelihood of the postsurgical outcome Not_SSI. The logistic regression model was statistically significant, $\chi 2$ =18256.819, p = 0.000, as shown in Appendix F, Table F3. The model explained 23.6% (Nagelkerke) of the variance in the analyses, and Hosmer and Lemeshow Test was not significant p=0.616 indicating that the model was well fit, see Appendix F, Tables F4 and F5). The null hypothesis was rejected. Overall, the model accurately classified 86.4% of 130 731cases included. The sensitivity is low, 8.2% and specificity is high, 99 %, listed in Table F6 (see Appendix F, Table F6). The significant SDOH variables *p*-value, odds ratio, and the 95% Confidence Interval for the odds, are displayed in Table 40. Significant covariates and SDOH in RQ4-Model-1 associated with an increase or decrease of Not_SSI occurrence after large intestinal surgery is listed in Table 41 and Table 42.

Table 41

Covariates in RQ4-Model-1 associated with increase or decrease of Not_SSI occurrence after large intestinal surgery

Variable type/Level	RQ4-Model-1	*p*	*OR*	95% C.I.	
	Covariates associated with Not_SSI increase			Lower	Upper
Clinical Patient level	Surgical Procedure Site (ref: Colon resection)	0.002			
Covariates	Total colectomy	0.000	1.209	1.096	1.333
	Surgical Approach (ref: Laparoscopic)	0.000			
	Open	0.000	1.121	1.067	1.177
	Other	0.003	1.152	1.048	1.267
	Anastomosis Distal End (ref: Anal)	0.000			
	Colon	0.019	1.243	1.037	1.491
	APRSOI risk (ref: Minor)	0.000			
	Moderate	0.000	1.525	1.434	1.622
	Major	0.000	2.844	2.660	3.040
	Extreme	0.000	6.400	5.939	6.897
	Admission Type-Elective	0.000	1.694	1.619	1.772
	Length of Hospital Stay /days (ref:≤ 4)	0.000			
	≥ 5 and ≤ 6	0.000	1.900	1.758	2.055
	≥ 7 and ≤ 9	0.000	3.862	3.588	4.157
	≥10	0.000	8.307	7.683	8.982
	Covariates associated with Not_SSI decrease				
Biological Patient level	Age in years (ref: 77 and above)	0.001			
	54 to 65	0.001	0.909	0.859	0.963
	66 to 76	0.002	0.931	0.888	0.975
	Sex Male	0.000	0.918	0.886	0.951
Clinical Patient level	Diverting Stoma - Yes	0.000	0.916	0.874	0.961

*N*ote. Dependent Variable: Not_SSI=Not Surgical Site Infectious Complications, *OR*=Odds Ratio, CI=confidence interval, *p<0.05

Table 42

SDOH in RQ4-Model-1 associated with increase or decrease of Not_SSI occurrence after large intestinal surgery

Variable type/Level	RQ4-Model-1	*p*	*OR*	95% C.I.	
				Lower	Upper
SDOH Zip code	SDOH associated with Not_SSI increase				
Hospital Facility	Annual Hospital Volume, cases (ref: ≤ 52)	0.001			
	≥53 and ≤ 122.7	0.001	1.089	1.037	1.144
	≥123 and ≤ 200.34	0.001	1.091	1.039	1.147
	≥201	0.044	1.057	1.001	1.115
Poverty	All Families below poverty level (ref:>13.5)	0.000			
	≤ 3.7	0.000	1.243	1.120	1.379
	>3.7 and ≤7.1	0.000	1.266	1.155	1.387
	>7.1 and ≤ 13.5	0.000	1.226	1.144	1.313
SDOH Zip code	SDOH associated with Not_SSI decrease				
Education	Limited English All Households (ref: >8.2)	0.001			
	>.7and ≤ 2.8	0.004	0.889	0.820	0.963
	>2.8 and ≤ 8.2	0.000	0.881	0.824	0.942
	Associate degree (ref: ≤ 6.6)	0.008			
	>11.3	0.005	0.894	0.827	0.966
Income	Median Household Income (ref: ≤ 46305)	0.014			
	>60526 and ≤ 82738	0.003	0.881	0.811	0.958
	>82738	0.005	0.857	0.770	0.955
Economic stability	No Vehicle OHU% (ref:>33.9)	0.039			
	>5.1 and ≤ 9.9	0.005	0.882	0.808	0.962
	>9.9 and ≤ 33.9	0.047	0.930	0.866	0.999
Health Care Access	Private insurance alone (ref: ≤ 46.3)	0.056			
	>46.3 and ≤ 56.7	0.024	0.925	0.865	0.990

Note. Dependent Variable: Not_SSI=Not Surgical Site Infectious Complications, *OR*=Odds Ratio, CI=confidence interval, **p*<0.05

The null hypothesis for Research Question 4 (RQ4) was rejected as RQ4-Model-1 (including single measure SDOH on individual and contextual levels) demonstrated a significant association of the SDOH in Table 42 with the increase or decrease of Not_SSI occurrence.

RQ4-Model-2a

RQ4-Model-2a evaluated the association of patient level SDOH, and the composite SDOH SVI Overall Themes on contextual level (ZIP code and County code areas) with Not_SSI occurrence after large intestinal surgery. Dependent Variable is Not_SSI. The independent SDOH variables initially included in RQ4-Model-2a based on the bivariate analyses were tested for multicollinearity, and no adjustments were needed to meet the cut-off marks for the Tolerance factor less than 0.2 and VIF 5 (Table F7). The final variables included in RQ4-Model-2a after multicollinearity test are listed in Figure F2(see Figure F2)

Results from SPSS analysis of RQ4-Model-2a

Table 43 *Binomial logistic regression results RQ4-Model-2a. Dependent variable Not_SSI*

Variables in the Equation *RQ4-Model-2a*	*B*	*S.E.*	*Wald*	df	*p*	*OR*	95% C.I.	
							Lower	Upper
Age in years (ref: 77 and above)			17.182	3	0.001			
up to 53	-0.032	0.032	0.973	1	0.324	0.969	0.909	1.032
54 to 65	-0.097	0.029	10.975	1	0.001	0.908	0.857	0.961
66 to 76	-0.073	0.024	9.424	1	0.002	0.930	0.888	0.974
Sex Male	-0.086	0.018	23.283	1	0.000	0.918	0.886	0.950
Principal Diagnosis (ref: Diverticulitis)			2.802	3	0.423			
IBD	-0.071	0.049	2.051	1	0.152	0.932	0.846	1.026
Neoplasms	-0.029	0.027	1.169	1	0.280	0.971	0.920	1.024
Other	-0.011	0.028	0.153	1	0.696	0.989	0.937	1.044
Surgical Procedure Site (ref: Colon resection)			14.912	3	0.002			
Other	0.050	0.051	0.960	1	0.327	1.051	0.951	1.162
Rectal resection	0.008	0.048	0.029	1	0.866	1.008	0.918	1.107
Total colectomy	0.185	0.050	13.755	1	0.000	1.204	1.091	1.327
Surgical Approach (ref: Laparoscopic)			24.536	2	0.000			
Open	0.118	0.025	22.520	1	0.000	1.125	1.072	1.182
Other	0.155	0.048	10.339	1	0.001	1.168	1.062	1.283
Anastomosis Distal End (ref: Anal)			19.654	2	0.000			
Colon	0.219	0.093	5.59	1	0.018	1.245	1.038	1.493
Rectal	0.127	0.091	1.933	1	0.164	1.136	0.949	1.359
Diverting Stoma - Yes	-0.089	0.024	13.289	1	0.000	0.915	0.872	0.960
APRSOI risk (ref: Minor)			3018.703	3	0.000			
Moderate	0.419	0.031	177.490	1	0.000	1.521	1.430	1.617
Major	1.039	0.034	929.319	1	0.000	2.826	2.644	3.021
Extreme	1.850	0.038	2357.495	1	0.000	6.362	5.904	6.855
Admission Type-Elective	0.524	0.023	521.748	1	0.000	1.688	1.614	1.766
Length of Hospital Stay /days (ref: ≤ 4)			3535.388	3	0.000			
≥ 5 and ≤ 6	0.646	0.040	262.945	1	0.000	1.908	1.765	2.063
≥ 7 and ≤ 9	1.355	0.038	1305.165	1	0.000	3.879	3.604	4.175
≥10	2.123	0.040	2843.782	1	0.000	8.355	7.728	9.033
Race (ref: White)			5.914	3	0.116			
Asian	-0.061	0.062	0.955	1	0.328	0.941	0.833	1.063
Black or African American	-0.047	0.029	2.537	1	0.111	0.955	0.901	1.011
Other	0.035	0.031	1.277	1	0.259	1.035	0.975	1.099

Table 42 continued

Variables in the Equation *RQ4-Model-2a*	*B*	*S.E.*	*Wald*	df	*p*	*OR*	95% C.I.	
							Lower	Upper
Health Insurance (ref: Medicaid)			5.933	4	0.204			
Medicare	0.013	0.044	0.082	1	0.774	1.013	0.929	1.104
Other	-0.040	0.166	0.057	1	0.811	0.961	0.694	1.330
Private/Commercial	0.002	0.041	0.004	1	0.952	1.002	0.925	1.086
Self-Pay	0.136	0.066	4.289	1	0.038	1.146	1.007	1.304
Annual Hospital Volume, cases (ref: ≤ 52)			14.993	3	0.002			
≥53 and ≤ 122.7	0.082	0.025	10.845	1	0.001	1.086	1.034	1.140
≥123 and ≤ 200.34	0.085	0.025	11.428	1	0.001	1.089	1.036	1.144
≥201	0.054	0.027	3.954	1	0.047	1.055	1.001	1.113
T0z_Overal SVI Themes Summary score (ref: ≤.1909)			0.767	3	0.857			
>.1909 and ≤ .3929	-0.003	0.026	0.010	1	0.919	0.997	0.948	1.049
>.3929 and ≤ .6590	0.018	0.027	0.437	1	0.509	1.018	0.966	1.073
> 0.6590	0.013	0.031	0.182	1	0.670	1.013	0.953	1.078
T0ct Overall SVI Themes Summary score (ref: ≤ .1639)			10.210	3	0.017			
>.1639 and ≤ 5410	0.073	0.026	7.584	1	0.006	1.076	1.021	1.133
>.5410 and ≤ .7213	0.074	0.027	7.494	1	0.006	1.077	1.021	1.136
>0.7213	0.046	0.030	2.398	1	0.122	1.047	0.988	1.110
Flags_TOTALz_SVI Themes Sum Flags3 (ref: =0 flags)			8.399	2	0.015			
1	0.010	0.022	0.196	1	0.658	1.010	0.967	1.055
≥ 2	0.076	0.027	7.908	1	0.005	1.079	1.023	1.137
Flags_TOTALct_SVI Themes Sum Flags3 (ref: =0 flags)			10.049	2	0.007			
1	0.000	0.034	0.000	1	0.999	1.000	0.935	1.069
≥ 2	0.065	0.022	8.428	1	0.004	1.067	1.021	1.114
Constant	-4.391	0.072	3670.987	1	0.000	0.012		

Note. Dependent Variable: Not_SSI=Not Surgical Site Infectious Complications, SVI=Social Vulnerability Index, *OR*=Odds Ratio, CI=confidence interval, **p*<0.05

Reporting results from the binomial logistic regression RQ4-Model-2a Dependent Variable: Not_SSI

Binomial logistic regression was performed to evaluate the effects of predictor variables entered in the RQ4-Model-2a in Table 43: age in years, sex, principal diagnosis, surgical approach, surgical_procedure_site, anastomosis distal end, diverting stoma, APRSOI severity of illness risk, admission type, race, health insurance, annual hospital volume, SVI Overall rank on zip code and county levels, and extreme SVI (called “flagged Overall Themes SVI on zip code and county levels on the likelihood of the postsurgical outcome Not_SSI. The logistic regression model was statistically significant, $\chi 2 = 18154.84$, $p = 0.000$, shown in Appendix F, Table F8. The model explained 23.5 % (Nagelkerke) of the variance in the analyses, and Hosmer and Lemeshow Test was not significant $p=0.644$ indicating that the model was well fit (see Appendix F, Tables F9 and F10). The null hypothesis was rejected. Overall, the model accurately classified 86.4% of 130 731cases included. The sensitivity is low at 7.1%, and specificity is very high 99.1 %, shown in Appendix F, Table F11. The significant SDOH variables *p-value*, odds ratio, and the 95% Confidence Interval for the odds, in Table 43. Significant covariates and SDOH with the likelihood of increase or decrease of Not_SSI are listed in Tables 44 and 45.

Table 44

Covariates in RQ4-Model-2a associated with increase or decrease of Not_SSI occurrence after large intestinal surgery

Variable type/Level	RQ4-Model-2a	*p*	*OR*	95% C.I.	
	Covariates associated with Not_SSI decrease			Lower	Upper
Biological Patient level	Age in years (ref: 77 and above)	0.001			
	54 to 65	0.001	0.908	0.857	0.961
	66 to 76	0.002	0.930	0.888	0.974
	Sex Male	0.000	0.918	0.886	0.950
Clinical Patient level	Diverting Stoma - Yes	0.000	0.915	0.872	0.960
	Covariates associated with Not_SSI increase				
Clinical Patient level	Surgical Procedure Site (ref: Colon resection)	0.002			
	Total colectomy	0.000	1.204	1.091	1.327
	Surgical Approach (ref: Laparoscopic)	0.000			
	Open	0.000	1.125	1.072	1.182
	Other	0.001	1.168	1.062	1.283
	Anastomosis Distal End (ref: Anal)	0.000			
	Colon	0.018	1.245	1.038	1.493
	APRSOI risk (ref: Minor)	0.000			
	Moderate	0.000	1.521	1.430	1.617
	Major	0.000	2.826	2.644	3.021
	Extreme	0.000	6.362	5.904	6.855
	Admission Type-Elective	0.000	1.688	1.614	1.766
	Length of Hospital Stay /days (ref: ≤ 4)	0.000			
	≥ 5 and ≤ 6	0.000	1.908	1.765	2.063
	≥ 7 and ≤ 9	0.000	3.879	3.604	4.175
	≥10	0.000	8.355	7.728	9.033

*N*ote. Dependent Variable: Not_SSI=Not Surgical Site Infectious Complications, *OR*=Odds Ratio, CI=confidence interval, *$p<0.05$

Table 45

SDOH RQ4-Model-2a associated with increase of Not_SSI occurrence after large intestinal surgery

Variable type/Level	RQ4-Model-2a	*p*	*OR*	95% C.I.	
				Lower	Upper
SDOH Zip code level	Single Measure SDOH associated with Not_SSI increase				
Health Care Access	Health Insurance (ref: Medicaid)	0.204			
	Self-Pay	0.038	1.146	1.007	1.304
Hospital Facility Used	Annual Hospital Volume, cases (ref: ≤ 52)	0.002			
	≥53 and ≤ 122.7	0.001	1.086	1.034	1.140
	≥123 and ≤ 200.34	0.001	1.089	1.036	1.144
	≥201	0.047	1.055	1.001	1.113
	Composite SVI SDOH associated with Not_SSI increase				
Extreme Social Vulnerability	Flags_TOTALz_SVI Themes Sum Flags3 (ref: =0 flags)	0.015			
	≥ 2	0.005	1.079	1.023	1.137
SDOH County level					
Social Vulnerability	T0ct Overall SVI Themes Summary score (ref: ≤ .1639)	0.017			
	>.1639 and ≤ 5410	0.006	1.076	1.021	1.133
	>.5410 and ≤ .7213	0.006	1.077	1.021	1.136
Extreme Social Vulnerability	Flags_TOTALct_SVI Themes Sum Flags3 (ref: 0 flags)	0.007			
	≥ 2	0.004	1.067	1.021	1.114

*N*ote. Dependent Variable: Not_SSI=Not Surgical Site Infectious Complications, *OR*=Odds Ratio, CI=confidence interval, *p<0.05

The SDOH Overall Social Vulnerability at the county level, High Social Vulnerability (flagged overall themes) at zip code and county code levels were significantly associated independent factors with the likelihood of the increase of Not_SSI occurrence after large intestinal surgery. A higher overall social vulnerability score on a county level and a higher number of extreme social vulnerability flags on the zip code and county level is associated with an increase in the likelihood of Not_SSI occurrence. Annual Hospital Volume of cases below 201 and people with Self-Pay for medical services are also related to increasing the possibility of Not_SSI occurrence. The biological and clinical covariates associated with the increase or decrease of Not_SSI occurrence are listed in Table 44. The null hypothesis for Research Question 4 (RQ4) was rejected as RQ4- Model-2a, including single and composite measure SDOH on individual and contextual levels, demonstrated a significant association of the SDOH in Table 44 and 45 with increase or decrease of Not_SSI occurrence.

RQ4-Model-2b

In RQ4-Model-2b the Social Vulnerability Themes as independent SDOH variables at the Zip code and County level were evaluated with dependent variable: Not SSI. The SVI Theme's compositions are listed in Appendix B, Table B4. The independent SDOH variables initially included in RQ4-Model-2b based on the bivariate analyses, were evaluated for multicollinearity. and adjustments were made to meet the cut-off marks for Tolerance factor less than 0.2 and VIF 5 (Appendix F). All assumptions 1-7 were met after collinearity adjustment. The final variables included in RQ4-Model-2b are listed on Figure F3, Appendix F.

Results from SPSS analysis of RQ4-Model-2b

Table 46

Binomial logistic regression results RQ4-Model-2b. Dependent variable Not_SSI

Variables in the Equation RQ4-Model-2b	*B*	*S.E.*	*Wald*	*df*	*p*	*OR*	95% C.I. Lower	Upper
Age in years (ref: 77 and above)			16.877	3	0.001			
up to 53	-0.026	0.032	0.646	1	0.422	0.974	0.915	1.038
54 to 65	-0.092	0.029	9.870	1	0.002	0.912	0.861	0.966
66 to 76	-0.073	0.024	9.490	1	0.002	0.930	0.888	0.974
Sex Male	-0.085	0.018	22.659	1	0.000	0.919	0.887	0.951
Principal Diagnosis (ref: Diverticulitis)			3.097	3	0.377			
IBD	-0.072	0.049	2.103	1	0.147	0.931	0.845	1.026
Neoplasms	-0.032	0.027	1.406	1	0.236	0.968	0.918	1.021
Other	-0.011	0.028	0.156	1	0.693	0.989	0.937	1.044
Surgical Procedure Site (ref: Colon resection)			16.331	3	0.001			
Other	0.052	0.051	1.027	1	0.311	1.053	0.953	1.164
Rectal resection	0.009	0.048	0.037	1	0.848	1.009	0.919	1.108
Total colectomy	0.194	0.050	15.113	1	0.000	1.215	1.101	1.340
Surgical Approach (ref: Laparoscopic)			25.181	2	0.000			
Open	0.120	0.025	23.300	1	0.000	1.128	1.074	1.185
Other	0.155	0.048	10.287	1	0.001	1.167	1.062	1.283
Anastomosis Distal End (ref: Anal)			19.593	2	0.000			
Colon	0.224	0.093	5.826	1	0.016	1.251	1.043	1.500
Rectal	0.132	0.092	2.094	1	0.148	1.142	0.954	1.366
Diverting Stoma - Yes	-0.091	0.024	13.873	1	0.000	0.913	0.870	0.958
APRSOI risk (ref: Minor)			3024.233	3	0.000			
Moderate	0.418	0.031	176.214	1	0.000	1.519	1.428	1.615
Major	1.040	0.034	928.593	1	0.000	2.829	2.646	3.025
Extreme	1.853	0.038	2359.804	1	0.000	6.378	5.919	6.873
Admission Type-Elective	0.527	0.023	524.996	1	0.000	1.694	1.619	1.772
Length of Hospital Stay /days (ref: ≤ 4)			3521.004	3	0.000			
≥ 5 and ≤ 6	0.643	0.040	260.454	1	0.000	1.903	1.760	2.057
≥ 7 and ≤ 9	1.352	0.038	1297.757	1	0.000	3.867	3.592	4.162
≥10	2.119	0.040	2830.449	1	0.000	8.326	7.701	9.002
Race (ref: White)			6.253	3	0.100			
Asian	-0.084	0.063	1.771	1	0.183	0.920	0.813	1.040
Black or African American	-0.067	0.030	4.919	1	0.027	0.935	0.881	0.992
Other	-0.008	0.032	0.069	1	0.793	0.992	0.932	1.056
Health Insurance (ref: Medicaid)			5.722	4	0.221			
Medicare	0.017	0.044	0.151	1	0.697	1.017	0.933	1.109
Other	-0.024	0.166	0.021	1	0.884	0.976	0.705	1.352
Private/Commercial	-0.002	0.041	0.002	1	0.966	0.998	0.921	1.082
Self-Pay	0.129	0.066	3.836	1	0.050	1.138	1.000	1.295

Variables in the Equation RQ4-Model-2b	*B*	*S.E.*	*Wald*	*df*	*p*	*OR*	95% C.I. Lower	Upper
Annual Hospital Volume, cases (ref: ≤ 52)			11.476	3	0.009			
≥53 and ≤ 122.7	0.080	0.026	9.609	1	0.002	1.084	1.030	1.140
≥123 and ≤ 200.34	0.071	0.026	7.311	1	0.007	1.074	1.020	1.130
≥201	0.051	0.028	3.309	1	0.069	1.053	0.996	1.113
T1z_Socioeconomic Status (ref: ≤ .1756)			7.255	3	0.064			
>.1756 and ≤.3799	-0.006	0.027	0.048	1	0.827	0.994	0.942	1.049
>.3799 and ≤.6453	0.063	0.032	3.882	1	0.049	1.065	1.000	1.135
>.6453	0.020	0.040	0.247	1	0.619	1.020	0.943	1.103
T2z_Houshold Composition and Disability (ref: ≤ .2863)			2.653	3	0.448			
>.2863 and ≤.5045	0.009	0.027	0.101	1	0.750	1.009	0.957	1.063
>.5045 and ≤ .7467	0.022	0.028	0.601	1	0.438	1.022	0.967	1.081
>.7467	0.049	0.032	2.369	1	0.124	1.050	0.987	1.117
T3z_Minority Status and Language (ref: >.6561)			5.472	3	0.140			
≤ .1820	0.098	0.045	4.739	1	0.029	1.103	1.010	1.206
>.1820 and ≤ .3850	0.049	0.040	1.494	1	0.222	1.050	0.971	1.136
>.3850 and ≤ .6561	0.031	0.032	0.939	1	0.333	1.032	0.969	1.099
T4z_Housing and Transportation (ref: ≤.2400)			4.546	3	0.208			
>.2400 and ≤ .4420	-0.027	0.026	1.020	1	0.312	0.974	0.925	1.025
>.4420 and ≤ .7240	0.025	0.028	0.779	1	0.378	1.025	0.970	1.084
>.7240	0.024	0.033	0.529	1	0.467	1.024	0.960	1.093
T1ct Socioeconomic Status (ref:>.7377)			5.812	3	0.121			
≤ .1475	-0.097	0.086	1.263	1	0.261	0.908	0.767	1.075
>.1475 and ≤ 0.3934	-0.005	0.070	0.006	1	0.940	0.995	0.867	1.141
>.3934 and ≤ 0.7377	-0.070	0.066	1.130	1	0.288	0.932	0.819	1.061
T2ct Household Composition and Disability (ref: >0.4754)			17.826	3	0.000			
≤ .0984	0.111	0.050	4.953	1	0.026	1.117	1.013	1.232
>.0984 and ≤ .3115	-0.037	0.047	0.617	1	0.432	0.964	0.879	1.057
>.3115 and ≤ .4754	0.080	0.041	3.891	1	0.049	1.084	1.001	1.174
T3ct Minority Status and Language (ref: ≤ .7213)			11.700	3	0.008			
>.7213 and ≤ .8525	-0.011	0.044	0.066	1	0.797	0.989	0.907	1.078
>.8525 and ≤ .9508	0.107	0.049	4.696	1	0.030	1.113	1.010	1.226
>.9508	0.169	0.082	4.191	1	0.041	1.184	1.007	1.391
T4ct Housing and Transportation (ref: ≤ .2787)			5.287	3	0.152			
>.2787 and ≤ .6230	-0.047	0.038	1.494	1	0.222	0.954	0.886	1.029
>.6230 and ≤ .7869	0.018	0.054	0.105	1	0.746	1.018	0.915	1.132
>.7869	0.054	0.056	0.935	1	0.334	1.056	0.946	1.179
Flags_T1z_Socioeconomic Status (ref:0)			2.771	4	0.597			
1	0.010	0.043	0.052	1	0.819	1.010	0.929	1.098
2	0.000	0.055	0.000	1	1.000	1.000	0.898	1.113
3	0.121	0.079	2.370	1	0.124	1.129	0.967	1.317
4	-0.017	0.090	0.036	1	0.849	0.983	0.824	1.173

Variables in the Equation RQ4-Model-2b	*B*	*S.E.*	*Wald*	*df*	*p*	*OR*	95% C.I. Lower	Upper
Flags_T2z_Household Composition & Disability(ref:0)			1.922	3	0.589			
1	0.016	0.025	0.431	1	0.512	1.016	0.968	1.067
2	-0.001	0.046	0.001	1	0.975	0.999	0.912	1.093
3	-0.098	0.090	1.183	1	0.277	0.907	0.761	1.081
Flags_T3z_ Minority Status and Language (ref:0)			4.728	2	0.094			
1	0.047	0.037	1.669	1	0.196	1.049	0.976	1.127
2	-0.119	0.089	1.794	1	0.180	0.888	0.747	1.056
Flags_T4z_Housing and Transportation (ref:0)			2.262	4	0.688			
1	-0.022	0.025	0.832	1	0.362	0.978	0.932	1.026
2	0.022	0.047	0.225	1	0.635	1.022	0.933	1.121
3	0.007	0.086	0.006	1	0.939	1.007	0.851	1.191
4	-0.247	0.274	0.813	1	0.367	0.781	0.457	1.336
Flags_T1ct Socioeconomic Status (ref:0)			18.068	4	0.001			
1	-0.077	0.063	1.504	1	0.220	0.926	0.819	1.047
2	-0.212	0.107	3.948	1	0.047	0.809	0.656	0.997
3	-0.121	0.115	1.124	1	0.289	0.886	0.708	1.109
4	0.064	0.137	0.219	1	0.640	1.066	0.816	1.394
Constant	-4.186	0.120	1216.910	1	0.000	0.015		

Note. Dependent Variable: Not_SSI=Not Surgical Site Infectious Complications, *OR*=Odds Ratio, CI=confidence interval, *$p<0.05$

Reporting results from the binomial logistic regression RQ4-Model-2b- Dependent Variable: Not_SSI

Binomial logistic regression was performed to evaluate the effects of predictor variables entered in the RQ4-Model-2b shown in Table 46: age in years, sex, principal diagnosis, surgical approach, anastomosis distal end, diverting stoma, admission type, APRSOI severity of illness risk, race, health insurance, annual hospital volume4, LOSS 4GR.(length of hospital stay in days),T1ct Socioeconomic Status, T2ct Household Composition and Disability, T3ct Minority Status and Language, T4ct Housing and Transportation, Flags_T1z_Socioeconomic Status, Flags_T2z_Household Composition & Disability, Flags_T3z_ Minority Status and Language, and Flags_T4z_Housing and Transportation, and Flags_T1ct_Socioeconomic Status on the likelihood of the postsurgical outcome Not_SSI. The logistic regression model was statistically significant, $\chi2$ =18247.115, *p* =.000, shown in Appendix F, Table F14. The model explained 23,6% (Nagelkerke) of the variance in Not_SSI, and Hosmer and Lemeshow Test was not significant *p*=0.572 indicating that the model was well fit, presented in Appendix F, Tables F15 and F16 respectively. The model accurately classified 86.4% of 130 731cases included, and the sensitivity is 8.2%, and the specificity is 90.0%, as shown in Appendix F, Table F17. The significant SDOH variables *p-value*, odds ratio, and the 95% Confidence Interval for the odds are listed in Table 46. Statistically significant covariates and SDOH with the likelihood of increasing or decreasing Not_SSI after large intestinal surgery are listed on tables 47 and 48.

Table 47

Covariates in RQ4-Model-2b associated with increase or decrease of Not_SSI occurrence after large intestinal surgery

Variable type/Level	RQ4-Model-2b	*p*	*OR*	95% C.I.	
	Covariates associated with Not_SSI decrease			Lower	Upper
Biological Patient	Age in years (ref: 77 and above)	0.001			
	54 to 65	0.002	0.912	0.861	0.966
	66 to 76	0.002	0.930	0.888	0.974
	Sex Male	0.000	0.919	0.887	0.951
Clinical Patient	Diverting Stoma - Yes	0.000	0.913	0.870	0.958
	Covariates associated with Not_SSI increase				
	Surgical Procedure Site (ref: Colon resection)	0.001			
	Total colectomy	0.000	1.215	1.101	1.340
	Surgical Approach (ref: Laparoscopic)	0.000			
	Open	0.000	1.128	1.074	1.185
	Other	0.001	1.167	1.062	1.283
	Anastomosis Distal End (ref: Anal)	0.000			
	Colon	0.016	1.251	1.043	1.500
	APRSOI risk (ref: Minor)	0.000			
	Moderate	0.000	1.519	1.428	1.615
	Major	0.000	2.829	2.646	3.025
	Extreme	0.000	6.378	5.919	6.873
	Admission Type-Elective	0.000	1.694	1.619	1.772
	Length of Hospital Stay /days (ref: ≤ 4)	0.000			
	≥ 5 and ≤ 6	0.000	1.903	1.760	2.057
	≥ 7 and ≤ 9	0.000	3.867	3.592	4.162
	≥10	0.000	8.326	7.701	9.002

*N*ote. Dependent Variable: Not_SSI=Not Surgical Site Infectious Complications, OR=Odds Ratio, CI=confidence interval, $p<0.05$

Table 48

SDOH RQ4-Model-2b associated with increase or decrease of Not_SSI occurrence after large intestinal surgery

Variable type/Level	RQ4-Model-2b	*p*	*OR*	95% C.I.	
				Lower	Upper
SDOH Zip code level	Single Measure SDOH associated with Not_SSI increase				
Hospital Facility Used	Annual Hospital Volume, cases (ref: ≤ 52)	0.009			
	≥53 and ≤ 122.7	0.002	1.084	1.030	1.140
	≥123 and ≤ 200.34	0.007	1.074	1.020	1.130
	Composite SVI SDOH associated with Not_SSI increase				
	T1z_Socioeconomic Status (ref: ≤ .1756)	0.064			
	>.3799 and ≤.6453	0.049	1.065	1.000	1.135
	T3z_Minority Status and Language (ref: >.6561)				
	≤ .1820	0.029	1.103	1.010	1.206
	T2ct Household Composition and Disability (ref:>0.4754)				
	≤ .0984	0.026	1.117	1.013	1.232
	>.3115 and ≤ .4754	0.049	1.084	1.001	1.174
SDOH County	T3ct Minority Status and Language (ref: ≤ .7213)	0.008			
	>.8525 and ≤ .9508	0.030	1.113	1.010	1.226
	>.9508	0.041	1.184	1.007	1.391
	Single Measure SDOH associated with Not_SSI decrease				
	Race (ref: White)	0.100			
	Black or African American	0.027	0.935	0.881	0.992
SDOH Zip code	Composite SVI SDOH associated with Not_SSI decrease				
	Flags_T1ct Socioeconomic Status (ref:0)	0.001			
	2	0.047	0.809	0.656	0.997

Note. Dependent Variable Not_SSI=Not Surgical Site Infectious Complications, OR=Odds Ratio, CI=confidence interval, **p*<0.05

On Zip code level, Higher Socioeconomic Status social vulnerability score, and Annual Hospital Volume, cases below 200.3 were associated with increased likelihood of Not_SSI (hospital-acquired infection) occurrence after large intestinal surgery. On Zip code level, the Minority Status and Language vulnerability rank ≤ .1820 showed higher odds for Not_SSI occurrence. Higher (90th percentile) Minority Status and Language vulnerability score is correlated with an increase of Not_SSI occurrence on a county level. On a county level, lower Household Composition and Disability vulnerability score have lower Odds for Not_SSI occurrence. In areas with Extreme (90^{th} percentile) Socioeconomic Status vulnerability, the social vulnerability showed that lower socioeconomic status social vulnerability levels (2flags level) were associated with less Not_SSI occurrence. Black or African American referenced to White people are less likely to develop Not_SSI, with Odds 0.935, presented in Table 48. The biological and clinical covariates associated with an increase or decrease of Not_SSI occurrence are listed in Table 47. The null hypothesis for Research Question 4 (RQ4) was rejected as RQ4- Model-2b, including single and composite measure SDOH on individual and contextual levels, demonstrated a significant association of the SDOH with an increase or decrease of Not_SSI occurrence shown in Tables 47 and 48.

Summary

Th primary aim in this research study was to evaluate the association of the SDOH with postsurgical complications AL, SSI, COMPL, and Not_SSI within 30 days after large intestinal surgery in an adult population. The four research questions analyses included single measure and composite measure SDOH on individual and contextual level (zip code and county code). Three regression models were created in each research question analysis to evaluate the single and composite SDOH in depth. The first regression model in each RQ included single measurement contextual SDOH from ACS and SDOH on individual patient levels. The 2nd and the 3rd regression model in each RQ evaluated on Zip code, and county code levels the composite SDOH social vulnerability index Overall Themes and the SVI Themes respectively as predictors for the RQs outcomes. Biological and clinical covariates were included in each regression model to control for confounding factors. Each model was created by including variables based on chi-square bivariate test. The three models were created to evaluate in depth the single and composite SDOH association with the four specific postoperative morbidity outcomes and to avoid multicollinearity. For each model, the final variables included the models were selected based on the multicollinearity test with Tolerance factor <0.2 and VIF 5 cut-off marks.

Summary RQ1

In summary, RQ1 analyses from all three regression models showed a significant association of the SDOH with AL increase or decrease. The race Black or African American was significantly associated with increased odds for AL in reference to White people. On Zip code area: education level (higher percentage of people with **"**Some College No degree ", and percentage of people with Bachelor degree below≤17.8%), povert*y* ("All Families below poverty" at every level above 3.7%, and areas with 5.1% of people "Below Poverty age 65 and above) were more likely to have

AL. Extreme Overall Social Vulnerability (sum of flags above 0), and the extreme vulnerability of “Minority Status and Language” on zip code level were associated with higher odds for AL. On a county level, higher Overall Social Vulnerability (Overall SVI Themes Summary score above .5410), higher Household Composition and Disability vulnerability (T2ct Household Composition and Disability more than 0.4754), Housing and Transportation social vulnerability (T4ct Housing and Transportation above 0.7869) and extreme (90^{th} percentile) social vulnerability related to Housing and Transportation on county-level were associated with an increased likelihood of AL.

Higher level of Median Household Income above $ 46 305 was associated with a reduction in the likelihood for AL. On the Zip code level, a lower percentage of households with “Limited English All Households below 8.2%,” and increase of the percentage of people with High School GED % (above 22.9%), and a percentage of people with Associate degree higher than 8.8%, were associated with a decreased likelihood of AL. Overall Social Vulnerability on county-level >.5410 was associated in an increase of AL. High level Overall SVI on zip code above “0” flags, was associated with an increased likelihood of AL, and lowering the “High Total SVI” below two flags on county level was associated with reducing AL likelihood. Also, lowering the extreme (90th percentile) Socioeconomic Status vulnerability on county-level (Flags_T1ct Socioeconomic Status) is associated with AL decrease (Tables 5, 9, and 12).

The covariates age male sex, preoperative diagnosis neoplasms, open surgical approach versus laparoscopic, surgical procedure site (total colectomy), anastomosis type colon and rectal, patients with diverted stoma, APRSOI risk, and elective admission were significantly associated with an increase of the likelihood of anastomotic leak in the three regression models of RQ1 (Tables 7, 10, and 13). The null hypothesis for Research Question 1 (RQ1) was rejected, and the alternative hypothesis was accepted as the statistical analyses, including single and composite measure SDOH on individual and contextual levels, demonstrated a significant association of the SDOH with increase or decrease of the likelihood of AL occurrence after large intestinal surgery.

Summary RQ2

In summary, RQ2 analyses from all three regression models showed a significant association of variety of SDOH with SSI increase or decrease. The following SDOH: race Black or African American, health insurance self-pay, annual hospital volume below 201 cases were associated with an SSI increase. On Zip code area level, the education level (higher percentage of people with “Some College No degree “), a lower percentage of people with “Bachelor Degree”, poverty (All Families below poverty level above 3.7%, Employed Population Ratio 16 yr between >55.1 and ≤ 59.4, higher Unemployment rate 16 yr +, and a higher percentage of No Vehicle OHU (above 33.9%) were associated with increased likelihood of SSI occurrence after large bowel surgery.

Extreme “Overall Social Vulnerability” with sum flags above 0 and the extreme vulnerability of Socioeconomic Status on Zip code level was associated with higher odds for SSI. On a county area, increasing the Overall Social Vulnerability (Overall SVI Themes Summary) score above .1639, Housing and Transportation vulnerability above 0.7869, and areas with extreme (90th percentile) Social Vulnerability were associated with an increased likelihood of SSI occurrence. All SDOH associated with SSI increase or decrease from the three regression models evaluated in RQ2 are listed in Tables 19, 22. and 25.

Increasing Median Household Income above $ 46 305 was associated with a reduction in the likelihood for SSI. On the Zip code level, a lower percentage of households with “Limited English All Households” and increasing the percentage of people with Associate degree higher than 8.8 were associated with a decreased likelihood of SSI. People with Medicare insurance had lower odds for SSI compared to those with Medicaid. Also, lowering the extreme (90th percentile) Socioeconomic Status vulnerability on the county level (Flags_T1ct Socioeconomic Status) is associated with a lower odds of SSI occurrence (see Tables 19, 22, and 25). The covariates age, male sex, open surgical approach versus laparoscopic, surgical procedure site (total colectomy), anastomosis type colon and rectal, patients with diverted stoma, APRSOI risk, and elective admission were significantly associated with an increase of the likelihood of SSI occurrence in the three regression models of RQ2 (see Tables 18, 21 and 24).

The null hypothesis for Research Question 2 (RQ2) was rejected based on this study findings, and the alternative hypothesis was accepted as the study analyses demonstrated a significant association of the SDOH on individual and contextual levels, with an increase or decrease of the likelihood of Surgical Site Infection occurrence after large intestinal surgery.

Summary RQ3

In summary, RQ3 analyses from all three regression models showed a significant association of the SDOH with the dependent variable COMPL increase or decrease. The following SDOH: race Black or African American in reference to White, and Annual Hospital Volume below 201 cases were associated with an increase of COMPL. On the Zip code area level, a higher Unemployment rate of 16 yr +, a higher percentage of No Vehicle OHU (above 33.9%), and a high percentage of All Families below the poverty level were associated with increased likelihood of COMPL occurrence after colorectal surgery. Extreme (90th percentile) Overall Social Vulnerability on Zip code level and increased Overall Social Vulnerability (Overall SVI Themes Summary) score on county-level above .1639 were associated with an increased likelihood of COMPL occurrence. On the county level, increasing Socioeconomic Status vulnerability, Household Composition and Disability, Minority Status and Language, and Housing and Transportation Social vulnerability status is associated with an increased likelihood of COMPL occurrence after colorectal surgery (see Tables 33 and 36).

Increasing Median Household Income above $ 46 305 was associated with a reduction in the likelihood for COMPL. On the Zip code level, a lower percentage of households with "Limited English All Households" and increasing the percentage of people with Associate degree higher than 8.8% were associated with a decreased likelihood of COMPL People with Private insurance alone had lower odds for COMPL. Also, a lower score of the GINI index of inequality was associated with lower odds for COMPL (see Table 31). The covariates, age in years ≥65, male sex, preoperative diagnosis neoplasms, open surgical approach versus laparoscopic, Surgical Procedure Site (total colectomy), anastomosis type colon and rectal, APRSOI risk, and elective admission were significantly associated with an increase of the likelihood of COMPL in the three regression models of RQ3 (see Tables 30, 33, 35).

The null hypothesis for Research Question 3 (RQ3) was rejected based on this study's findings. The alternative hypothesis is accepted as the analyses, including single and composite measure SDOH on individual and contextual levels, demonstrated a significant association of the SDOH with increase or decrease of the likelihood of COMPL occurrence after colorectal surgery.

Summary RQ4

In summary, RQ4 analyses from all three regression models showed a significant association of the SDOH with Not_SSI increase or decrease. The following SDOH: race Black or African American, Health Insurance, Annual Hospital Volume below 201 cases were associated with an AL increase. On Zip code area level, poverty measured as All Families below poverty level above 3.7%, and extreme Overall Social

Vulnerability with a sum of flags above 0, are associated with higher odds for Not_SSI. On a county area, increasing the Overall Social Vulnerability (Overall SVI Themes Summary) score above .1639, Socioeconomic Status vulnerability above 0.7869, regions with high Minority Status and Language Vulnerability (T3z_Minority Status and Language), and on county level Household Composition and Disability vulnerability (T2ct Household Composition and Disability) were associated with an increased likelihood of Not_SSI occurrence. All SDOH associated with Not_SSI increase or decrease in the three regression models evaluated in RQ4 are listed in Tables 42, 45 and 48.

Increasing Median Household Income above $ 46 305 was associated with a reduction in the likelihood for SSI. On the Zip code level, a lower percentage of households with "Limited English All Households" and increasing the rate of people with Associate degree higher than 8.8 were associated with a decreased likelihood of Not_SSI occurrence. People with Private insurance alone have lower odds for Not_SSI. Also, reducing the extreme Socioeconomic Status vulnerability on the county level (Flags_T1ct Socioeconomic Status) is associated with Not_SSI decrease (Table 48). The covariates, open surgical approach versus laparoscopic, Surgical Procedure Site (total colectomy), anastomosis type colon, APRSOI risk, Length of Hospital Stay /days, and elective admission were significantly associated with an increase of the likelihood of Not_SSI occurrence (see Tables 41, 44, and 47). The null hypothesis for Research Question 4 (RQ4) was rejected based on this study's findings. The alternative hypothesis was accepted as the analyses, including single and composite measure

SDOH on individual and contextual levels, demonstrated a significant association of the SDOH with an increased or decreased likelihood of Not_SSI occurrence after large intestinal surgery.

Overall, the results of this study demonstrated that there is association of multiple SDOH at a different level (individual and contextual) with the postsurgical complications AL, SSI, COMPL and Not SSI occurrence. Therefore, the null hypothesis in each research question was rejected, and the alternative one was accepted based on the study findings.

Transition to Section 4.

In the following section the interpretation of the study findings was presented and how they confirm/disconfirm or extend the current literature findings. Further, the study findings were interpreted in the context of the theoretical, conceptual framework guiding this study. The limitation of the study was also described in the next section, and recommendations were presented based on the study findings and current literature.

Section 4: Application to Professional Practice and Implications for Social Change

Introduction

The purpose of this quantitative cross-sectional study was to evaluate the association between individual and area-based levels SDOH with the AL, SSI, Not SSI, and overall surgical COMPL (infectious and non-infectious) occurrence within 30 days after surgery in and out of the hospital in adult patients after initial colorectal surgery in New York State, in the United States. The study's primary outcomes were AL, SSI, COMPL, and Not_SSI within 30 days after colorectal resection with anastomosis in and out of the hospital. The independent variables were SDOH on individual and community levels (zip code and county level) and reflected the following areas: economic stability, education access and quality, social and community context, health care access and quality, neighborhood and built environment (Healthy People 2020, 2018, Healthy People 2030, 2021). The SDOH data in this study were measures from ACS, CDC SVI, USDA 2013 Rural-Urban Continuum Code, and on an individual level from SPARCS data. The SDOH data were linked to the clinical patient ten-years' time SPARCS data on zip code and county code levels, using the closest estimates available on contextual level (Figure 7).

Summary of Key Findings

In summary, this study results showed that the SDOH on individual and contextual level (zip code and county level) were significantly associated with increase or decrease of the likelihood of postoperative occurrence of AL, SSI, Not_SSI, and overall COMPL after colorectal surgery in adult patients. Interpretation of the results related to the specific SDOH in each area will be discussed following the summary of key findings per research questions.

Overall for Research Question 1, evaluating the association between SDOH and the outcome AL, the SDOH race, annual hospital volume cases, language proficiency, education, poverty, income, SVI for both overall and high social vulnerability, high SVI Socioeconomic Status vulnerability, SVI Household Composition and Disability, high SVI Minority Status and Language vulnerability, SVI Housing and Transportation, and high Housing and Transportation vulnerability on individual and contextual levels (zip code and county code) were significantly associated with an increased or decreased odds for AL occurrence after colorectal surgery. The covariates age, male sex, preoperative diagnosis neoplasms, open(conventional) surgical approach, surgical procedure site (total colectomy), anastomosis type (colon and rectal), patients with a diverted stoma, APRSOI risk, and elective admission were associated with significantly increased likelihood of anastomotic leak occurrence.

The specific significant SDOH from each area were:

- On individual patient level: Race Black or African American and Annual Hospital Volume cases.
- On Zip code level: Language proficiency: “Limited English All Households" below 8.2%; Education: "People with High School GED" above 22.9%, percentage of people with "Some College No degree,” percentage of people with “Associate degree” higher than 8.8%, and percentage of people with “Bachelor’s degree” below ≤17.8%; Poverty ("All Families below poverty" at every level above

3.7%, and areas with 5.1% of people "Below Poverty age 65 and above"); Income level: “Median Household Income” above $ 46 305, " High Overall Social Vulnerability” (sum of flags above 0), the extreme "Minority Status and Language" vulnerability.

- On County-level: SVI Overall Social Vulnerability (Overall SVI Themes Summary score above .5410), High (90th percentile) SVI Overall Social Vulnerability (Flags_TOTALct_Themes Sum Flags3, below two flags), higher Household Composition and Disability (T2ct Household Composition and Disability more than 0.4754), Housing and Transportation (T4ct Housing and Transportation) and extreme Housing and Transportation vulnerability, and the High(90th percentile) SVI Socioeconomic Status vulnerability on county-level (Flags_T1ct Socioeconomic Status).

A summary for Research Question 2*,* evaluating the association of the SDOH with the outcome SSI, the following SDOH: race, health insurance, annual hospital volume cases, language proficiency, education, poverty, employment, unemployment, “No Vehicle OHU %”, income, “Overall Social Vulnerability”, high (90^{th} percentile)Overall Social Vulnerability, high (90th percentile) SVI Socioeconomic Status, and SVI Housing and Transportation vulnerability on individual and/or contextual levels (zip code and/or county code) were significantly associated with an increased or decreased odds for SSI occurrence after colorectal surgery. The covariates age, male sex, open surgical approach versus laparoscopic, surgical procedure site (total colectomy), anastomosis type (colon and rectal), patients with a diverting stoma, APRSOI risk, and elective admission, were significantly associated with an increased likelihood of SSI occurrence. The specific significant SDOH for each area were:

- On the individual patient level: Race Black or African American, Health Insurance (Medicare, self-pay), Annual Hospital Volume below 201 cases.
- On Zip code level: Language proficiency: ("Limited English All Households"); Education: (higher percentage of people with "Some College No degree ", percentage of people with "Associate degree" higher than 8.8 %, a lower rate of people with "Bachelor Degree"); Poverty (All Families below poverty level above 3.7%); "Employed Population Ratio 16 yr" between >55.1 and ≤ 59.4; higher "Unemployment rate 16 yr +"; a higher percentage of "No Vehicle OHU" (above 33.9%); Income: "Median Household Income" above $ 46 305, high (90th percentile) Overall SVI Social Vulnerability with sum flags above 0
- On County area: increasing the SVI Overall Social Vulnerability (Overall SVI Themes Summary) score above .1639, Housing and Transportation vulnerability above 0.7869, and regions with High Socioeconomic Status vulnerability (Flags_T1ct Socioeconomic Status).

A summary for Research Question 3, evaluating the association of the SDOH with the outcome COMPL, the following SDOH: race, annual hospital volume cases, health insurance, language proficiency, education, unemployment rate, "No Vehicle OHU%", poverty, income, GINI index of inequality, SVI Overall Social Vulnerability, high (90th percentile) Overall Social Vulnerability, SVI Socioeconomic Status vulnerability, SVI

Household Composition and Disability, SVI Minority Status and Language, and SVI Housing and Transportation on individual and/or contextual levels (zip code and/or county code) were significantly associated with an increased or decreased likelihood for COMPL occurrence after colorectal surgery. The covariates, age in years ≥65, male sex, preoperative diagnosis neoplasms, open surgical approach versus laparoscopic, surgical procedure site (total colectomy), anastomosis type colon and rectal, APRSOI risk, and elective admission were significantly associated with an increase of the likelihood of COMPL occurrence after colorectal surgery.

The specific significant SDOH for each area were:

- On the individual patient level: Race Black or African American in reference to White, Annual Hospital Volume below 201 cases.
- On the Zip code level: Language Proficiency: ("Limited English All Households"); Education: (the percentage of people with "Associate degree" higher than 8.8%); higher "Unemployment rate of 16 yrs. +"; a higher percentage of "No Vehicle OHU" (above 33.9%); Poverty: (high percentage of "All Families below the poverty" level); Income: "Median Household Income" above $ 46 305; Private insurance alone; GINI index of inequality; and high (90th percentile) SVI Overall Social Vulnerability.
- On the county level: Overall Social Vulnerability (Overall SVI Themes Summary score above .1639), SVI Socioeconomic Status vulnerability, SVI Household Composition and Disability, SVI Minority Status and Language, and SVI Housing and Transportation Social vulnerability.

A summary for Research Question 4, evaluating the association of the SDOH with the outcome Not_SSI the following SDOH: race, health insurance, annual hospital volume below 201 cases, language proficiency, education, poverty, income, private insurance alone, “No Vehicle OHU%”, SVI Overall Social Vulnerability, SVI Minority Status and Language Vulnerability, SVI Household Composition and Disability vulnerability, extreme (90th percentile) SVI Socioeconomic Status vulnerability. On individual and/or contextual levels (zip code and/or county code) were significantly associated with an increased or decreased likelihood for Not_SSI occurrence after large intestinal surgery. The covariates, open surgical approach versus laparoscopic, surgical procedure site (total colectomy), anastomosis type colon, APRSOI risk, length of hospital stay /days, and elective admission were significantly associated with an increase of the likelihood of Not_SSI occurrence. The specific significant SDOH for each area were:

- On the individual patient level: Race Black or African American, Annual Hospital Volume below 201
- On Zip code level: Language proficiency: (“Limited English All Households”); Education: (people with “Associate degree” higher than 8.8); Poverty: (“All Families below poverty level” above 3.7%); Income: (“Median Household Income” above $ 46 305); Private insurance alone; High (90th percentile) Overall SVI Social Vulnerability with a sum of

flags above 0, high SVI Minority Status and Language Vulnerability (T3z_Minority Status and Language)

- On County area: Overall SVI Themes Summary score above .1639, SVI Socioeconomic Status vulnerability above 0.7869, extreme (90th percentile) SVI Socioeconomic Status vulnerability (Flags_T1ct Socioeconomic Status), and Household Composition and Disability vulnerability (T2ct Household Composition and Disability).

Overall, this study demonstrated a significant association of multiple SDOH at a different level (individual and contextual) with the postsurgical complications AL, SSI, COMPL, and Not SSI occurrence. Therefore, the null hypotheses in each research question were rejected, and the alternative one was accepted based on the study findings.

Interpretation of the Findings

In this section, the discussion of the SDOH was organized by SDOH domain, and each key significant SDOH finding was discussed for all four research questions, beginning first with the individual patient level if appropriate, followed by a discussion on contextual levels- on Zip code and County code levels.

Race and SVI Minority Status and Language

In this study, results showed that in reference to White, Black, or African American patients had significantly higher odds for AL, SSI, and COMPL occurrence after colorectal surgery, and a lower likelihood of Not_SSI occurrence. Even though the total sample included only 14 844 (11.4%) Black or African American, and 99,050

(75.8%) White people, within the race, the percentage of AL, SSI, COMPL, and Not_SSI, was significantly higher in Black or African American compared to the other races. Racial disparities related to colorectal cancer incidence and mortality are well described in the literature, but differences in the postoperative morbidity after colon and rectal resection have not been adequately explored (Debarros & Steele, 2013; DeSantis, 2013). Some studies reported race as an independent predictor for 30-day readmission after colectomy, showing black people had a significantly higher risk of readmission (Gunnels et al., 2016; Park et al., 2019). Two recent studies reported racial disparities: one by Schlottmann et al. (2020) reported significant racial differences in emergent surgery for colorectal cancer, and another one was showing that Back and African American and other minorities groups have higher postoperative complications after surgery for stoma creation (Sharp et al., 2020). This study's findings further extend the knowledge about the racial disparity in postoperative colorectal morbidity by reporting race as a significant independent determinant for AL, SSI, COMPL, and Not_SSI occurrence after colon and rectal resection. Race as an SDOH is part of the Social and Community Context domain. Racial discrimination, social injustices based on race, and health disparities due to race create health inequality, less equitable health care, and impact health outcomes (Healthy People 2030, 2021b).

On a contextual level (Zip code area), the association of race with the primary study outcomes AL, SSI, COMPL, and Not_SSI (respectively outcomes for RQ1, RQ2, RQ3, and RQ4) was evaluated using the composite SVI for Minority Status and Language. This variable comprises two single measure estimates from the U.S. Census ACS:

minority; and "Speak English Less than Well." Minority includes all people except white, non-Hispanic. The SVI percentile rank range from 0 to 1, and the higher the percentile rank, the higher the vulnerability is (CDC, 2017e). The results showed that on Zip code level, SVI Theme Minority Status and Language vulnerability equal to or lower than .3850 was associated with a significantly lower likelihood of SSI occurrence (*OR*=0.950, 95% CI [0.904, 0.998]). However, for Not_SSI infections, Minority Status and Language vulnerability even equal or less than .1820 showed higher odds for Not_SSI occurrence. SVI tracts (areas) with the 90th percentile in each SVI theme were marked as high vulnerability and were assigned one flag to indicate high vulnerability. Tracts with percentile rank below 90th were given 0. For each SVI theme (composite variable), the flags from each variable part of the theme's composition were summed, thus creating an overall sum of flags for each SVI composite theme indicating the high vulnerability areas (CDC, 2017e). Zip code areas with High (90th percentile) Minority Status and Language vulnerability with overall flags above 0 were associated with significantly increased likelihood for AL and COMPL occurrence after colorectal surgery (*OR* =1.076, *OR*=1.065 respectively).

On the county level, SVI Minority Status and Language vulnerability score above >.8525 was associated with a significant increase of Not_SSI occurrence, but not with the other primary outcomes. The Not_SSI infections are called hospital-acquired infection in the surgical patients if any of the Not_SSI infectious complications occur within 30 days after the surgical procedure regardless if it was diagnosed during the hospital stay or after discharge (Alkaaki et al., 2019; Horan et al., 2008). In this study, Not_SSI included pneumonia, bloodstream infections, Clostridium difficile colitis, MRSA, VRE, and urinary tract infection, all public health priority. Hospital-acquired infections after colon and rectal resection are higher than the other surgical fields and are reported to be up to 33 % and even 40% if untreated and have been a public health priority (Healthy People 2020, 2018; Healthy People 2030, 2021; Paulson et al., 2017). These study findings expand the knowledge in the field about the racial disparity in postoperative morbidity after colorectal surgery on the individual level and provide novel information on a contextual level by evaluating SVI Minority Status and Language vulnerability. However, this study cannot find what aspect of race leads to disparity in postoperative morbidity after colorectal surgery. Further research is needed to evaluate the aspect of the racial disparity affecting postoperative morbidity after colorectal surgery.

Language Proficiency

The results in this study showed that a lower percentage of “Limited English All Households” below ≤ 8.2 % on zip code level was significantly associated with decreased odds in the four research questions primary outcomes AL, SSI, COMPL, and Not_SSI occurrence after large intestinal resection with respective odds *OR*= 0.925, 0.922, 0.934, and 0.881. Language barriers could be a significant reason for health care access disparity; miscommunication at every healthcare level can lead to misunderstanding of the treatment, follow-up care, and poor health outcomes after surgery. This study results are consistent with the literature in that, that surgical patients after colorectal surgery with limited English proficiency have higher infectious complications SSI and Not_SSI related such as pneumonia and others and have significantly higher readmission rate and emergency room visits mostly due to infectious complications (Narula et al., 2016). Tang et al. (2016) also reported that "Limited English-proficient" patients had significantly higher infectious complications after cardiac bypass surgery and a higher length of stay. Furthermore, language proficiency is part of the SVI Minority Status and Language composition and reflects people who speak English "less than well". In this study, "Language proficiency" was evaluated on zip code and county code level and discussed in the race and minority section. A lower level of SVI Minority Status and Language vulnerability equal to or below .3850 on neighborhood zip code was associated with significantly lower SSI occurrence (*OR*= 0.950) consistent with the finding above in terms of SSI. A study in the United States involving six Joint Commission-accredited hospitals reported that the language barrier increases the patient safety risk and recommended language service for patients who have limited language proficiency (Divi et al., 2007). This study finding expands the knowledge of language limitations impact on postoperative complication after colorectal surgery and could be considered in patient care.

Education

The study results showed that increasing the rate of people with "High School GED" above 22.9 % was associated with a significantly lower likelihood of AL, and the chances to have AL after surgery were decreasing as the percentage of people with "High School GED" was increasing on zip code area. In the four research questions evaluation, increasing the percentage of people with an "Associate degree" on zip code area level was associated with a significant reduction of the likelihood of the occurrence of AL, SSI, COMPL, and Not_SSI (primary outcomes for RQ1, RQ2, RQ3, and RQ4 respectively). However, a higher percentage of people with "Some College No degree" equal or above 14.3%, and areas with "Bachelor's degree" between 13.2% and 17.8 % were associated with increased odds for AL and SSI occurrence. These results show that the Associate degree attainment was consistently an independent protective factor associated with a significant decrease of all primary outcomes occurrence. A higher degree does not necessarily indicate a protective role in the complication's occurrence, and in some instances increased it, as the low % of bachelor's degree in this study. Other factors may play a role on a contextual level in addition to the education on the postoperative morbidity after large bowel surgery. These findings are consistent with the literature as other studies also published that while educational attainment is an essential social determinant of health, a higher level of education or years of education does not necessarily have a linear relation with the health outcomes (Zimmerman et al., 2015). Education is related to health literacy, employment, occupations, economic resources, access to health care, life expectancy, decision making, health outcomes, and it is part of the socioeconomic status. Not enough studies have evaluated the association of the educational level on postoperative morbidity after colorectal surgery. A study from Denmark evaluated education on 8763 patients with colorectal cancer and reported better overall survival after surgery in colorectal cancer patients with a high level of education (Frederiksen et al., 2009). Another study on 35 661 patients showed poor one-year survival after emergency colorectal cancer surgery in patients with lower education (Degettet al., 2020). This study expands the knowledge about the education role in postoperative morbidity after colorectal surgery and could be taken into considerations in colorectal patients' surgical care.

Employment and Unemployment

Directly related SDOH to education is employment status pertaining to income and economic resources and not less important to health care access through work health insurance and benefits (Healthy People 2030, 2021). In this study, employment was evaluated only as "Employed Population Ratio 16 yr +", a single variable estimates from ACS on the zip code level. "Employed Population Ratio 16 yr +" equal or lower than 59.4 on zip code level was related to significantly increased odds for SSI occurrence after colorectal resection.

Employment status has been correlated in multiple studies to better functional outcomes, shorter stay in the hospital and lower readmission rate in patients after surgery, and superior clinical outcomes, but has not been evaluated for postoperative morbidity after colorectal surgery (Adogwa et al., 2017). In this study, a higher unemployment rate above 8.9% was associated with a higher likelihood of SSI and overall COMPL occurrence. These findings are consistent with the published literature in that low-level employment and high-level unemployment has negative health consequences (Healthy People 2030, 2021). The results of this study about employment and unemployment are extending the knowledge about the SDOH from the Economic Stability domain. Unemployment is part of the SVI composite Socioeconomic Status vulnerability on a zip code and county code levels and will be discussed with SES discussion as well.

Poverty

The study results showed an increased percentage of "All Families below the poverty level" in each quartile, in reference to 4th quartile (poverty above 13.5%), was associated with significantly increased odds for AL, SSI, COMPL, and Not_SSI occurrence after colorectal resection at every level, while "Below Poverty age 65 and above" was associated with increased likelihood of AL and SSI occurrence but not with the other two outcomes. Poverty is another social determinant in the economic stability domain that has been correlated with health outcomes and has been used as a strong predictor for death and poor health, especially in communities with concentrated poverty where the poverty rate is above 20% (Goodman et al., 2018). One of the challenges in evaluating poverty as a prognostic factor for health outcomes, especially after surgery, is related to how poverty is measured using the poverty line method in the United States. Intricate medical conditions such as postoperative morbidity as AL, SSI, and other hospital acquired infections would require a more complex measure of poverty to reflect better its multidimensional aspect and impact on these health outcomes. It is essential to understand the multifaceted aspects of poverty when using it in health research because poverty has been used as a central tenet when SES is evaluated on the contextual or macro-level (Berzofsky et al., 2014; Wagle, 2002). Poverty has been associated with income and is part of socioeconomic status in the SVI Theme -Socioeconomic Status, used in this study.

Income

The study results showed that the increase of the “Median Household Income” was associated with significantly decreased odds for AL, SSI, COMPL, and Not_SSI occurrence after colorectal surgery. Income above >46 305 USD (1st Quartile) was an independent protective factor against AL and SSI, and above >60 526 USD for overall COMPL and Not_SSI related complications. With the increase of income from 1st Quartile to the 4th Quartile, the odds for the likelihood of AL, SSI, COMPL, and Not_SSI occurrence were significantly decreased, and the percentage of the AL, SSI, COMPL, and Not_SSI occurrence from 1st Quartile (low income) to the 4th Quartile (high income) decreased with 1.4% for AL, 2.4% for the SSI, 3.1% for overall COMPL, and 2.5% for Not_SSI, considering that the income in this study was evaluated as an estimate at a neighborhood level on patient Zip code, and not direct income measure of the actual patient. This shows the significant role of the income on the postoperative morbidity after colorectal resection, which may have been even more apparent if income was measured directly on patient level. The median family, median household, and per capita income have been used as measures either as single measurement direct or estimated or used as part of the calculation for socioeconomic status (SES), SVI, or in GINI index. Some published studies report that people with high income have better health and can afford access to health care and better health care resources (Braveman et al., 2005; Shavers, 2007). Surgical morbidity has been correlated with a significant increase of the hospital cost, and with increased personal financial constraints causing additional stress to the patients and families, and non-adherence to the recommended treatment and recovery after colorectal surgery (Regenbogen et al., 2014; Zoucas & Lydrup, 2014). Hospital-acquired infections after large intestinal resection are higher than the other surgical fields and have been a public health priority, making income important SDOH to consider when taking care of these patients (Healthy People 2020, 2018; Healthy People 2030, 2021; Paulson et al., 2017). This study reported a similar finding to a multicenter study with 975 from Netherlands evaluating gross household income impact on the postsurgical outcomes after colorectal surgery for stage I-III cancer. The study showed that overall postoperative complication was significantly decreased with an increase of the gross income, from 53.3% in lower income (first Quartile) to 36.0% in the high-income group (fourth Quartile) with $p < 0.001$. Similar were the findings in the same study, related to the major complications, decreasing with higher household income increase. However, that study used the patient's direct household income (van den Berg et al., 2019). The current research findings of the median household income were consistent with the result of van den Berg et al. (2019) in that that the odds for AL, SSI, COMPL, and Not_SSI occurrence were decreasing with the household income increase, thus showing that higher income was associated to better outcomes. The finding of this study expands the knowledge by presenting valuable information about the income association with postoperative morbidity AL, SSI, COMPL, and Not _SSI after colorectal surgery in New York state, in the United States.

SVI Socioeconomic Status

On Zip code level, the results from this study showed that higher SVI Socioeconomic Status vulnerability within >.3799 and ≤.6453 (second quartile) was associated with significantly increased odds for Not_SSI occurrence after colorectal resection (*OR*=1.065), and High (90th percentile) Socioeconomic Status vulnerability in the 90th percentile with one flag, significantly increased the likelihood of SSI occurrence *OR*= 1.079. On a larger geographic area of county code, SVI Socioeconomic Status vulnerability at second quartile level (above .1475 and below or equal 0.3934) score was associated with an increased likelihood of the overall COMPL occurrence, *OR*=1.103, and areas with very "High Socioeconomic Status" vulnerability at 90th percentile with three flags, was significantly increasing the odds for COMPL occurrence. Lowering the "High Socioeconomic Status" vulnerability was associated with reducing the likelihood of AL and Not_SSI occurrence following colorectal resection. These findings are new and expand the knowledge in the field about the Socioeconomic Status Social Vulnerability Index association with AL, SSI, COMPL, and Not_SSI occurrence after colorectal surgery. There are no studies that have used SVI SES vulnerability influence on the postoperative morbidity after colorectal surgery. Usually, SES has been used in the literature as a composite measure traditionally including income, education, and occupation at individual level regardless of the geographical position of the individual, or as a contextual(area) measure presenting the social and the ecologic environment such as neighborhood, the individuals or families live in (Berzofsky et al., 2014; Shavers, 2007). In the CSDH theoretical model used in this study, the occurrence of the diseases and other health outcomes are explained as a result of the interplay between SES and socio-political context as a key concept, with structural and intermediary determinants of health concepts (WHO, 2010). Even though all SVI THEMES are well designed contextual composite variables using 15 single SDOH variables from U.S. Census data, very few studies have used them to evaluate the surgical outcomes in the community levels (Carmichael et al., 2019; Mehta et al., 2019). Carmichael et al. recently (2019) used SVI to evaluate disparities in elective and emergent cholecystectomy. The authors reported that patients with emergency surgery lived in an area with higher SVI compared to patients with an elective surgery $p<0.001$. In the same article, the authors also further discussed the SVI's potential utility for use in evaluating health care disparities and the opportunity to link SVI as a composite index to a variety of other datasets as it is calculated on census track and different geographical levels.

GINI Index of Inequality

Income, unemployment, low education and poverty, and low SES lead to health disparities and health inequalities. GINI index is a specific measurement for inequality or wealth distribution based on per capita income amongst the people within a geographical area- county, state, etc. The index range is between 0 and 1, and higher values indicate greater inequality, with 0 meaning perfect equality and one meaning perfect inequality. The GINI index for New York State is higher than the national GINI coefficient with 0.484 for United States 2019 and 0.51 for NYS 2019 (U.S. Census Bureau, 2016). This study showed that a lower GINI index between >.4318 and ≤

.4706, in reference to above .4706) on zip code area level was significantly associated with decreased odds for the overall COMPL occurrence but not with the other outcomes. The American College of Physician position paper on SDOH reported that in the United States in the year 2000, there have been 133 000 deaths due to poverty at an individual level, and 119 000 due to income inequality (Daniel et al., 2018; Galea et al., 2011). A very recent study used the GINI index to evaluated SSI inequalities in the operating rooms, but that study did not evaluate the postoperative SSI (Dexter et al., 2021). The results from the current study are consistent with another recent publication, evaluating the sociodemographic and special factors for predicting SSI. In that study GINI index was significant in univariate analysis but not in the multivariable analysis (Carvalho et al., 2021). In this study, GINI was significant in all research questions bivariate analyses as well but was significant in multivariable regression only for overall COMPL occurrence and not associated independently with AL, SSI, and Not_SSI outcomes. New York is the highest state with GINI inequality and however limited this factor is as a prognostic factor for the income distribution, GINI index may be useful to be considered in the evaluation of the postoperative morbidity together with other potential social predictors. This study extends the knowledge in the surgical field about income inequality role on postsurgical morbidity.

SVI Housing and Transportation

Study results showed that zip code areas with a high percentage of "No Vehicle Occupied Housing Units-(OHU)" above >33.9 (in 4th quartile), significantly increased the odds for SSI and overall COMPL occurrence after surgery (*OR*=1.114, 95%CI

0.914, 0.994), while decreasing the percentage of “No Vehicle OHU” below ≤ 33.9 down to the 3rd and 2nd quartile, was significantly decreasing the odds of Not_SSI occurrence after intestinal surgery. The “No Vehicle OHU” was not significant for AL.

In this study, similar results to those found in the evaluation of the single measurement estimate “No Vehicle Occupied Housing Units-OHU “, were also found when evaluating “SVI Housing and Transportation” vulnerability, a composite variable including five single measure estimates from the ACS: Multi-Unit Structure, Mobile Homes, Crowding, No Vehicle, and Group Quarters. The SVI Housing and Transportation vulnerability shows the social vulnerability level related to all these five variables. The current study finding showed that zip code areas with 90th percentile very “High Housing and Transportation” vulnerability with two flags score were associated with a significant increase of the likelihood of SSI and overall COMPL. On a larger geographic area as County level, “Housing and Transportation” vulnerability above.7869(4th quartile) increased the odds of AL and the overall COMPL, and below .7869 was significantly reducing the odds for SSI and the overall COMPL. Counties with very high SVI Housing and Transportation vulnerability above zero flags were associated with a significant increase of odds for AL. Consistently, this study demonstrated that lack of transportation and social vulnerability related to the housing and transportation increase complications, and improving these conditions, could improve the outcomes after surgery. Regrettably, very few studies had evaluated “Housing and Transportation” vulnerability as a social structural determinant of health that could affect public health and medical care. Carvalho et al. (2021) reported that a greater distance from the central hospital was correlated to a higher incidence of SSI, but the study did not evaluate the transportation. A recent study from Colorado University, United States, reported that geographic areas on census tract with high population of minority and people with no vehicle had significantly increased travel time to health care facility utilizing public transportation (Tran et al., 2020). It is reported that because of transportation barriers, 3.6 million Americans lack health care access (American Hospital Association, 2021). The current study provides valuable information and expands the knowledge about the association of SVI Housing and Transportation as a structural determinant of health on the postoperative complications AL, SSI, Not_SSI, and overall COMPL after colorectal surgery. It could be used by hospitals and public health to address transportation barriers to health care access in surgical patients, thus leading to a positive social change on a larger scale.

SVI Household Composition and Disability

Another not well explored yet composite SDOH evaluated in this study was SVI Household Composition and Disability on contextual levels of neighborhood zip code and county area. This composite SVI Theme includes four individual estimates from ACS: Age 65 and above; Age 17 and Younger; Civilian with a Disability; and Single-Parent Households presented as composite as a percentile rank. In this study, on zip code level, "Household Composition and Disability" vulnerability did not demonstrate an association with any of the primary outcomes. On a larger geographical area, county level, the study showed that "Household Composition and Disability" vulnerability at a level high as 2nd quartile (>.0984 and ≤ .3115) was significantly increasing the odds for AL, and higher vulnerability rank level at 3rd quartile (>.3115 and ≤ .4754) was significantly increasing the odds for Not_SSI occurrence, and at the 4th quartile (the highest level above >0.4754) was significantly increasing the odds for SSI and the overall COMPL. Household Composition and Disability vulnerability below ≤ .3115 on county-level showed a reduction of the odds for only SSI in this study. No studies have evaluated the SVI Household Composition and Disability vulnerability association with postoperative morbidity after colon and rectal surgery; thus, this study expands the knowledge in the field about this SDOH on AL, SSI, Not_SSI, and overall COMPL. Household Composition and Disability as SDOH is part of the social and community context domain. People with disabilities are a vulnerable population, as they face multi-aspect barriers in life, including access and utilization of health care services (WHO, 2021). In 2001, WHO adopted the "bio-psycho-social" model of disability, according to which disability is socially constructed (Fiorati & Elui, 2014). This new social approach to disability encourages social inclusion and more independent life in society for disabled people. The health care system needed to make the necessary changed to improve health equity for people with disabilities. People with disabilities are a vulnerable population, and coupled with surgical intervention, the social vulnerability increases even more, as surgical patients are a vulnerable population on their own (Sebastian, 2008; Zinn, 2013). There are no studies that have evaluated the postoperative complication after colorectal surgery in surgical patients with disabilities. This study expands the knowledge in the field and could shift the focus for further discussion and evaluation of the surgical care for people with disability and household composition vulnerability. SVI Overall Social Vulnerability

The overall Social Vulnerability was evaluated as SDOH on zip code and county code areas. The SVI is part of the neighborhood and built environment key areas of SDOH. It shows the social vulnerability of the communities defined as "community resilience during external stresses such as natural or human disaster as disease outbreaks" (CDC, 2017e). The overall vulnerability index ranking score has been created by summing the sums of the four SVI themes (Socioeconomic Status, Household Composition and Disability, Minority Status and Language, and Housing and Transportation), and subsequently calculating the percentile ranking. Also, 90th percentile rank values were assigned value 1 to mark high vulnerability and those below 90th percentile, 0 to calculate the very High Overall Vulnerability, as a sum of all flags from all the variables included on the composite themes (CDC, 2017e; Flanagan et al., 2018).

This study showed that on zip code level, areas with 90th percentile "High Overall Social Vulnerability" with one and two flags were associated with significantly increased odds for AL, SSI, Not_SSI, and overall COMPL occurrence after colorectal surgery. On the county level, the results showed that "Overall Social Vulnerability" significantly increased the postoperative occurrence of AL, SSI, Not_SSI related infections, and overall COMPL after colorectal surgery (see Tables 22, 33, and 45) The county areas with 90th percentile high "Overall Social Vulnerability" with two flags and above were increasing significantly the likelihood of SSI, Not_SSI, and overall

COMPL after intestinal surgery, and with one flag high vulnerability was associated with reduction of the AL occurrence chances. No studies have evaluated the Overall Social Vulnerability Index as a predictor of postoperative complications after colorectal surgery. Even though SVI Themes are well designed contextual composite variables using 15 single SDOH variables from U.S. Census data, very few studies have used to evaluate the surgical outcomes in the community levels (Carmichael et al., 2019; Flanagan et al., 2020; Mehta et al., 2019). This study provides novel information and thus expand the knowledge about the association of SVI with the postoperative outcomes of AL, SSI, Not_SSI, and COMPL after colorectal surgery. Carmichael et al., recently in (2019) discussed the SVI potential utility for use in the evaluation of health care disparities and the opportunity to link SVI as a composite index to a variety of other datasets as it is calculated on census track and different geographical levels.

Health Insurance

Patient Health insurance was used as an SDOH for access to health care. The study showed that "Medicare" significantly reduced the odds for SSI occurrence but not for the other outcomes. "Self-Pay" had significantly higher odds for SSI and NOT-SSI occurrence after colorectal surgery than Medicaid in this study. Also, on the neighborhood Zip code level, the percentage of people with "Private insurance alone" was used to evaluate the association of 3rd party payer for SSI, Not_SSI, and overall COMPL. Areas with a percentage of people above 46.3% with "Private insurance alone" were associated with a significant decrease of the likelihood of SSI, overall COMPL, and Not_SSI occurrence. The results of this study are similar to other published works showing that people without health insurance and self-pay, experience higher surgical complications, whereas people with private insurance have better outcomes and access to care (Kelz et al., 2004; Robbins et al., 2009; Schneider et al., 2018). The finding of the Medicare role contradicts some reports that patients with Medicare coverage have more complications after colorectal surgery. Qi et al. (2019) reported that Medicare and Medicaid patients have higher odds for SSI occurrence. One possible expiation is the heterogeneity of this sample regarding diagnosis and surgical procedures. However, both the preoperative diagnosis and surgical procedure were used as covariates in the multivariable analyses. The wide variety of third-party payer (public, commercial and private), different pricing system with the individual hospitals, and various coding system amongst the health plans make the evaluation of health insurance as a social factor challenging, especially in population from a vast number of hospitals as in this study (Reinhardt, 2006).

Annual Hospital Volume

Overall, this study showed that annual hospital volume of surgical cases in all quartiles the increased the odds for all the primary outcomes occurrence. This finding is inconsistent with some published data that a very high volume of cases is associated with lower postsurgical occurrence (Billingsley et al., 2007; Mahmoudi et al., 2017). One possible explanation for not finding a difference with this stratification of the case volume is that quartiles were used for categories instead of a more specific categorization of the number of cases assigned to low, medium, high, and very high volume. Both of the studies above used different categorizations with a much higher cut-off point for the lower level of volume (Billingsley et al., 2007; Mahmoudi et al., 2017). This study could not account for surgeon volume and other factors that may play a role in evaluating the annual hospital volume, as this data is secondary and with limited identifiers access.

Covariates

In this study, several covariates were used to control for confounding factors: age, sex, preoperative diagnosis, surgical approach, anastomosis type, diverting stoma, admission type, APRSOI risk and length of stay in the hospital. Some of these factors have been reported in the literature to affect postoperative surgical morbidity (Pak et al.,2020). The covariates were from the SPARCS clinical data.

Preoperative Diagnosis

Since this study sample included patients with various preoperative diagnoses who underwent colorectal surgery, the preoperative diagnosis was included in the analyses as covariate. On multivariable analyses, the preoperative diagnosis neoplasm was found to increase the odds for AL and overall COMPL but was not significantly associated with the other outcomes. Neoplasm patients were 61 777 (47%) of the entire sample, and in the bivariate analyses showed the highest rate of AL, SSI, Not_SSI, and overall COMPL. Also, cancer patients have more extensive surgery due to the lymph node dissection; thus, this may lead to more complications postoperatively, especially AL. This study result is consistent with a recent article reporting that cancer patients after colorectal surgery have four times higher complications than other colorectal surgery for other medical conditions (Pak et al., 2020).

Age

In this study age was associated with increasing the odds for AL, SSI and COMPL. Also age above 65 significantly increase the likelihood of overall COMPL which is consistent with the literature (Chan et al., 2020; McGillicuddy et al., 2009).

Sex

The male sex in the current study was an independent predictor for AL, SSI, and overall COMPL but had a significantly lower likelihood for Not_SSI occurrence than females. The results are consistent with the published literature in terms of AL, SSI, and overall COMPL. Other studies have reported similar results about the higher risks in males for AL and SSI (Frasson et al., 2018; Nikolian et al., 2017; Pak et al., 2020).

Surgical Approach

The conventional open surgical approach and the surgical approach “other” (including surgical approach other than laparoscopic or open) significantly increased the odds for AL, SSI, Not_SSI, and overall COMPL occurrence. It is well described in the literature that the open surgical approach has higher post-surgical complications after abdominal surgery, even though there are conflicting reports. The current study results are consistent with these studies reporting higher postoperative complications in conventional open surgery than laparoscopic surgery (Braga et al., 2002, Numata et al., 2018). However, other studies reported similar outcomes between laparoscopic and open surgical approaches (Rose et al., 2004). A multicenter trial comparing laparoscopic versus hand-assisted laparoscopic surgery reported similar outcomes between both techniques (Marcello et al., 2008). The surgical procedure “Total

Colectomy" had significantly increased likelihood for AL, SSI, Not_SSI, and overall COMPL occurrence after surgery than colon surgeries not removing the total colon. Total colectomy as a procedure means removing surgically the entire colon to the rectum. It is usually performed in patients with diseases that involve the entire colon, such as ulcerative colitis, polyposis, and colonic dysmotility mention a few. Total colectomy is a major surgery associated with a high rate of postoperative complications due to multiple surgical and clinical factors such as immunosuppressive therapy, diabetes, surgical intervention, and others. This study finding is consistent with the reports of other studies (Cotte et al., 2011; Eriksen et al., 2014; Tang et al., 2001).

Anastomotic Type

Anastomosis type or anastomosis site as a location in the colon segment has been described in the literature to be correlated to AL and surgical complication after colorectal surgery (NasirKhan et al., 2006; Trencheva et al, 2013). In the current study, the anastomosis type was determined by anastomosis distal end based on the surgical procedure. This study results showed that the colon anastomosis had significantly higher odds for AL, SSI, and overall COMPL than the anal anastomoses. This finding may be due to a large number of procedures with colon anastomoses compared to anal and also to a large number of neoplasm patients in this sample. The New York State, Department of Health report on Hospital Acquired Infection for 2018 show that colon surgeries are still contributing to the SSI infection rate even though there has been improvement since 2015 (New York State Department of Health, 2021). The rectal anastomoses had significantly higher odds for AL and SSI occurrence but not an independent factor for the other outcomes in this study. This finding is consistent with other studies reporting high anastomotic leak rate and complications associated with rectal anastomoses (NasirKhan et al., 2006; Schmidt et al., 2003; Turrentine et al., 2015).

Diverting Stoma

Diverting Stoma in this study had higher odds for AL occurrence, and significantly lower odds for Not_SSI occurrence after colorectal surgery. The reporting in the literature about the protective role of the stoma for AL is contradicting. The creation of diverting stoma is an additional surgical procedure with its own complications. Some reports show that stoma is decreasing the AL, and others show it does not affect the AL rate but rather decrease the severity of AL and the complications and suggest being used in high-risk patients for AL (Floodeen et al., 2017; Hanna et al., 2015; Koperna, 2003; Stey et al., 2014).

All Patient Refined Severity of Illness (APRSOI)

In this study, APRSOI was used as covariates to cover for confounding variables related to comorbidities and patient characteristics that were not available otherwise with the SPACRS data. The APRSOI has four categories: Minor Severity of Illness; Moderate Severity of Illness; Major Severity of Illness; and Extreme Severity of Illness and it is specific to the calendar year the patient had surgery. It has been used for reimbursement and research purpose. This risk of illness indicator also reflects age. APRSOI presents by definition of SOI according to the SPARCS data dictionary “the extent of physiologic decomposition or organ system loss of function” (New York

Statewide Planning and Research Cooperative System, 2014). This study showed that APRSOI was associated with a significant increase of odds for AL, SSI, Not_SSI, and overall COMPL occurrence after colorectal surgery consistently at all levels above "Minor Severity of Illness". The APRSOI allows for risk stratification of a diverse population. It was used in this study as the study sample includes patients with various preoperative diagnoses and, subsequently, different surgical procedures. There are not many studies that have used SOI in the evaluation of postoperative complication evaluation, as the Charlson Comorbidly Index is more widely used in the clinical setting, even though SOI has been recommended for use as a measure of perioperative risk (Li et al.,2008; McCormick et al., 2018). This study findings extend the colorectal field knowledge about the APRSOI as a prognostic factor for postoperative complications.

Surgery Type

Elective surgery usually is reported to have fewer surgical complications. However, this study shows that patients with elective surgery have a significantly high likelihood to have AL, SSI, Not_SSI, and overall COMPL after colorectal surgery. This disconfirming result could be explained by the high volume of patients with surgery for neoplasm or comorbidities and other factors that cannot be considered with this study analysis. Some studies reported that urgent cases have a higher complication rate than emergency cases (Bayar et al., 2016; Mullen et al., 2017). In this study, the urgent cases we combined with the emergency cases for protection of patients as the number was very low.

Length of Hospital Stay

Length of Hospital Stay was used as a covariate in the evaluation only for the Not_SSI infections as it has been reported that prolonged length of stay in the hospital after colorectal surgery increase the hospital-acquired infections (HAI) such as Not_SSI (Clostridium difficile, MRSA, Catheter-Associated Infections (Urinary Tract Infection, and others) (New York State Department of Health, 2021). This study showed that "Length of Hospital Stay" was an independent predictor for Not_SSI occurrence and increased the odds for Not_SSI infections gradually after four days, with corresponding odds of OR=1.903 for the ≥ 5 and ≤ 6 days, OR=3.867 for ≥ 7 and ≤ 9 days, and or=8.326 for more than ≥10 days, p=0.000 for all three quartiles. This study confirms the New York Department Health report of 2018 regarding HAI and post-surgical length of hospital stay (New York State Department of Health, 2021). The Length of Hospital Stay was not used as a predictor for the AL, SSI, and overall COMPL as it could be both a confounding factor and predictor. Other types of statistical analyses may be more appropriate, to evaluate the length of hospital stay as predictor for AL, SSI, and overall COMPL, which are not in the scope of this study.

Interpretation of The Findings in the Context of The Study Theoretical /Conceptual Framework

The WHO conceptual framework for the social determinants of health (CSDH) was used in this study to explain the social production perspective of the disease/surgical complications AL, SSI, Not_SSI, and overall COMPL occurrence in relation to SDOH

(WHO, 2010). The Diderichsen's aspect in the CSDH model explains the occurrence of diseases and in this study, the surgical complications, using the interplay between socioeconomic position and socio-political context as a key concept, with structural and intermediary determinants of health concepts (Diderichsen et al., 2001; Solar & Irwin, 2010, WHO, 2010). The CSDH is a dynamic model and incorporates social, economic, and political mechanisms that play a role in creating the social position and social stratification, leading to health inequalities through differential exposure, differential vulnerability, and differential consequences (WHO, 2010). In the CSDH model, there are two types of SDOH: a) Structural (such as socioeconomic position defined by income, education, and occupation, gender, ethnicity, and race); and b) Intermediary SDOH addressing material conditions (living and working condition, food availability, neighborhood quality), psychosocial factors (stress, social support, social isolation), and behavior and biological factors (smoking, alcohol use, genetic factors, and others). The theoretical model for this study was adopted from the WHO 2010 CSDH model to reflect and explain the current study outcomes (Figure 2). The second model incorporated in Figure 2 is Socio-Ecological Models (SEM), a part of the CSDH, which guided the selection of the independent variables and covariates on individual and community levels from the secondary data. (Glanz et al., 2008).

This study results demonstrated the interplay between the structural SDOH (language proficiency, education, income, employment, unemployment, poverty, GINI inequality, race), the intermediary SDOH (Social Vulnerability Index [Overall SVI, and the four SVI THEMES: Socioeconomic Status; Household Composition and Disability;

Minority Status and Language; and Housing and Transportation], biological factors as age, sex, and the covariates), and Health System (presented by health insurance and annual hospital volume) leading to “Differential Exposure” and “Differential Vulnerability”, and subsequently to “Differential Health Consequences” (surgical complications AL, SSI, NOT-SSI, and overall COMPL) after colorectal surgery.

In this study, structural SDOH playing a role in the creation of the social position and social stratification such as education, income, employment status, poverty, and sociocultural context SDOH (race, inequality) were significantly associated with an increase or decrease of the odds for the occurrence of the study health outcomes postsurgical complications. Income's role in health consequences was demonstrated, showing a negative correlation between income increase and postsurgical complication decrease. On neighborhood zip code, areas with 90th percentile “High Overall Social Vulnerability” were associated with significantly increased odds for AL, SSI, Not_SSI, and overall COMPL occurrence after colorectal surgery. On the county level, the results were the same, showing that Overall Social Vulnerability at the level of 3rd and 4th Quartiles (>.5410 and ≤ .7213; >0.7213 respectively), significantly increased the odds for the postoperative occurrence of AL, SSI, Not_SSI, and overall COMPL s after colorectal surgery. The four specific SVI Themes uncovered the differential vulnerability exposure in different intermediary SHOH areas such as SES, Minority Status and Language, Household and Composition, Housing, and Transportation, and demonstrated that differential vulnerability exposure has different health outcomes. Even though SDOH affects individuals' or populations' health status in and out of the hospital, in-hospital recovery after surgery ensures a standardized health care plan for all patients regardless of their insurance, socioeconomic status, or education level, to mention a few SDOH factors. After hospital discharge, the care lands in the individual patients with differential exposures and differential vulnerabilities on personal and community levels, even though patients in the United States report to their surgeon up to 90 days after surgery. The different individual social position and social stratification according to the CSDH model determine the differential exposure and vulnerability, and subsequently the deferential consequences in this study the surgical complications AL, SSI, Not_SSI, and overall COMPL. The patient's different race as part of the social context showed different association with the health outcomes in the study and demonstrated racial disparity in AL, SSI, and overall COMPL. The CSDOH model only offers an explanation of the role of the SDOH on health outcomes and does not prove causation, as this is a retrospective cross-sectional study on secondary data.

This theoretical model presents both the ecological system and social system perspectives and allows for both positivism (evidence oriented) and constructivism's philosophical views (the reality is socially constructed and modifiable) to be applied (Israel et al., 1998). While this study results show information and evidence about the influence of SDOH on postsurgical recovery (positivism's view), and the CSDOH framework explains the social production perspective of the disease/surgical complications, this theoretical model also makes perceptible the constructivism's philosophical paradigm that the AL, SSI, Not_SSI, and overall COMPL are occurring in a socially constructed and modifiable environment. Modifying the environment and removing transportation barriers or language barriers on community level, for example, may potentially have a larger scale positive effect on this study population health outcomes. Using CSDOH model in this study, present to the colorectal field a novel social production view and explanation of the occurrence of postoperative morbidity, which may bring further discussion and utilization of this framework. By using this specifics-to-objectives theoretical frameworks, this doctoral project provides valuable information to the community from a scientific inquiry guided by frameworks specifically designed to evaluate the outlined health issues.

Limitations of the Study

Some of the limitations in this study are related to the use of secondary data; thus, the analyses are limited to the data available in the dataset, the quality of the data, missing data, and the way the variables were defined in the datasets, and some important factors may not be part of the dataset (Cheng & Phillips, 2014). The results from the SRARCS data can be generalized only to New York State. Some limitation in SDOH data may be related to the socio-cultural aspect of the SDOH. For example, it is well known that income is age and sex dependent and influenced (Braveman, et al., 2005).

Further, the SDOH in this study are on a contextual level, and not SDOH collected in the longitudinal study directly from patients, which may provide better information of the SDOH impact on an individual level. As this is a cross-sectional study on secondary data, this study does not offer a causal explanation but only explains the associations of the SDOH with the outcome variables. Furthermore, because the study uses secondary data, construct validity was considered to minimize the study bias. The secondary datasets consist of prospectively collected data from hospital electronic medical records. In the SPARCS data, all 200 hospitals contributing to the state data are using the same methodology to collect it and report it to the state annually, thus increasing the reliability of the data. The data from U.S. Census, CDC SVI, and USDARS data are collected under predefined definitions systematically and updated periodically. The definitions used at the time of the data collection were used in this study to minimize bias (New York State Department of Health, 2016). The data dictionaries are listed in Appendix A.

Strength of the Study

One of the study's strengths is that it uses a representative sample. The SPARCS clinical data sample is representative for New York State as data is collected from 200 hospitals. The SDOH estimates for New York State from U.S. Census ACS and CDC SVI on zip code and county code are also representative for the New York State; thus, the study result could be generalized for the New York State. The SDOH data files were linked by a professional team of the data provider based on the best scientific recommendation for crossover. Also, the sample size is 130 731, which is considered a large sample, thus minimizing the study bias.

Finally, this study is guided by WHO CSDOH theoretical framework specially designed to evaluate SDOH influence on health outcomes and explain the outcomes as social production, thus strengthening the study's research methodology. Using existing theoretical models or frameworks to guide research inquiry and explain the finding is an essential part of the research methodology that strengthens the scientific basis of the investigations. The CSDOH and the embedded Social-Ecological Model are used in social epidemiology (Krieger, 2001). Using this specifics-to-the objective theoretical framework, this doctoral project provided: a) valuable information to the community from a scientific inquiry guided by frameworks specifically designed to evaluate the SDOH that influence outlined health issues, and b) offered a different and novel social approach philosophical view to explain postoperative morbidity after colorectal surgery.

Recommendations for Future Research

Based on the study findings, further research related to postsurgical morbidity after colorectal surgery that may further expand knowledge in the field could be related to:

- Geospatial Analyses: This data set is deidentified and had only a 3-digit zip code for the purpose of this study evaluation, and it was not possible to evaluate zip code as a social determinant itself. Future research conducting geospatial analyses and mapping of the postoperative morbidity may be valuable to identify areas in need of both public health and medical care. Reducing SSI and Not_SSI is a public health priority and geospatial analyses may provide valuable information to address the HAI in a geographical area.
- Further research about the role of housing and transportation and household composition and disability may be valuable for current and future programs related to

healthcare access programs and engaging communities to decrease postoperative infectious complications.

- Racial disparity: While this study provided valuable information about the racial disparity in the postoperative morbidity after colorectal surgery, in-depth evaluation of racial disparity related to postoperative morbidity and SDOH after colorectal surgery could provide additional information about the other races and not only Black and African American Population. Another type of statistical analyses may be more appropriate to clarify the disparity issue further.
- This study used secondary data and future prospective longitudinal observational study with direct patient-level data measurement of SDOH, may be warranted to understand better and in depth the influence of the SDOH on the surgical morbidity.

Implications for Professional Practice and Social Change

Recommendations for Professional Practice

Based on the study findings of the association of the SDOH with the postsurgical morbidity after colorectal surgery, the following recommendations could be utilized by the professional practice to decrease surgical morbidity and specifically AL, SSI, Not_SSI related, and overall COMPL and ultimately HAI overall after colorectal surgery in adult patients.

- Establishing the SDOH evaluation as routine component of the patient health evaluation in the medical and public health practices, by utilization of the already standardized ICD-10-CM Z coding (based on the WHO International Classification of the diseases) for SDOH, which codes have been adopted already by HIPAA for all settings in the United States, is a one recommendation for improvement of the health outcomes after colorectal surgery, and decreasing HAI, both SSI and Not_SSI related. These are special ICD-10-CM codes, “Z” codes (previously V- codes) Z55-Z65 that depict SDOH socioeconomic and psychosocial conditions in patients during hospital visits. Some of the Z codes mark illiteracy and low-level literacy, homelessness, extreme poverty, problems with the physical environment, inadequate housing, social exclusion, and others. Utilizing the SDOH ICD-10-CM Z coding will provide additional and valuable information for providers and payors for patients in need, provide a basis for strategies and solutions, and ultimately improve the population's health. This is very feasible recommendation with already available tools to implement, and with high potential for societal benefits and positive social change. Furthermore, using the Z codes for SDOH, will assist not only the professional practice, but also will help researchers, if these codes are part of the Electronic Health Records System (EHR), to use them for evaluation and strategize solution and social interventions for decreasing the SSI and other health care acquired infections, which are a public health priority issue.

- Another feasible and useful recommendation is to utilize in the professional practice and research the Social Vulnerability Index- the “Overall Social Vulnerability” and the four specific themes (Socioeconomic Status; Household Composition and Disability; Minority Status and Language; and Housing and Transportation vulnerabilities) as a measure to evaluate patient vulnerability status as per the SVI index, which will provide direct relevant information about the patient vulnerability, that could be taken under consideration during surgical care and overall care as well (Bergstrand et al., 2015; Flanagan et al., 2018). According to CDC and Agency for Toxic Substances and Disease Registry, the SVI originally has been designed to assess the "community resilience and vulnerability during stresses from natural or human-caused disasters or disease outbreaks" and is used for assessment in needs for hazard preparedness and support and is also recommended for assessment of medical situation (Agency for Toxic Substances and Disease Registry, 2018; CDC, 2017e; Bergstrand et al., 2015). In this study, SVI (overall and themes) were significantly associated with AL, SSI, Not_SSI, and overall COMPL occurrence after colorectal surgery. SVI offers well-constructed four composite variables/Themes reflecting and presenting a better way to evaluate vital social issues with complex nature and challenging to measure and may be a new useful tool.

- Furthermore, it would be beneficial for professional and public health practices to evaluate further the "Housing and Transportation", and "Household Composition and Disability" status of existing, or for the lack of programs assisting vulnerable populations, and strategize for more inclusive of stakeholder programs with community engagement to utilize available community, public health, and medical care resources to help people with transportation, and other barriers to health care access.
- educate public health and medical care practitioners about the SDOH and how to apply them in the professional practice

Positive Social Change

The current study results support positive social change intended at bringing awareness and expanding knowledge and the understanding of SDOH association with the postoperative HAI, both SSI and Not_SSI, and overall COMPL after colorectal surgery, by examining the SDOH influence on the postoperative morbidity on an individual, zip code, and county level. The study results showed a significant positive relationship between Social Vulnerability Index (Overall and the SVI specific four Themes: Socioeconomic Status; Household Composition and Disability; Minority Status and Language; and Housing and Transportation) and study outcomes, meaning that areas with increased “Social Vulnerability” were associated with increased postoperative morbidity on zip code and county levels. Decreasing the “Overall Social Vulnerability” was improving postsurgical morbidity. Even though this study cannot establish causation, and may not resolve the problem with HAIs, it could initiate discussion about “Social Vulnerability” and SDOH's role on postsurgical morbidity, thus increasing SDOH awareness and comprehension

The study results could support a change of the current practice paradigm of surgical care and health evaluation, and adaptation of more holistic strategies for health evaluation, and patient-centered care considering the SDOH, especially those that directly impact patients surgical care like socioeconomic status, race, social vulnerability, education, transportation barriers, and others. Utilization of the SDOH in the professional practice into the electronic medical records, using the already available ICD-10-CM Z codes for SDOH, or through SDOH screening checklist, will offer critical information about the surgical patient that can help for tailored surgical care accounting for patient's social and community determinants, especially now when the role of the community is increasing with the same day or shortly after surgery hospital discharge. New patient care and educational strategies and policies more inclusive of patient's social conditions and community-engaging, ultimately will strengthen the patient-provider-community relationship and bring positive social change in surgical care practices, decrease SSI and Not_SSI related complications and improve health outcomes on individuals and community level for the surgical patients' population.

The study' finding further extended the knowledge about the racial disparity in surgical morbidity after colorectal surgery, information that could be utilized for positive social change in the professional practice and programs to develop strategies and policies to address upstream SDOH and racial disparity and improve surgical care by decreasing the racial disparity gap, and provide more equitable healthcare, thus ultimately improve the population health.

The implications for social change from this research also include prevention or decreasing SSI (AL in this group), and Not_SSI related HAI presented in Figure 3 (Healthy People 2030, 2021; New York State Department of Health, 2021). The three public health priority programs and goals: Safe Surgery Saves Lives; Healthy People 2030 objective to reduce HAI; Healthy People 2030 Surgical Site Infection prevention and reduction goal; and colorectal cancer prevention can be informed about the role of selected SDOH on AL, COMPL, SSI and Not SSI related postsurgical morbidity, and consider the SDOH when developing preventive strategies and policies to decrease the

HAI (CDC, 2017a; Healthy People 2030, 2018; WHO, 2008). This study results can be used from professional practice to enhance outcomes centered on both a public health and medical care approach, and in setting up integrative health promotion, education, and prevention programs involving communities and hospitals to decrease surgery-related morbidity, improve surgical safety, and thus the population health. The concept of socially responsible surgery (SRS) specifically emphasizes the integration of surgical care and public health to evaluate the influence of the SDOH impacts on patients. This study results support SRS concept and public health mission (American College of Surgeons, 2020; Robinson et al., 2017; Rothstein, 2014).

Furthermore, this research study provides a novel social approach explanation of postoperative morbidity as social production after colorectal surgery. This novel view offers a new platform for surgical care considered of SDOH and could be utilized for positive social change to support development of new inclusive of SDOH and social and community context strategies and policies for surgical care. This novel view also offers new platform for further research inquiries and discussion about the SDOH influence on significant public health and surgical issues as SSI, AL, Not_SSI, and overall surgical morbidity. This study may also encourage researchers to apply a theoretical foundation to future research studies, and thus improve the scientific methods of the research work. In addition, this study could inform future research studies with a more robust design, and guide Spatio-temporal analyses and mapping of postoperative colorectal complications in New York state to identify and help communities in need and improve the population health.

Summary and Conclusion

In summary, this research inquiry addressed the role of the SDOH on a significant public health issue of HAI after colorectal surgery. Specifically, in this quantitative cross-sectional study the goal was to evaluate the association between individual and area-based levels SDOH and the AL, SSI, Not SSI, and overall surgical COMPL (infectious and non-infectious) occurrence within 30 days, in and out of the hospital, after initial colorectal surgery in adult patients in New York State, in the United States. The primary outcomes AL, SSI, Not SSI, and overall surgical COMPL were evaluated in four separate research questions. The study results showed SDOH on individual and contextual level (zip code and county level) were significantly associated with an increase or decrease of the likelihood of postoperative occurrence of AL, SSI, Not_SSI, and overall COMPL after colorectal surgery in adult patients. Based on these results, the null hypotheses in the four research questions were rejected, and the alternative hypotheses accepted.

The study results showed novel information about the impact of the SDOH on postoperative morbidity, provided a novel explanation about the postoperative morbidity occurrence as social production, expanded the knowledge about the racial disparity, demonstrated the inverse relationship of income on the postoperative complication occurrence, and reconfirmed the role of comorbidity risk and other clinical covariates on the postsurgical morbidity after colorectal surgery. Specifically, the study results showed that the “SVI Overall Social Vulnerability” on county code, and “High (90th percentile) Overall Social Vulnerability” on zip code and county code were significantly associated with increasing all four outcomes AL, SSI, Not SSI, and overall surgical COMPL after colorectal surgery. The study also demonstrated the significant role of the specific SVI Themes: Socioeconomic Status; Household Composition and Disability; Minority Status and Language; and Housing and Transportation vulnerabilities on the study outcomes, especially providing novel information about the “Household Composition and Disability” and “Housing and Transportation” vulnerability on zip code and county code.

Additionally, the study showed an inverse relationship between income and postsurgical complications on neighborhood zip code, meaning that increasing the income on area level significantly decreased postoperative morbidity outcomes AL, SSI, Not SSI, and COMPL after colorectal surgery. Further, this study findings showed a racial disparity in postoperative colorectal morbidity, with Black and African Americans having significantly higher AL, SSI, and overall COMPL after colorectal surgery in reference to the White population. Another essential aspect of this research study was utilizing CSDOH theoretical framework. The study provided a novel social approach explanation of the postoperative morbidity occurrence after colorectal surgery (AL, SSI, Not_SSI, and overall COMPL) utilizing the WHO CSDOH framework, applied widely by social epidemiology, to explain the surgical morbidity as social production of interplay between structural and intermediary SDOH leading to differential exposure and differential vulnerability, and subsequently to differential consequences of health outcomes AL, SSI, Not_SSI, and overall COMPL.

In conclusion, SDOH are significantly associated with AL, SSI, Not_SSI, and overall surgical COMPL within 30 days after colorectal surgery in the adult population and should be considered in surgical care to decrease surgical morbidity and improve surgical safety. Public health practitioners could utilize the SDOH for positive social change by developing programs, strategies, and policies considered of SDOH to reduce HAI (SSI and Not_SSI) after colorectal surgery; and to address upstream SDOH to improve surgical care by reducing the racial disparity gap in surgical morbidity, providing more equitable healthcare, and ultimately improving population health. The CSDOH theoretical framework utilizing the social production of the disease paradigm may be used in future studies to evaluate and explain postoperative morbidity as social production and support the development of new inclusive of SDOH and social and community context strategies and policies for surgical care. While this study results are generalizable only to the New York State population, researchers from other parts of the United States may use the methodology to assess the impact of the SDOH on surgical morbidity.

References

Aarts, M. J., Lemmens, V. E., Louwman, M. W., Kunst, A. E., & Coebergh, J. W. W. (2010). Socioeconomic status and changing inequalities in colorectal cancer? A review of the associations with risk, treatment and outcome. *European Journal of Cancer*, *46*(15), 2681–2695. https://doi.org/10.1016/j.ejca.2010.04.026

Adogwa, O., Elsamadicy, A. A., Fialkoff, J., Mehta, A. I., Vasquez, R. A., Cheng, J., Karikari, I. O., & Bagley, C. A. (2017). Effect of employment status on length of hospital stay, 30-day readmission and patient reported outcomes after spine surgery. *Journal of spine surgery (Hong Kong), 3*(1), 44 – 49. https://doi.org/10.21037/jss.2017.03.08

Agabiti, N., Cesaroni, G., Picciotto, S., Bisanti, L., Caranci, N., Costa, G., ... & Perucci, C. A. (2008). The association of socioeconomic disadvantage with postoperative complications after major elective cardiovascular surgery. *Journal of Epidemiology & Community Health*, *62*(10), 882 – 889. http://dx.doi.org/10.1136/jech.2007.067470

Agency for Toxic Substances and Disease Registry (2018). Social vulnerability index. https://svi.cdc.gov/

Alkaaki, A., Al-Radi, O. O., Khoja, A., Alnawawi, A., Alnawawi, A., Maghrabi, A., … Aljiffry, M. (2019). Surgical site infection following abdominal surgery: a prospective cohort study. *Canadian journal of surgery. Journal canadien de chirurgie*, *62*(2), 111–117. https://doi.org/10.1503/cjs.004818

Alkire, B. C., Raykar, N. P., Shrime, M. G., Weiser, T. G., Bickler, S. W., Rose, J. A., ... & Esquivel, M. (2015). Global access to surgical care: a modelling study. *The Lancet Global Health*, *3*(6), e316 – e323. http://dx.doi.org/%2010.1016/S2214-109X(15)70115-4

American College of Surgeon (2020). Social determinants of health and surgery: An overview. https://bulletin.facs.org/2021/05/social-determinants-of-health-and-surgery-an-overview/

American Hospital Association. (2021). Social Determinates of Health Series: Transportation and Role of the Hospitals. https://www.aha.org/ahahret-guides/2017-11-15-social-determinants-health-series-transportation-and-role-hospitals

American Psychological Association, T. F. O. S. S. (2007). Report of the APA task force on socioeconomic status.

An, R., & Xiang, X. (2015). Social vulnerability and obesity among US adults. *International Journal of Health Sciences*, *3*(3), 7 – 21. http://dx.doi.org/10.15640/ijhs.v3n3a2

Aoyama, T., Oba, K., Honda, M., Sadahiro, S., Hamada, C., Mayanagi, S., ... & Saji, S. (2017). Impact of postoperative complications on the colorectal cancer survival and recurrence: analyses of pooled individual patients' data from three large phase III randomized trials. *Cancer medicine*, *6*(7), 1573 – 1580. https://doi.org/10.1002/cam4.1126

Aschengrau, A., & Seage, G. R., III. (2014). *Essentials of epidemiology in public health* (3rd ed.). Jones & Bartlett.

Ashraf, S. Q., Burns, E. M., Jani, A., Altman, S., Young, J. D., Cunningham, C., & Mortensen, N. J. (2013). The economic impact of anastomotic leakage after anterior resections in English NHS hospitals: are we adequately remunerating them? *Colorectal Disease, 15*(4), e190-e198. https://doi.org/10.1111/codi.12125

Azoury, S. C., Farrow, N. E., Hu, Q. L., Soares, K. C., Hicks, C. W., Azar, F., & Eckhauser, F. (2015). Postoperative abdominal wound infection–epidemiology, risk factors, identification, and management. *Clinical wound care management and research*, *2*, 137 – 48. https://pdfs.semanticscholar.org/85b3/91ea81a43064a2e599f9502615400da36839.pdf

Bagger, J. P., Zindrou, D., & Taylor, K. M. (2004). Postoperative infection with meticillin-resistant Staphylococcus aureus and socioeconomic background. *The Lancet, 363*(9410), 706–708. https://doi.org/10.1016/S0140-6736(04)15647-X

Bankhead, C. (2015). Payers' perspectives: health economics outcomes in managed care. *American Health & Drug Benefits*, *8*(3), 144 – 147. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4467015/pdf/ahdb-08-144.pdf

Bayar, B., Yılmaz, K. B., Akıncı, M., Şahin, A., & Kulaçoğlu, H. (2016). An evaluation of treatment results of emergency versus elective surgery in colorectal cancer patients. *Turkish Journal of Surgery/Ulusal cerrahi dergisi, 32*(1), 11. https://pubmed.ncbi.nlm.nih.gov/26985154/

Bergs, J., Hellings, J., Cleemput, I., Zurel, Ö., De Troyer, V., Van Hiel, M., ... & Vandijck, D. (2014). Systematic review and meta-analysis of the effect of the World Health Organization surgical safety checklist on postoperative complications. *British Journal of Surgery*, *101*(3), 15 – 158. https://doi.org/10.1002/bjs.9381

Bergstrand, K., Mayer, B., Brumback, B., & Zhang, Y. (2015). Assessing the relationship between social vulnerability and community resilience to hazards. *Social Indicators Research*, *122*(2), 391 – 409. https://link.springer.com/article/10.1007%2Fs11205-014-0698-3

Berrios-Torres, S. I., Umscheid, C. A., Bratzler, D. W., Leas, B., Stone, E. C., Kelz, R. R., ... & Dellinger, E. P. (2017). Centers for Disease Control and Prevention guideline for the prevention of surgical site infection, 2017. *JAMA surgery*, *152*(8), 784 – 791. https://jamanetwork.com/journals/jamasurgery/fullarticle/2623725

Berzofsky, M., Smiley-McDonald, H., Moore, A., & Krebs, C. (2014). Measuring socioeconomic status (SES) in the NCVS: background, options, and recommendations. *Report. [Table 2-1. Victimization rates by type of crime and household income, 2010, p. 13.] Washington, DC: Bureau of Justice Statistics*. https://bjs.ojp.gov/sites/g/files/xyckuh236/files/media/document/measuring_ses-paper_authorship_corrected.pdf

Billingsley, K. G., Morris, A. M., Dominitz, J. A., Matthews, B., Dobie, S., Barlow, W., ... & Baldwin, L. M. (2007). Surgeon and hospital characteristics as predictors of major adverse outcomes following colon cancer surgery: understanding the volume-outcome relationship. *Archives of Surgery, 142*(1), 23 – 31. https://jamanetwork.com/journals/jamasurgery/fullarticle/399609

Bolin, J. N., Bellamy, G. R., Ferdinand, A. O., Vuong, A. M., Kash, B. A., Schulze, A., & Helduser, J. W. (2015). Rural healthy people 2020: new decade, same challenges. *The Journal of Rural Health*, *31*(3), 326 – 333. https://doi.org/10.1111/jrh.12116

Braga, M., Vignali, A., Gianotti, L., Zuliani, W., Radaelli, G., Gruarin, P., Dellabona, P., & Di Carlo, V. (2002). Laparoscopic versus open colorectal surgery: a randomized trial on short-term outcome. *Annals of surgery, 236*(6), 759–767. https://doi.org/10.1097/01.SLA.0000036269.60340.AE

Braveman, P. A., Cubbin, C., Egerter, S., Chideya, S., Marchi, K. S., Metzler, M., & Posner, S. (2005). Socioeconomic status in health research: one size does not fit all. *Jama*, *294*(22), 2879 – 2888. https://jamanetwork.com/journals/jama/fullarticle/202015

Burkholder, G. J., Cox, K. A., & Crawford, L. M. (2016). *The scholar-practitioner's guide to research design.* Baltimore, MD: Laureate Publishing.

Chan, D. K. H., Ang, J. J., Tan, J. K. H., & Chia, D. K. A. (2020). Age is an independent risk factor for increased morbidity in elective colorectal cancer surgery despite an ERAS protocol. *Langenbeck's Archives of Surgery, 405*(5), 673 – 689. https://doi.org/10.1007/s00423-020-01930-y

Carvalho, A. G. M. L., Limaylla, D. C., Vilches, T. N., de Almeida, G. B., Madalosso, G., de Assis, D. B., & Fortaleza, C. M. C. B. (2021). Spatial and sociodemographic factors associated with surgical site infection rates in hospitals in inner São Paulo State, Brazil. *Journal of Hospital Infection, 108*, 181–184. https://doi.org/10.1016/j.jhin.2020.11.018

Carmichael, H., Moore, A., Steward, L., & Velopulos, C. G. (2019). Using the Social Vulnerability Index to Examine Local Disparities in Emergent and Elective Cholecystectomy. *Journal of Surgical Research*, *243*, 160 –164. https://doi.org/10.1016/j.jss.2019.05.022

Centers for Disease Control and Prevention. (2011). CDC health disparities and inequalities report: United States. States. https://www.cdc.gov/mmwr/pdf/other/su6001.pdf

Centers for Disease Control and Prevention (2017a). Guideline for the prevention of surgical site infection, 2017. https://www.cdc.gov/infectioncontrol/guidelines/ssi/index.html

Centers for Disease Control and Prevention (2017b). Inflammatory bowel disease (IBD). https://www.cdc.gov/ibd/data-statistics.htm

Centers for Disease Control and Prevention (2017c). Social determinants of health. https://www.cdc.gov/nchhstp/socialdeterminants/faq.html#c

Centers for Disease Control and Prevention (2017d). Rural Americans at higher risk of death from five leading causes. https://www.cdc.gov/media/releases/2017/p0112-rural-death-risk.html

Centers for Disease Control and Prevention (2017e). CDC's Social Vulnerability Index (SVI). https://svi.cdc.gov/

Centers for Disease Control and Prevention (2021). Social determinants of health. know what affects health. https://www.cdc.gov/socialdeterminants/about.html

Chew, R. T., Sprague, S., & Thoma, A. (2005). A systematic review of utility measurements in the surgical literature. *Journal of the American College of Surgeons*, *200*(6), 954 – 964. https://doi.org/10.1016/j.jamcollsurg.2005.01.021

Cheng, H. G., & Phillips, M. R. (2014). Secondary analysis of existing data: opportunities and implementation. *Shanghai Archives of Psychiatry*, *26*(6), 371 – 375. http://doi.org/10.11919/j.issn.1002-0829.214171

Chung, K. C., & Kotsis, S. V. (2012). Complications in surgery: root cause analysis and preventive measures. *Plastic and reconstructive surgery*, *129*(6), 1421. 10.1097/PRS.0b013e31824ecda0

Cotte, E., Mohamed, F., Nancey, S., François, Y., Glehen, O., Flourié, B., Saurin, J. C., & Poncet, G. (2011). Laparoscopic total colectomy: Does the indication influence the outcome? *World journal of gastrointestinal surgery, 3*(11), 177 – 182. https://doi.org/10.4240/wjgs.v3.i11.177

Daniel, H., Bornstein, S. S., & Kane, G. C. (2018). Addressing social determinants to improve patient care and promote health equity: an American College of Physicians position paper. *Annals of internal medicine*, *168*(8), 577 – 578. https://doi.org/10.7326/M17-2441

Davenport, D. L., Henderson, W. G., Khuri, S. F., & Mentzer Jr, R. M. (2005). Preoperative risk factors and surgical complexity are more predictive of costs than postoperative complications: a case study using the National Surgical Quality Improvement Program (NSQIP) database. *Annals of surgery*, *242*(4), 463. 10.1097/01.sla.0000183348.15117.ab

Debarros, M. & Steele, S.R. (2013). Colorectal cancer screening in an equal access healthcare system. *J Cancer*. *4*, 270 – 80. https://www.jcancer.org/v04p0270.htm

Degett, T. H., Christensen, J., Thomsen, L. A., Iversen, L. H., Gögenur, I., & Dalton, S. O. (2020). Nationwide cohort study of the impact of education, income and social isolation on survival after acute colorectal cancer surgery. *BJS open, 4*(1), 133 – 144. https://doi.org/10.1002/bjs5.50218

Den Hartog, Y. M., Mathijssen, N. M., & Vehmeijer, S. B. (2013). Reduced length of hospital stay after the introduction of a rapid recovery protocol for primary THA procedures: A retrospective cohort study with 1,180 unselected patients. *Acta Orthopaedica*, *84*(5), 444 – 447. https://doi.org/10.3109/17453674.2013.838657

DeSantis, C., Naishadham, D., & Jemal, A. (2013). Cancer statistics for African Americans, 2013. *CA: a cancer journal for clinicians*, *63*(3), 151–166. https://doi.org/10.3322/caac.21173

Dexter, F., Epstein, R. H., & Loftus, R. W. (2021). Quantifying and interpreting inequality of surgical site infections among operating rooms. *Canadian Journal* *of Anesthesia/Journal canadien d'anesthésie, 1*–13. https://doi.org/10.1007/s12630-021-01931-5

Diderichsen, F., Evans, T., & Whitehead, M. (2001). The social basis of disparities in health. *Challenging inequities in health: From ethics to action*, *1*, 12–23.

Dik, V. K., Aarts, M. J., Van Grevenstein, W. M., Koopman, M., Van Oijen, M. G., Lemmens, V. E., & Siersema, P. D. (2014). Association between socioeconomic status, surgical treatment and mortality in patients with colorectal cancer. *British Journal of Surgery*, *101*(9), 1173 – 1182. https://doi.org/10.1002/bjs.9555

Din, A., & Wilson, R. (2020). Crosswalking ZIP Codes to Census Geographies. *Cityscape, 22*(1), 293–314. https://www.jstor.org/stable/10.2307/26915499

Dindo, D., Demartines, N., & Clavien, P.-A. (2004). Classification of surgical complications: a new proposal with evaluation in a cohort of 6336 patients and results of a survey. *Annals of Surgery*, *240*(2), 205 – 213. https://journals.lww.com/annalsofsurgery/Fulltext/2004/08000/Classification_of_Surgical_Complications__A_New.3.aspx

Divi, C., Koss, R. G., Schmaltz, S. P., & Loeb, J. M. (2007). Language proficiency and adverse events in US hospitals: a pilot study. *International journal for quality in health care, 19*(2), 60 – 67. https://doi.org/10.1093/intqhc/mzl069

Donkin, A., Goldblatt, P., Allen, J., Nathanson, V., & Marmot, M. (2018). Global action on the social determinants of health. *BMJ global health*, *3*(Suppl 1), e000603. http://dx.doi.org/10.1136/bmjgh-2017-000603

Ellis, H., & Mahadevan, V. (2014). Anatomy of the caecum, appendix and colon. *Surgery (Oxford)*, *32*(4), 155 – 158. https://daneshyari.com/article/preview/3838484.pdf

Eriksen, T. F., Lassen, C. B., & Gögenur, I. (2014). Treatment with corticosteroids and the risk of anastomotic leakage following lower gastrointestinal surgery: a literature survey. *Colorectal Disease, 16*(5), O154 – O160. https://doi.org/10.1111/codi.12490

Fiorati, R. C., & Elui, V. M. (2014). Social determinants of health and inequity among people with disabilities: A Brazilian experience. *Journal of Public Health and Epidemiology, 6*(11), 326 – 337. http://www.academicjournals.org/JPHE

Flanagan, B. E., Gregory, E. W., Hallisey, E. J., Heitgerd, J. L., & Lewis, B. (2011). A social vulnerability index for disaster management. *Journal of homeland security and emergency management*, *8*(1). http://www.bepress.com/jhsem/vol8/iss1/3

Flanagan, B. E., Hallisey, E. J., Adams, E., & Lavery, A. (2018). Measuring Community Vulnerability to Natural and Anthropogenic Hazards: The Centers for Disease Control and Prevention's Social Vulnerability Index. Journal of environmental health, 80(10), 34–36. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7179070/pdf/nihms-1063751.pdf

Flanagan, B., Hallisey, E., Sharpe, J. D., Mertzlufft, C. E., & Grossman, M. (2020). On the Validity of Validation: A Commentary on Rufat, Tate, Emrich, and

Antolini's "How Valid Are Social Vulnerability Models?". *Annals of the American Association of Geographers, 111*(4), em-i. https://doi.org/10.1080/24694452.2020.1857220

Floodeen, H., Hallböök, O., Hagberg, L. A., & Matthiessen, P. (2017). Costs and resource use following defunctioning stoma in low anterior resection for cancer–A long-term analysis of a randomized multicenter trial. *European Journal of Surgical Oncology (EJSO)*, *43*(2), 330 – 336. https://doi.org/10.1016/j.ejso.2016.12.003

Frankfort Nachmias, C., & Leon-Guerrero, A. (2015). *Social statistics for a diverse society* (7th ed.). Sage Publications

Frasson, M., Flor-Lorente, B., Rodríguez, J. L. R., Granero-Castro, P., Hervás, D., Alvarez Rico, M. A., ... & ANACO Study Group. (2015). Risk factors for anastomotic leak after colon resection for cancer. *Annals of surgery*, *262*(2), 321–330. 10.1097/SLA.0000000000000973

Frederiksen, B. L., Osler, M., Harling, H., Ladelund, S., & Jørgensen, T. (2009). Do patient characteristics, disease, or treatment explain social inequality in survival from colorectal cancer? *Social science & medicine, 69*(7), 1107–1115. https://doi.org/10.1016/j.socscimed.2009.07.040

Frühbeck, G. (2015). Bariatric and metabolic surgery: a shift in eligibility and success criteria. *Nature Reviews Endocrinology*, *11*(8), 465. https://www.nature.com/articles/nrendo.2015.84.pdf

Fry, D. E. (2013). The prevention of surgical site infection in elective colon surgery. *Scientifica*, *2013*. https://doi.org/10.1155/2013/896297

Funk, L. M., Weiser, T. G., Berry, W. R., Lipsitz, S. R., Merry, A. F., Enright, A. C., ... & Gawande, A. A. (2010). Global operating theatre distribution and pulse oximetry supply: an estimation from reported data. *The Lancet, 376*(9746), 1055 – 1061. https://doi.org/10.1016/S0140-6736(10)60392-3

Galea, S., Tracy, M., Hoggatt, K. J., DiMaggio, C., & Karpati, A. (2011). Estimated deaths attributable to social factors in the United States. *American journal of public health*, *101*(8), 1456 – 1465. https://doi.org/10.2105/AJPH.2010.300086

Glanz, K., Rimer, B. K., & Viswanath, K. (Eds.). (2008). *Health behavior and health education: theory, research, and practice*. John Wiley & Sons.

Goodman, S. M., Mandl, L. A., Mehta, B., Navarro-Millan, I., Russell, L. A., Parks, M. L., ... & Szymonifka, J. (2018). Does education level mitigate the effect of poverty on total knee arthroplasty outcomes? *Arthritis care & research*, *70*(6), 884 – 891. https://doi.org/10.1002/acr.23442

Goulder, F. (2012). Bowel anastomoses: The theory, the practice and the evidence base. *World Journal of Gastrointestinal Surgery*, *4*(9), 208 – 213. http://dx.doi.org/10.4240/wjgs.v4.i9.208

Ghaferi, A. A., Birkmeyer, J. D., & Dimick, J. B. (2009). Variation in hospital mortality associated with inpatient surgery. *New England Journal of Medicine*, *361*(14), 1368 – 1375. https://www.nejm.org/doi/full/10.1056/NEJMsa0903048

Guh, A. Y., Mu, Y., Winston, L. G., Johnston, H., Olson, D., Farley, M. M., ... & McDonald, L. C. (2020). Trends in US burden of Clostridioides difficile infection and outcomes. *New England Journal of Medicine, 382*(14), 1320 – 1330. https://www.nejm.org/doi/10.1056/NEJMoa1910215

Hall, M. J., Schwartzman, A., Zhang, J., & Liu, X. (2017). Ambulatory surgery data from hospitals and ambulatory surgery centers: United States, 2010. *National health statistics reports*, (102), 1 – 15. https://www.cdc.gov/nchs/data/nhsr/nhsr102.pdf

Hammond, J., Lim, S., Wan, Y., Gao, X., & Patkar, A. (2014). The burden of gastrointestinal anastomotic leaks: an evaluation of clinical and economic outcomes. *Journal of Gastrointestinal Surgery*, *18*(6), 1176 – 1185. https://link.springer.com/article/10.1007%2Fs11605-014-2506-4

Hanna, M. H., Vinci, A., & Pigazzi, A. (2015). Diverting ileostomy in colorectal surgery: when is it necessary? *Langenbeck's archives of surgery, 400*(2), 145 – 152. https://link.springer.com/article/10.1007%2Fs00423-015-1275-1

Hartmann, L. C., & Lindor, N. M. (2016). The role of risk-reducing surgery in hereditary breast and ovarian cancer. *New England Journal of Medicine*, *374*(5), 454 – 468. https://www.nejm.org/doi/10.1056/NEJMra1503523

Healthy People 2020 (2018). Social Determinants of Health. https://www.healthypeople.gov/2020/topics-objectives/topic/social-determinants-of-health

Healthy People 2030 (2021a). Social Determinants of Health.

https://health.gov/healthypeople/objectives-and-data/social-determinants-health

Healthy People 2030 (2021b). Discrimination. https://health.gov/healthypeople/objectives-and-data/social-determinants-health/literature-summaries/discrimination

Ho, Y. H., & Ashour, M. A. T. (2010). Techniques for colorectal anastomosis. *World Journal of Gastroenterology: WJG*, *16*(13), 1610. http://dx.doi.org/10.3748/wjg.v16.i13.1610

Horan, T. C., Andrus, M., & Dudeck, M. A. (2008). CDC/NHSN surveillance definition of health care–associated infection and criteria for specific types of infections in the acute care setting. *American journal of infection control*, *36*(5), 309 – 332. https://doi.org/10.1016/j.ajic.2008.03.002

Hulley, S. B. (Ed.). (2007). *Designing clinical research*. Lippincott Williams & Wilkins.

International Surgical Outcomes Study Group. (2016). Global patient outcomes after elective surgery: prospective cohort study in 27 low-, middle-and high-income countries. *British journal of anaesthesia*, *117*(5), 601– 609

Ioannidis, J. P., & Garber, A. M. (2011). Individualized cost-effectiveness analysis. *PLoS Med*, *8*(7), e1001058. https://doi.org/10.1371/journal.pmed.1001058

Israel, B. A., Schulz, A. J., Parker, E. A., & Becker, A. B. (1998). Review of community-based research: assessing partnership approaches to improve public health. *Annual review of public health*, *19*(1), 173 – 202. https://doi.org/10.1146/annurev.publhealth.19.1.173

Iyer, S., Saunders, W. B., & Stemkowski, S. (2009). Economic burden of postoperative ileus associated with colectomy in the United States. *Journal of Managed Care Pharmacy*, *15*(6), 485-494. https://doi.org/10.18553/jmcp.2009.15.6.485

Jönsson, B. (2009). Ten arguments for a societal perspective in the economic evaluation of medical innovations. *The European Journal of Health Economics*, *10*(4), 357–359. https://doi.org/10.1007/s10198-009-0173-2

Kalra, A. D., Fisher, R. S., & Axelrod, P. (2010). Decreased Length of Stay and Cumulative Hospitalized Days Despite Increased Patient Admissions and Readmissions in an Area of Urban Poverty. *Journal of General Internal Medicine*, *25*(9), 930 – 935. https://doi.org/10.1007/s11606-010-1370-5

Kazaryan, A. M., Røsok, B. I., & Edwin, B. (2013). Morbidity assessment in surgery: refinement proposal based on a concept of perioperative adverse events. *ISRN surgery*, *2013*. https://doi.org/10.1155/2013/625093

Kazaure, H. S., Roman, S. A., & Sosa, J. A. (2012). Association of postdischarge complications with reoperation and mortality in general surgery. *Archives of Surgery*, *147*(11), 1000-1007. https://doi.org/10.1001/2013.jamasurg.114

Kelz, R. R., Gimotty, P. A., Polsky, D., Norman, S., Fraker, D., & DeMichele, A. (2004). Morbidity and mortality of colorectal carcinoma surgery differs by insurance status. Cancer: *Interdisciplinary International Journal of the*

American Cancer Society, 101(10), 2187–2194. https://doi.org/10.1002/cncr.20624

Kempker, R. R., Vashakidze, S., Solomonia, N., Dzidzikashvili, N., & Blumberg, H. M. (2012). Surgical treatment of drug-resistant tuberculosis. *The Lancet infectious diseases*, *12*(2), 157–166. https://doi.org/10.1016/s1473-3099(11)70244-4

Kim, F. J., da Silva, R. D., Gustafson, D., Nogueira, L., Harlin, T., & Paul, D. L. (2015). Current issues in patient safety in surgery: a review. *Patient safety in surgery*, *9*(1), 26. https://doi.org/10.1186/s13037-015-0067-4

Klevens, R. M., Edwards, J. R., Richards Jr, C. L., Horan, T. C., Gaynes, R. P., Pollock, D. A., & Cardo, D. M. (2007). Estimating health care-associated infections and deaths in US hospitals, 2002. *Public health reports, 122*(2), 160 –166. https://doi.org/10.1177/003335490712200205

Koperna, T. (2003). Cost-effectiveness of defunctioning stomas in low anterior resections for rectal cancer: a call for benchmarking. *Archives of Surgery, 138*(12), 1334 – 8. https://doi.org/10.1001/archsurg.138.12.1334

Krarup, P. M., Nordholm-Carstensen, A., Jorgensen, L. N., & Harling, H. (2014). Anastomotic leak increases distant recurrence and long-term mortality after curative resection for colonic cancer: a nationwide cohort study. *Annals of surgery*, *259*(5), 930 – 938. https://doi.org/10.1097/sla.0b013e3182a6f2fc

Krieger, N. (2001). Theories for social epidemiology in the 21st century: an ecosocial perspective. *International journal of epidemiology*, *30*(4), 668 – 677. https://doi.org/10.1093/ije/30.4.668

Laerd Statistics (2018). Binomial Logistic Regression using SPSS Statistics. https://statistics.laerd.com/spss-tutorials/binomial-logistic-regression-using-spss-statistics.php

Lacassie, H. J., Ferdinand, C., Guzmán, S., Camus, L., & Echevarria, G. C. (2016). World Health Organization (WHO) surgical safety checklist implementation and its impact on perioperative morbidity and mortality in an academic medical center in Chile. *Medicine*, *95*(23). https://doi.org/10.1097/md.0000000000003844

Leotsakos, A., Zheng, H., Croteau, R., Loeb, J. M., Sherman, H., Hoffman, C., ... & Duguid, M. (2014). Standardization in patient safety: the WHO High 5s project. *International journal for quality in health care*, *26*(2), 109 – 116. https://doi.org/10.1093/intqhc/mzu010

Lessa, F. C., Mu, Y., Bamberg, W. M., Beldavs, Z. G., Dumyati, G. K., Dunn, J. R., ... & McDonald, L. C. (2015). Burden of Clostridium difficile infection in the United States. *New England Journal of Medicine, 372*(9), 825 – 834. https://doi.org/10.1056/nejmoa1408913

Ley, R. E., Peterson, D. A., & Gordon, J. I. (2006). Ecological and evolutionary forces shaping microbial diversity in the human intestine. *Cell*, *124*(4), 837 – 848. https://doi.org/10.1016/j.cell.2006.02.017

Li, B., Evans, D., Faris, P., Dean, S., & Quan, H. (2008). Risk adjustment performance of Charlson and Elixhauser comorbidities in ICD-9 and ICD-10 administrative databases. *BMC health services research*, *8*(1), 12. https://doi.org/10.1186/1472-6963-8-12

Magill, S. S., Edwards, J. R., Bamberg, W., Beldavs, Z. G., Dumyati, G., Kainer, M. A., ... & Fridkin, S. K. (2014). Multistate point-prevalence survey of health care–associated infections. *New England Journal of Medicine, 370*(13), 1198–1208. https://doi.org/10.1056/nejmoa1306801

Mahadevan, V. (2017). Anatomy of the caecum, appendix and colon. *Surgery (Oxford)*, *35*(3), 115 –120. https://doi.org/10.1016/j.mpsur.2017.01.014

Mahmoudi, E., Lu, Y., Chang, S. C., Lin, C. Y., Wang, Y. C., Chang, C. J., ... & Chung, K. C. (2017). The associations of hospital volume, surgeon volume, and surgeon experience with complications and 30-day rehospitalization after free tissue transfer: A national population study. *Plastic and reconstructive surgery, 140*(2), 403. https://dx.doi.org/10.1097%2FPRS.0000000000003515

Makin, G. B., Breen, D. J., & Monson, J. R. (2001). The impact of new technology on surgery for colorectal cancer. *World journal of gastroenterology*, *7*(5), 612. https://doi.org/10.3748/wjg.v7.i5.612

Marcello, P. W., Fleshman, J. W., Milsom, J. W., Read, T. E., Arnell, T. D., Birnbaum, E. H., ... & Whelan, R. L. (2008). Hand-assisted laparoscopic vs. laparoscopic colorectal surgery: a multicenter, prospective, randomized trial. *Diseases of the colon & rectum, 51*(6), 818 – 828. https://doi.org/10.1007/s10350-008-9269-5

McCormick, P. J., Lin, H. M., Deiner, S. G., & Levin, M. A. (2018). Validation of the all-patient refined diagnosis related group (APR-DRG) risk of mortality and severity of illness modifiers as a measure of perioperative risk. *Journal of medical systems, 42*(5), 1– 6. https://doi.org/10.1007/s10916-018-0936-3

McDermott, F. D., Heeney, A., Kelly, M. E., Steele, R. J., Carlson, G. L., & Winter, D. C. (2015). Systematic review of preoperative, intraoperative and postoperative risk factors for colorectal anastomotic leaks. *British Journal of Surgery*, *102*(5), 462– 479. https://doi.org/10.1002/bjs.9697

McGillicuddy, E. A., Schuster, K. M., Davis, K. A., & Longo, W. E. (2009). Factors predicting morbidity and mortality in emergency colorectal procedures in elderly patients. *Archives of Surgery, 144*(12), 1157–1162. https://doi.org/10.1001/archsurg.2009.203

Mehta, B., Goodman, S., Ho, K., D'angelo, D., Parks, M., & Ibrahim, S. (2019). Thu0442 Social Vulnerability and Discharge Disposition after Elective Total Hip Replacement? Risk-Adjusted Analysis of Large Regional Dataset. *Annals of the Rheumatic Diseases, 78*, 510 –511. https://doi.org/10.1089/heq.2019.0083

Meyers, A. G., Salanitro, A., Wallston, K. A., Cawthon, C., Vasilevskis, E. E., Goggins, K. M., ... & Schnelle, J. F. (2014). Determinants of health after hospital discharge: rationale and design of the Vanderbilt Inpatient Cohort Study (VICS). *BMC health services research*, *14*(1), 10. https://doi.org/10.1186/1472 6963-14-10

Midura, E. F., Hanseman, D., Davis, B. R., Atkinson, S. J., Abbott, D. E., Shah, S. A., & Paquette, I. M. (2015). Risk factors and consequences of anastomotic leak after colectomy: a national analysis. *Diseases of the Colon & Rectum*, *58*(3), 333 – 338. https://doi.org/10.1097/dcr.0000000000000249

Miller, K. D., Siegel, R. L., Lin, C. C., Mariotto, A. B., Kramer, J. L., Rowland, J. H., ... & Jemal, A. (2016). Cancer treatment and survivorship statistics, 2016. *CA: a cancer journal for clinicians*, *66*(4), 271 – 289. https://doi.org/10.3322/caac.21349

Miller, T. E., Thacker, J. K., White, W. D., Mantyh, C., Migaly, J., Jin, J., ... & Moon, R. E. (2014). Reduced length of hospital stay in colorectal surgery after implementation of an enhanced recovery protocol. *Anesthesia & Analgesia*, *118*(5), 1052–1061. https://doi.org/10.1213/ane.0000000000000206

Milsom, J. W., Böhm, B., & Nakajima, K. (2006). *Laparoscopic colorectal surgery* (pp. 133 –135). New York: Springer.

Min B. W. (2015). Efforts to prevent surgical site infection after colorectal surgery. *Annals of coloproctology*, *31*(6), 211– 212. https://doi.org/10.3393/ac.2015.31.6.211

Mirnezami, A., Mirnezami, R., Chandrakumaran, K., Sasapu, K., Sagar, P., & Finan, P. (2011). Increased local recurrence and reduced survival from colorectal cancer following anastomotic leak: systematic review and meta-analysis. *Annals of surgery*, *253*(5), 890 – 899. https://doi.org/10.1097/sla.0b013e3182128929

Mitchell, R. J., & Bates, P. (2011). Measuring health-related productivity loss. *Population health management*, *14*(2), 93 – 98. https://doi.org/10.1089/pop.2010.0014

Moghadamyeghaneh, Z., Mills, S. D., Carmichael, J. C., Pigazzi, A., & Stamos, M. J. (2015). Risk factors of postoperative myocardial infarction after colorectal surgeries. *The American Surgeon*, *81*(4), 358 – 364. https://doi.org/10.1177/000313481508100425

Molena, D., Mungo, B., Stem, M., Feinberg, R. L., & Lidor, A. O. (2015). Prevalence, impact, and risk factors for hospital-acquired conditions after major surgical resection for cancer: a NSQIP analysis. *Journal of Gastrointestinal Surgery*, *19*(1), 142–151. https://doi.org/10.1007/s11605-014-2642-x

Møller, H., Sandin, F., Robinson, D., Bray, F., Klint, Å., Linklater, K. M., ... & Morris, E. (2012). Colorectal cancer survival in socioeconomic groups in England: variation is mainly in the short term after diagnosis. *European Journal of Cancer*, *48*(1), 46 –53. https://doi.org/10.1016/j.ejca.2011.05.018

Möslein, G., Pistorius, S., Saeger, H. D., & Schackert, H. K. (2003). Preventive surgery for colon cancer in familial adenomatous polyposis and hereditary nonpolyposis colorectal cancer syndrome. *Langenbeck's archives of surgery*, *388*(1), 9 –16. https://doi.org/10.1007/s00423-003-0364-8

Mullen, M. G., Michaels, A. D., Mehaffey, J. H., Guidry, C. A., Turrentine, F. E., Hedrick, T. L., & Friel, C. M. (2017). Risk associated with complications and mortality after urgent surgery vs elective and emergency surgery: implications for defining "quality" and reporting outcomes for urgent surgery. *JAMA surgery, 152*(8), 768–774. https://doi.org/10.1001/jamasurg.2017.0918

Munro, B. H. (2005). *Statistical methods for health care research* (Vol. 1). Lippincott Williams & Wilkins.

Murray, A. C. A., Pasam, R., Estrada, D., & Kiran, R. P. (2016). Risk of surgical site infection varies based on location of disease and segment of colorectal resection for cancer. *Diseases of the Colon & Rectum*, *59*(6), 493 –500. https://doi.org/10.1097/dcr.0000000000000577

Narula MD, N., Curran MD, T., & Nagle MD, D. (2016). Return To The Hospital In Limited English Proficiency Patients After Inpatient Colorectal Surgery. *World Journal of Colorectal Surgery, 6*(1), 1. https://services.bepress.com/cgi/viewcontent.cgi?article=1215&context=wjcs

Nasirkhan, M.U., Abir, F., Longo, W., & Kozol, R. (2006). Anastomotic disruption after large bowel resection. *World Journal of Gastroenterology, 12* (16), 2497–504. https://doi.org/10.3748/wjg.v12.i16.2497

National Institute of Diabetes and Digestive and Kidney Diseases (2014). Digestive Diseases Statistics for the United States. https://www.niddk.nih.gov/health-information/health-statistics/digestive-diseases

National Health Care Network (2021). Surgical Site Infection Event (SSI). https://www.cdc.gov/nhsn/pdfs/pscmanual/9pscssicurrent.pdf

Neutzling, C. B., Lustosa, S. A., Proenca, I. M., da Silva, E. M., & Matos, D. (2012). Stapled versus handsewn methods for colorectal anastomosis surgery. *The Cochrane Library*. https://doi.org/10.1002/14651858.cd003144.pub2

New York Statewide Planning and Research Cooperative System (2014). Data output dictionary. https://www.health.ny.gov/statistics/sparcs/sysdoc/inpatientoutputdd.pdf

New York State Department of Health (2016). Statewide Planning and Research Cooperative System (SPARCS). https://www.health.ny.gov/statistics/sparcs/

New York State Department of Health (2021). Hospital-Acquired Infections in New York State, 2018 https://www.health.ny.gov/statistics/facilities/hospital/hospital_acquired_infections/

Nikolian, V. C., Kamdar, N. S., Regenbogen, S. E., Morris, A. M., Byrn, J. C., Suwanabol, P. A., ... & Hendren, S. (2017). Anastomotic leak after colorectal resection: a population-based study of risk factors and hospital variation. *Surgery*, *161*(6), 1619 –1627. https://doi.org/10.1016/j.surg.2016.12.033

Nordholm-Carstensen, A., Rolff, H. C., & Krarup, P. M. (2017). Differential Impact of Anastomotic Leak in Patients with Stage IV Colonic or Rectal Cancer: A Nationwide Cohort Study. *Diseases of the Colon & Rectum*, *60*(5), 497–507. https://doi.org/10.1097/dcr.0000000000000761

Numata, M., Sawazaki, S., Morita, J., Maezawa, Y., Amano, S., Aoyama, T., ... & Masuda, M. (2018). Comparison of laparoscopic and open surgery for colorectal cancer in patients with severe comorbidities. *Anticancer research, 38*(2), 963–967. https://doi.org/10.21873/anticanres.12310

Nutbeam, D. (1998). Health promotion glossary. Health promotion international, 13(4), 349-364. https://www.researchgate.net/profile/Don-Nutbeam/publication/12979284_The_WHO_health_promotion_glossary/links/542022590cf203f155c2aa6e/The-WHO-health-promotion-glossary.pdf

Ohland, C. L., & Jobin, C. (2015). Microbial activities and intestinal homeostasis: a delicate balance between health and disease. *Cellular and molecular gastroenterology and hepatology*, *1*(1), 28 – 40. https://doi.org/10.1016/j.jcmgh.2014.11.004

Panteleimonitis, S., Harper, M., Hall, S., Figueiredo, N., Qureshi, T., & Parvaiz, A. (2017). Precision in robotic rectal surgery using the da Vinci Xi system and integrated table motion, a technical note. *Journal of robotic surgery*, 1– 4. https://doi.org/10.1007/s11701-017-0752-7

Pak, H., Maghsoudi, L. H., Soltanian, A., & Gholami, F. (2020). Surgical complications in colorectal cancer patients. *Annals of Medicine and Surgery.* https://doi.org/10.1016/j.amsu.2020.04.024

Park, H. S., White, R. S., Ma, X., Lui, B., & Pryor, K. O. (2019). Social determinants of health and their impact on postcolectomy surgery readmissions: a multistate analysis, 2009 –2014. *Journal of comparative effectiveness research, 8*(16), 1365 – 1379. https://doi.org/10.2217/cer-2019-0114

Patel, M. R., Piette, J. D., Resnicow, K., Kowalski-Dobson, T., & Heisler, M. (2016). Social determinants of health, cost-related non-adherence, and cost-reducing behaviors among adults with diabetes: findings from the National Health Interview Survey. *Medical care*, *54*(8), 796. https://doi.org/10.1097/mlr.0000000000000565

Paulson, E. C., Thompson, E., & Mahmoud, N. (2017). Surgical site infection and colorectal surgical procedures: a prospective analysis of risk factors. *Surgical infections*, *18*(4), 520 – 526. https://doi.org/10.1089/sur.2016.258

Peduzzi, P., Concato, J., Kemper, E., Holford, T. R., & Feinstein, A. R. (1996). A simulation study of the number of events per variable in logistic regression analysis. *Journal of clinical epidemiology, 49(*12), 1373 –1379. https://doi.org/10.1016/s0895-4356(96)00236-3

Perencevich, E. N., Sands, K. E., Cosgrove, S. E., Guadagnoli, E., Meara, E., & Platt, R. (2003). Health and economic impact of surgical site infections diagnosed after hospital discharge. *Emerging infectious diseases*, *9*(2), 196. https://doi.org/10.3201/eid0902.020232

Polimeni, J. M., Vichansavakul, K., Iorgulescu, R. I., & Chandrasekara, R. (2013). Why perspective matters in health outcomes research analyses. *The International Business & Economics Research Journal (Online)*, *12*(11), 1503. https://doi.org/10.19030/iber.v12i11.8186

Qi, A. C., Peacock, K., Luke, A. A., Barker, A., Olsen, M. A., & Maddox, K. E. J. (2019). Associations between social risk factors and surgical site infections after colectomy and abdominal hysterectomy. *JAMA network open, 2*(10), e1912339-e1912339. https://doi.org/10.1001/jamanetworkopen.2019.12339

Regenbogen, S. E., Veenstra, C. M., Hawley, S. T., Banerjee, M., Ward, K. C., Kato, I., & Morris, A. M. (2014). The personal financial burden of complications after colorectal cancer surgery. *Cancer*, *120*(19), 3074 – 3081. https://doi.org/10.1002/cncr.28812

Reinhardt, U. E. (2006). The pricing of US hospital services: chaos behind a veil of secrecy. *Health Affairs*, *25*(1), 57–69. https://doi.org/10.1377/hlthaff.25.1.57

Reinhardt, U. E. (2011). The many different prices paid to providers and the flawed theory of cost shifting: is it time for a more rational all-payer system? *Health Affairs*, *30*(11), 2125 – 2133. https://doi.org/10.1377/hlthaff.2011.0813

Rickles, A. S., Iannuzzi, J. C., Kelly, K. N., Cooney, R. N., Brown, D. A., Davidson, M., ... & McGurrin, M. (2013). Anastomotic leak or organ space surgical site infection: What are we missing in our quality improvement programs? *Surgery*, *154*(4), 680 – 689. https://doi.org/10.1016/j.surg.2013.06.035

Robbins, A. S., Pavluck, A. L., Fedewa, S. A., Chen, A. Y., & Ward, E. M. (2009). Insurance status, comorbidity level, and survival among colorectal cancer patients age 18 to 64 years in the National Cancer Data Base from 2003 to 2005.

Journal of Clinical Oncology, 27(22), 3627–3633.
https://doi.org/10.1200/jco.2008.20.8025

Rolhion, N., & Chassaing, B. (2016). When pathogenic bacteria meet the intestinal microbiota. Philosophical transactions of the Royal Society of London. Series B, Biological sciences, *371(*1707) https://doi.org/10.1098/rstb.2015.0504

Rose, J., Schneider, C., Yildirim, C., Geers, P., Scheidbach, H., & Köckerling, F. (2004). Complications in laparoscopic colorectal surgery: results of a multicentre trial. *Techniques in coloproctology, 8*(1), s25-s28. https://doi.org/10.1007/s10151-004-0103-3

Rose, J., Weiser, T. G., Hider, P., Wilson, L., Gruen, R. L., & Bickler, S. W. (2015). Estimated need for surgery worldwide based on prevalence of diseases: a modelling strategy for the WHO Global Health Estimate. *The Lancet Global Health*, *3*, S13–S20. https://doi.org/10.1016/S2214-109X(15)70087-2

Sammour, T., Hayes, I. P., Jones, I. T., Steel, M. C., Faragher, I., & Gibbs, P. (2018). Impact of anastomotic leak on recurrence and survival after colorectal cancer surgery: a BioGrid Australia analysis. *ANZ journal of surgery*, *88*(1–2), E6-E10. https://doi.org/10.1111/ans.13648

Schlottmann, F., Strassle, P. D., Cairns, A. L., Herbella, F. A. M., Fichera, A., & Patti, M. G. (2020). Disparities in emergent colectomy for colorectal cancer contribute to inequalities in postoperative morbidity and mortality in the US health care system. *Scandinavian Journal of Surgery, 109*(2), 102–107. https://doi.org/10.1177/1457496919826720

Schmidt, O., Merkel, S., & Hohenberger, W. (2003). Anastomotic leakage after low rectal stapler anastomosis: significance of intraoperative anastomotic testing. *European Journal of Surgical Oncology (EJSO), 29*(3), 239–243. https://doi.org/10.1053/ejso.2002.1416

Sebastian, J. G. (2008). Vulnerability and vulnerable populations: an overview. *Public Health Nursing: Population-Centered Health Care in the Community. St Louis, MO: Mosby Elsevier*, *2008*, 710–733.

Sharp, S. P., Ata, A., Chismark, A. D., Canete, J. J., Valerian, B. T., Wexner, S. D., & Lee, E. C. (2020). Racial disparities after stoma construction in colorectal surgery. *Colorectal Disease, 22*(6), 713–722. https://doi.org/10.1111/codi.14943

Shavers V. L. (2007). Measurement of socioeconomic status in health disparities research. *Journal of the National Medical Association*, *99*(9), 1013–1023. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2575866/pdf/jnma00208-0045.pdf

Shi, L., & Johnson, J. A. (2013). *Novick & Morrow's Public Health Administration*. Jones & Bartlett Publishers.

Schneider, M. A., Rickenbacher, A., Frick, L., Cabalzar-Wondberg, D., Käser, S., Clavien, P. A., & Turina, M. (2018). Insurance status does not affect short-term outcomes after oncological colorectal surgery in Europe, but influences the use of minimally invasive techniques: a propensity score-matched analysis. *Langenbeck's archives of surgery, 403*(7), 863 – 872. https://www.zora.uzh.ch/id/eprint/167898/1/Manuscript_LAOS_forZORA_complete.pdf

Sieber, F. E., & Barnett, S. R. (2011). Preventing postoperative complications in the elderly. *Anesthesiology clinics*, *29*(1), 83 – 97. https://doi.org/10.1016/j.anclin.2010.11.011

Sinno, H., & Prakash, S. (2013). Complements and the wound healing cascade: an updated review. *Plastic surgery international*, *2013*. https://doi.org/10.1155/2013/146764

Slesser, A. A. P., Pellino, G., Shariq, O., Cocker, D., Kontovounisios, C., Rasheed, S., & Tekkis, P. P. (2016). Compression versus hand-sewn and stapled anastomosis in colorectal surgery: a systematic review and meta-analysis of randomized controlled trials. *Techniques in coloproctology*, *20*(10), 667– 676. https://doi.org/10.1007/s10151-016-1521-8

Solar, O., & Irwin, A. (2010). *A conceptual framework for action on the social determinants of health.* WHO Document Production Services. http://hdl.handle.net/1903/23135

Sparreboom, C. L., Zhou-Qiao Wu, J. F. J., & Lange, J. F. (2016). Integrated approach to colorectal anastomotic leakage: Communication, infection and healing disturbances. *World journal of gastroenterology*, *22*(32), 7226. https://doi.org/10.3748/wjg.v22.i32.7226

Stanford Health Care (2020). Surgery Statistics. https://stanfordhealthcare.org/medical-clinics/surgery-clinic/patient-resources/surgery-statistics.html

Stanhope, M., & Lancaster, J. (2015). *Public health nursing-e-book: Population-centered health care in the community*. Elsevier Health Sciences.

Stey, A. M., Brook, R. H., Keeler, E., Harris, M. T., Heimann, T., & Steinhagen, R. M. (2014). Outcomes and Cost of Diverted Versus Undiverted Restorative Proctocolectomy. *Journal of Gastrointestinal Surgery*, *18*(5), 995 –1002. https://doi.org/10.1007/s11605-014-2479-3

Stewart, W. F., Ricci, J. A., Chee, E., & Morganstein, D. (2003). Lost productive work time costs from health conditions in the United States: results from the American Productivity Audit. *Journal of Occupational and Environmental Medicine*, *45*(12), 1234 –1246. https://doi.org/10.1001/jama.290.18.2443

Stommel, M., Given, C. W., & Given, B. A. (1993). The cost of cancer home care to families. *Cancer*, *71*(5), 1867–1874. https://doi.org/10.1002/1097-0142(19930301)71:5%3C1867::aid-cncr2820710525%3E3.0.co;2-7

Tang, E. W., Go, J., Kwok, A., Leung, B., Lauck, S., Wong, S. T., ... & Ratner, P. A. (2016). The relationship between language proficiency and surgical length of stay following cardiac bypass surgery. *European journal of cardiovascular nursing, 15*(6), 438–446. https://doi.org/10.1177/1474515115596645

Tang, R., Chen, H. H., Wang, Y. L., Changchien, C. R., Chen, J. S., Hsu, K. C., Chiang, J. M., & Wang, J. Y. (2001). Risk factors for surgical site infection after elective resection of the colon and rectum: a single-center prospective study of 2,809 consecutive patients. *Annals of surgery, 234*(2), 181–189. https://doi.org/10.1097/00000658-200108000-00007

Takahashi, H., Haraguchi, N., Nishimura, J., Hata, T., Yamamoto, H., Matsuda, C., ... & Mori, M. (2018). The Severity of Anastomotic Leakage May Negatively Impact the Long-term Prognosis of Colorectal Cancer. *Anticancer research*, *38*(1), 533 –539. https://doi.org/10.21873/anticanres.12255

The National Institute of Diabetes and Digestive and Kidney Diseases Health Information Center (n.d). Digestive Diseases Statistics for the United States. https://www.niddk.nih.gov/health-information/health-statistics/digestive-diseases

Thompson, D. A., Makary, M. A., Dorman, T., & Pronovost, P. J. (2006). Clinical and economic outcomes of hospital acquired pneumonia in intra-abdominal surgery patients. *Annals of surgery, 243*(4), 547–552. https://doi.org/10.1097/01.sla.0000207097.38963.3b

Topaz, M., Shafran-Topaz, L., & Bowles, K. H. (2013). ICD-9 to ICD-10: evolution, revolution, and current debates in the United States. *Perspectives in health information management/AHIMA, American Health Information Management Association*, *10*(Spring). https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3692324/pdf/phim0010-0001d.pdf

Tran, B., Carmichael, H., & Velopulos, C. G. (2020). When More Is Less: Increased Time Burden and Disparity in Access to Surgical Care by Transportation

Means. *Journal of the American College of Surgeons, 231*(4), S154. https://doi.org/10.1016/j.jamcollsurg.2020.07.752

Trencheva, K., Morrissey, K.P., Wells, M., Mancuso, C.A., Lee, S.W., Sonoda, T., Michelassi, F., Charlson, M.E. and Milsom, J.W. (2013). Identifying important predictors for anastomotic leak after colon and rectal resection: prospective study on 616 patients. *Annals of surgery, 257*(1), 108 –113. https://doi.org/10.1097/sla.0b013e318262a6cd

Turrentine, F. E., Denlinger, C. E., Simpson, V. B., Garwood, R. A., Guerlain, S., Agrawal, A., ... & Jones, R. S. (2015). Morbidity, mortality, cost, and survival estimates of gastrointestinal anastomotic leaks. *Journal of the American College of Surgeons*, *220*(2), 195 – 206. https://doi.org/10.1016/j.jamcollsurg.2014.11.002

U.S. Census Bureau. (2016). Income inequalities. https://www.census.gov/topics/income-poverty/income inequality/about/metrics/gini-index.html

U.S. Census Bureau (2018b). American Community Survey. https://www.census.gov/programs-surveys/acs/about.html

U.S. Census Bureau (2018c). American Fact Finder. https://factfinder.census.gov/faces/nav/jsf/pages/searchresults.xhtml?refresh=t

United States Department of Agriculture Economic Research Service [USDARS] (2019). Rural-Urban Continuum Codes. https://www.ers.usda.gov/data-products/rural-urban-continuum-codes.aspx#.UYJuVEpZRvY

Van Eeghen, E. E., den Boer, F. C., & Loffeld, R. J. L. F. (2015). Thirty days post-operative mortality after surgery for colorectal cancer: a descriptive study. *Journal of Gastrointestinal Oncology, 6*(6), 613 – 617. https://doi.org/10.3978/j.issn.2078-6891.2015.079

van den Berg, I., Büttner, S., van den Braak, R. C., Ultee, K. H. J., Lingsma, H. F., van Vugt, J. L. A., & Ijzermans, J. N. M. (2019). Low socioeconomic status is associated with worse outcomes after curative surgery for colorectal cancer: results from a large, multicenter study. *Journal of Gastrointestinal Surgery,1*–9. https://doi.org/10.1007/s11605-019-04435-2

Vonlanthen, R., Slankamenac, K., Breitenstein, S., Puhan, M. A., Muller, M. K., Hahnloser, D., & Clavien, P. A. (2011). The impact of complications on costs of major surgical procedures: a cost analysis of 1200 patients. *Annals of surgery*, *254*(6), 907–913. https://doi.org/10.1097/sla.0b013e31821d4a43

Wagle, U. (2002). Rethinking poverty: definition and measurement. *International Social Science Journal*, *54*(171), 155 – 165. https://doi.org/10.1111/issj.12192

Weiser, T. G., Regenbogen, S. E., Thompson, K. D., Haynes, A. B., Lipsitz, S. R., Berry, W. R., & Gawande, A. A. (2008). An estimation of the global volume of surgery: a modelling strategy based on available data. *The Lancet*, *372*(9633), 139 –144. https://doi.org/10.1016/s0140-6736(08)60878-8

Wilkinson, R., & Pickett, K. (2011). *The spirit level: Why greater equality makes societies stronger*. Bloomsbury Publishing United States.

World Health Organization (2002). Prevention of hospital-acquired infections.

https://www.who.int/csr/resources/publications/whocdscsreph200212.pdf

World Health Organization (2008). Safe surgery saves lives. http://apps.who.int/iris/bitstream/10665/70080/1/WHO_IER_PSP_2008.07_eng.pdf

World Health Organization (2010). A conceptual framework for action on the social determinants of health. Social Determinants of Health Discussion Paper 2 (Policy and Practice) http://www.who.int/sdhconference/resources/ConceptualframeworkforactiononSDH_eng.pdf.

World Health Organization (2021). Disability. https://www.who.int/health-topics/disability#tab=tab_1

World Health Organization (2021). Social determinants of health. https://www.who.int/health-topics/social-determinants-of-health#tab=tab_1

The evolution of cancer surgery and future perspectives. *Nature Reviews Clinical Oncology*, *12*(2), 115. https://doi.org/10.1038/nrclinonc.2014.191

You, Y. N., Lakhani, V. T., & Wells, S. A. (2007). The role of prophylactic surgery in cancer prevention. *World journal of surgery*, *31*(3), 450 – 464. https://doi.org/10.1007/s00268-006-0616-1

Ziegler, M. A., Catto, J. A., Riggs, T. W., Gates, E. R., Grodsky, M. B., & Wasvary, H. J. (2012). Risk factors for anastomotic leak and mortality in diabetic patients undergoing colectomy: analysis from a statewide surgical quality collaborative. *Archives of surgery*, *147*(7), 600 – 605. https://doi.org/10.1001/archsurg.2012.77

Zinn, J. (2013). Surgical patients: a vulnerable population. *AORN journal*, *98*(6), 647–652. https://doi.org/10.1016/j.aorn.2013.09.004

Zimmerman, E. B., Woolf, S. H., & Haley, A. (2015). Understanding the relationship between education and health: a review of the evidence and an examination of community perspectives. Population health: behavioral and social science insights. Rockville (MD): *Agency for Health-care Research and Quality,347*-84. https://nam.edu/wp-content/uploads/2015/06/BPH UnderstandingTheRelationship1.pdf

Zoucas, E., & Lydrup, M. L. (2014). Hospital costs associated with surgical morbidity after elective colorectal procedures: a retrospective observational cohort study in 530 patients. *Patient safety in surgery*, *8*(1), 2. https://doi.org/10.1186/1754-9493-8-2

Appendix A: Definitions and Data Dictionaries

Definition of Variables

Age: Subject's age measured in years at the time of surgery, numerical, example: "55", or categorical "Above 65"

Gender: categorical, male, female

Preoperative diagnosis(s): patient diagnosis or medical condition for which the patient is undergoing surgical treatment coded via ICD 9 codes or IC10 codes

Comorbidities: any other existing medical condition in addition to the medical condition for which the patient is receiving treatment at the time of surgery.

Surgical Procedure(s): collected with the corresponding ICD 9 and ICD 10 procedure codes

Length of Hospital Stay (LOS): length of stay in the hospital from admission day to the discharge day, measured in days.

Length of Postsurgical Stay (POS): length of stay in the hospital, from day of surgery to the day of discharge, measured in days.

Major Anastomotic Leaks: AL which require interventional radiology or a surgical procedure to resolve, and consequently prolonged hospitalization or readmission/s with additional hospital days.

Minor Anastomotic Leaks: anastomotic leaks not requiring interventional radiology or additional surgeries and are manageable by antibiotics or minor hospital or office treatments.

Post-surgical Complications: any adverse event or deviation from the normal recovery course following surgery in or out of the hospital up to 30 days after surgery. Dichotomous variable “yes” or “no”.

Major Postsurgical Complications: postsurgical complications which lead to one or more of the following: prolonged hospital stay, readmission, interventional radiology intervention or reoperation in order to be resolved

Minor Postsurgical Complications: postsurgical complications requiring medical management, minor office procedures or readmission with medical management to achieve resolution.

Overall Infectious postsurgical complications: any infection within 30 days of surgery caused by bacteria, virus or fungi and with documented treatment. Overall infectious complications include surgical site and non-surgical site infection such a nosocomial pneumonia, urinary tract infections and others.

Surgical Site Infection: include infection related to the actual surgical resection site of the surgery such as: wound infection, abdominal abscess, pelvic abscess, retroperitoneal abscess, AL, and septicemia.

Not Surgical Site Infection Complication: Not_SSI related infections are infections after surgery not related to the surgical site incision but other parts of the body and include infections such as pneumonia, bloodstream infections, Clostridium difficile colitis, Methicillin-Resistant Staphylococcus Aureus (MRSA), Vancomycin-resistant Enterococci (VRE) and urinary tract infection, caused by bacteria, virus or fungi and requiring treatment.

Non-infectious surgical complications: complication after surgery not caused by infectious agent but from other factors such as physiological, environmental, behavioral, and genetic factors and others. Example of such complications are myocardial infarction, stroke, pulmonary embolism, DVT and others.

Mortality: mortality after colorectal surgery is defined as any death occurring within 30 days after surgery in or out of the hospital regardless of cause. It is collected as dichotomous "yes" or "no" variable in the data. In the SPARCS dataset Mortality depicts only in hospital mortality and is coded under the Discharge disposition with code 20.

Data Dictionaries

NY SPARCS data dictionary Version 1.0 2014

NY SPARCS data dictionary is described in detail at Inpatient Output Data Dictionary Version 1.0 2014 at the following link: https://www.health.ny.gov/statistics/sparcs/sysdoc/inpatientoutputdd.pdf.

American Community Survey 2016 data dictionary

link: https://www2.census.gov/programs-surveys/acs/tech_docs/subject_definitions/2016_ACSSubjectDefinitions.pdf?#

CDC SVI Dictionary

https://svi.cdc.gov/Documents/Data/2016_SVI_Data/SVI2016Documentation.pdf

USDA Rural Urban Continuum Dictionary

USDA ERS - Rural-Urban Continuum Codes

Appendix B: ICD Codding, Data Identification and Variables Presentation

Diagnostic, Procedure, Dependent and Independent Variables Codes

This Appendix consist of diagnostic and procedure ICD 9 and ICD 10 codes used to identify the data sample from the SPARCS data master file, and to define the study outcomes from SPARCS data. The identified dependent variables, Social Determinants of Health (Independent Variables) and covariates used in the study are presented in this Appendix B.

Table B1

Primary Diagnostic and Procedure ICD 9 and ICD 10 codes to identify the data

	Diagnostic and Procedure codes	ICD-9 Codes	ICD-10 Codes
Diagnostic Category	Diagnostic groups		
1. Neoplasms	Colon Cancer	1530, 1531, 1532, 1533, 1534, 1536, 1537, 1538, 1539, 2303	C183, C184, C186, C180, C182, C185, C188, C189, C187
	Rectal Cancer	1540, 1541, 1542,1543, 1548, 2304, 2305, 2306	C19, C20, C21, C211, C218
	Benign neoplasm	2113,2114,2119	D126, D128
2. IBD	Ulcerative Colitis	5560, 5561, 5562, 5563, 5564, 5565, 5566, 5568, 5569	K5100, K51011, K51012, K51013, K51014, K51018, K51019, K5120, K51211, K51212, K51213, K51214, K51218, K51219, K5130, K51311, K51312, K51313, K51314, K51318, K51319, K5140, K51411, K51412, K51413, K51414, K51418, K51419, K5150, K51511, K51512, K51513, K51514, K51518, K51519, K5180, K51811, K51812, K51813, K51814, K51818, K51819, K5190, K51911, K51912, K51913, K51914, K51918, K51919
	Crohn's disease	555,5550, 5551,5552, 5559, 56089	K5010, K5080, K50112, K50113, K50114, K50118, K50119, K5080, K50811, K50812, K50813, K50814, K50818, K50819, K5090, K50911, K50912, K50913, K50914, K50918, K50919
3. Diverticulitis	Diverticulitis	5621, 56210, 56211, 56212, 56213,	K5732, K5792,
4. OTHER Include Obstruction and other diagnosis	Obstruction	56089, 5609, 5602, 5603, 5608, 56081	K5669, K5660, K56609, K5650, K5651, K5652
	Other Diagnosis	Include Anything else that is not part of Cancer, IBD, Diverticulitis or Obstruction	
Diverting Stoma	Stoma creation Yes No	4610, 4611, 4613, 4620, 4621, 4622, 4623, 463, 4631, 4632, 4639	0D1H0Z4, 0D1H4Z4, 0D1H8Z4, 0D1K0Z4, 0D1K4Z4, 0D1K8Z4, 0D1L0Z4, 0D1L4Z4, 0D1L8Z4, 0D1N0Z4, 0D1N4Z4, 0D1N8Z4, 0D1B0Z4, 0D1B4Z4, 0D1B8Z4
Percutaneous drainage of an abscess within 30 days	Yes No	5491	Z4803, 0W9G30Z

Table B 2

ICD 9 and ICD 10 codes used to identify the study outcomes from SPARCS data

Study Outcomes within 30 days after surgery		Type of variable	ICD 9 Code	ICD10 Code
Overall Surgical complications (Include presence of any infectious and/or non-infectious complications below)		Yes_No		
Infectious Surgical complications (include SSI and Not_SSI infectious complications)		Yes_No		
Surgical Site Infectious Complications (SSI) Yes _ No	Anastomotic Leak	Yes_No	'99749', '9974', '56722', '56981', '56721','4694', '56729', 5679, 98831, 9093, 99889, 5491	'K9189', 'K651', 'K632' 'K9181', 'K9189', 'K658', 'K659', T8132XA, T8189XA, K9185
	Abdominal Abscess	Yes_No	'56722', 5491	'K651'
	Pelvic Abscess	Yes_No	'56722', 5491	'K651' , 'N73.9', 'K611'
	Retroperitoneal Abscess	Yes_No	'99859', 5673, 56738, 5491	'K6811', 'K6819'
	Peritonitis	Yes_No	'567', '5671', '5672','56721','56722', '56729', '5679',56789	'K658', 'K659'
	Wound Infection	Yes_No	'99859'	'T814XXA', 'T8140','T8141', 'T8142', 'T8143', 'T8140XA','T8141XA ', T8142XA','T8143XA, 'T8145', ,'T8149', T8131XA, T813
Not_SSI Infectious Complications Yes _ No	Sepsis, Septicemia generalized	Yes_No	'99591', '99859',	'K6811', T8144, A419
	MRSA/VRE	Yes_No	'04112', V098, 03812	'B9562', Z1621, A4902, A4102, J15212, Z1611, Z16431
	Pneumonia	Yes_No	'9973', 486, 4808, 4828	'J189', 'J9589',
	Urinary Tract Infection	Yes_No	'5990',	'N390'
	C Diff. /Infectious colitis	Yes_No	00845, 00846, 5589	A0474
Non-Infectious Surgical Complications (include any non-infectious complication)		Yes_No		
	Myocardial Infarction	Yes_No	'4111', '4118', '41181', '41189', '9971', '9980	I 219','I97111', 'I200', 'I21', 'I22', 'I240', 'I248', 'I249', 'I9789'
	Stroke	Yes_No	'99702', '430', '431', '432', '4320', '4321', '4329' 43491,43401	'I97821', 'I609', 'I619', 'I621', 'I6200', 'I629' 'I639' I1635
	Pulmonary embolism	Yes_No	'4151', '41511', '41512', '41513', '41519'	'I2690', 'I2692', 'I2699', 'T800XXA', 'T81718A', 'T8172XA', 'T82817A', 'T82818A'

Hemorrhage/Bleeding	Yes_No	'99811', 5789	'L7622', K91840, K8187
Shock	Yes_No	'9980', '99800', '99801', '99802', '99809'	'T8110XA', 'T8111XA', 'T8112XA'
DVT (Deep Vein Thrombosis)	Yes_No	'4534', '9972', 4511,45111, 4512,45340,45341, 45342, 45380,45382,45383,4539	'I82401', 'I82402', ' I82403'
SBO (Small Bowel Obstruction)	Yes_No	'56081"5609', 5602, 5603, 5608, 56089	'K56609', 'K5650','K5651', 'K5652' , K913, K9131, K9132, K5660, K5669
Postoperative Ileus	Yes_No	'5601', 3449, 56089	'K9189', 'K560', K567, K598
Mortality in-hospital	Yes_No	'7999'	'Z634' (NOT PRESENT ON ADMISSION)

Note: ICD 9 and ICD 10 codes used to identify the study outcomes from SPARCS data, identified at index admission as a diagnosis "NOT Present on Admission" to any hospital in NY State within 30 days of surgery. Present on Admission (POA) indicator 1-24, page 153 NYS SPARCS Dictionary Version 1.0 2014 will be used.

Independent and Dependent Variables NY SPARCS

Table B 3

SPARCS data variables included in the sample

Variables from the SPARCS data	Type of Variable	SPARCS dictionary 2014 page	Comment
Age	Continuous	51	Year at time of admission
Sex	Dichotomous/ Y_N	53	Male/Female
Preoperative Diagnosis Neoplasm/ /IBD/DIVERTICULITIS/OTHER	Categorical 4 cat		ICD 9 and ICD 10Table 1
Admitting Diagnosis Code	ICD 9 and ICD 10	148	
Principal Diagnosis Code	ICD 9 and ICD 10	149	
Name of the principal diagnosis	Categorical 4 cat		ICD 9 and ICD 10 name
Neoplasm Type	Categorical 3 cat		ICD 9 and ICD 10Table 1
IBD Type	Categorical 2 cat		ICD 9 and ICD 10Table 1
Principal Surgical Procedure Code	ICD 9 and ICD 10	161	ICD 9 and ICD 10 name
Name of the Surgical Procedure	Categorical		ICD 9 and ICD 10 name
Procedure groups (colon/rectal resection)	Categorical 2 cat		ICD 9 and ICD 10 name
Surgery site (right, left, transverse, rectal, total, other)	Categorical 6 cat		ICD 9 and ICD 10Table 1
Surgical approach-Laparoscopic, Open	Categorical 2 cat		ICD 9 and ICD 10Table 1
Diverting Stoma at the index procedure	Dichotomous/ Y_N		ICD 9 and ICD 10Table 1
Anastomosis type	Categorical		ICD 9 and ICD 10Table 1
Anastomosis distal connection	Categorical 3 cat		
Type of Admission –Elective/Emergency /Urgent	Categorical 3 cat	145	
Admit Type 2_Elective-Emergency	Categorical 2 cat		Collapsed
CCS Diagnostic Category	Categorical	155	
CCS Procedure category	Categorical	169	
Unscheduled/Scheduled Admission	Categorical	124	
Refined risk of mortality	Continuous	189	
All patients refined severity of illness (APRSOI)	Continuous	190	
Race	Categorical	54	
Minority vs. White	Categorical 2 cat		Race Collapsed to 2 cat
Type of Insurance/Source of payment info 1-6	Categorical	81	Name of the primary insurance that will pay
Insured Days	Continuous	129	
Non-Insured Days	Continuous	130	
Service Category Group	Categorical	144	Surgical service
Hospital name		70	SPARCS
Hospital county code/location	Number/Categorical	72	
Hospital volume case volume per year	Continuous		(# of cases of large bowel per year in each hospital)
Hospital volume categories	Categorical		Quartiles
Residence indicator (homeless vs. none)	Categorical	107	SPARCS
Patient County code	Number/Categorical	61	SPARCS
Patient County Name			SPARCS
Patient Zip code (last 3 number)	Number/Categorical	60	Need to connect ACS SDOH data
Patient City		58	SPARCS
Length of stay in the hospital	Continuous	128	SPARCS
Post-Op Days	Continuous	165	SPARCS
Readmission within 30 days	Categorical Y_N		As Y_N variable

Reoperation within 30 days	Categorical Y_N		As Y_N variable
Mortality in hospital	Categorical Y_N		SPARCS has special code
Total Leave of Absence (LOA) Days		131	SPARCS
Pre-Admit Procedure Indicator 1-15		163	SPARCS
Present on Admission (POA) indicator 1-24		153	SPARCS
Outcome Variables			
All outcomes are within 30 days after the surgery date			
Anastomotic Leak within 30 days	Categorical Y_N		ICD 9 and ICD 10Table
Overall Surgical Complications within 30 days	Categorical Y_N		ICD 9 and ICD 10Table
Infectious Complications within 30 days	Categorical Y_N		ICD 9 and ICD 10Table
Surgical Site Infection (SSI) within 30 days	Categorical Y_N		ICD 9 and ICD 10Table
Not_SSI related infections within 30 days	Categorical Y_N		ICD 9 and ICD 10Table
Noninfectious complications within 30 days	Categorical Y_N		ICD 9 and ICD 10Table
Mortality(in-hospital) after surgery	Categorical Y_N		ICD 9 and ICD 10Table
Post Discharge Out of Hospital (OH) Up 30days after surgery			
OH_Anastomotic Leak within 30 days	Categorical Y_N		ICD 9 and ICD 10Table
OH_Overall Surgical Complications within 30 days	Categorical Y_N		ICD 9 and ICD 10Table
OH_Infectious Complications within 30 days	Categorical Y_N		ICD 9 and ICD 10Table
OH_Surgical Site Infection (SSI) within 30 days	Categorical Y_N		ICD 9 and ICD 10Table
OH_Not_SSI related infections within 30 days	Categorical Y_N		ICD 9 and ICD 10Table
OH_Noninfectious complications within 30 days	Categorical Y_N		ICD 9 and ICD 10Table

Social Determinants of Health (Independent Variables)

Table B4

Social Determinants of Health (Independent Variables)

Independent Variables Social Determinants of Health (SDOH)	Variable type	Description of the SDOH variable	Data Source
SPARCS data Patient level SDOH			
Race	Categorical	Individual patient race	SPARCS
Minority vs. White	Categorical	Individual patient race	SPARCS
Type of Insurance/Source of payment	Categorical	Patient health insurance	SPARCS
Medicaid	Categorical	Patient health insurance	SPARCS
Medicare	Categorical	Patient health insurance	SPARCS
Other Federal Program	Categorical	Patient health insurance	SPARCS
Private/Commercial Insurance	Categorical	Patient health insurance	SPARCS
Self-Pay	Categorical	Patient health insurance	
Annual Hospital Case Volume	Categorical	Number of cases per year in the facility patient has index surgery	SPARCS
Community /Areas on ZIP code level SDOH Single Measurement Estimates			
U.S. Native	Continuous	% Native Born in US	ACS
Foreign Born	Continuous	% Foreign Born	ACS
Language and Education			
Englspvwell_S1601p	Continuous	% Percent speak English only or speak English "very well"	ACS
Engllessthanvwell_S1601p	Continuous	% Percent speak English less than "very well"	ACS
SpeakonlyEngl_S1601p	Continuous	% Speak only English	ACS
LimEngl_allhh_S1602p	Continuous	%Percent limited English-speaking households	ACS
Education Level (8 levels)	Continuous	% Percent of people in education level	ACS
Less than 9th grade	Continuous	% Percent of people	ACS
Has 9th to 12th grade no Diploma	Continuous	% Percent of people	ACS
High School GED	Continuous	% Percent of people	ACS
Some College No degree	Continuous	% Percent of people	ACS
Associate Degree	Continuous	% Percent of people	ACS
Bachelor Degree	Continuous	% Percent of people	ACS
Graduate/Professional degree	Continuous	% Percent of people	ACS
High School or Higher	Continuous	% Percent of people	ACS
Bachelor or Higher degree	Continuous	% Percent of people	ACS
Economic Stability			
EmplPopratio16ov_S2301	Continuous	Employment/Population Ratio	ACS
Unemployment rate 16ov_S2301	Continuous	Unemployment rate	ACS
Per Capita Income	Continuous	Per capita income in the past 12 months	ACS
Median Family Income	Continuous	Median family income in the past 12 months	ACS
Median Household Income	Continuous	Median household income in the past 12 months	ACS

AllFambelpoverty12m_S1702p	Continuous	% Percent All families below poverty level	ACS
Popbelowpoverty12m_S1701p	Continuous	% Percent people below poverty level	ACS
Belowpoverty12m18_64_S1701p	Continuous	% Percent people below poverty level; AGE - 18 to 64 years	ACS
Belowpoverty12m65and_S1701p	Continuous	% Percent people below poverty level; AGE - 65 years and over	ACS
GINI inequality index	Continuous	GINI Index	ACS
Health and Health Care			
PublicHI_aloneS2704p	Continuous	% Percent Public Coverage; Public health insurance alone	ACS
Medicare_onlyS2704p	Continuous	% Percent Public Coverage; Public health insurance alone - Medicare coverage alone	ACS
Medicaid_onlyS2704P	Continuous	% Percent Public Coverage; Public health insurance alone - Medicaid coverage alone	ACS
PrivateHI_aloneS2703p	Continuous	% Percent Public Coverage; Private health insurance alone	ACS
Index Hospital Volume	Continuous	Hospital where had the surgery	SPARCS
Neighborhood and Built Environment			
Metro/Nonmetro area setting	Categorical	Area classification based on USDA rural Urban continuum	USDA
Composite Area Based SDOH ZIP Code and County Code levels			
Social Vulnerability Index (SVI)		CDC Social Vulnerability Index	CDC
SVI THEME1-Socioeconomic Status (SES)	Continuous	Socioeconomic Status	CDC
People Below Poverty	Continuous	People Below Poverty	CDC
Unemployed	Continuous	People age 16 and above who are unemployed	CDC
Per Capita Income	Continuous	Per Capita Income estimate	CDC
No High School Diploma	Continuous		CDC
SVI THEME2-Household Composition and Disability		Household Composition and Disability	CDC
Aged 65 and Older	Continuous		CDC
Age 17 or younger	Continuous		CDC
Civilians with disability	Continuous		CDC
Single Parent Households	Continuous		CDC
SVI THEME3-Minority Status and Language			CDC
Minority	Continuous	Minority (all persons except white, non-Hispanic)	CDC
Speak English “Less than Well”	Continuous	All people age 5 and above from all ethnic background who speak English less than well	CDC
SVI THEME4-Housing and Transportation			CDC
Multi-Unit Structures	Continuous	Housing Structure with 10 or more housing units	CDC
Mobile Homes	Continuous	Mobile Homes	CDC
Crowding	Continuous	At household level (occupied housing units with more people than rooms available	CDC
No Vehicle	Continuous	Households with no vehicles	CDC
Group Quarters	Continuous	Persons in institutionalized group quarters	CDC
SVI THEME-Overall Score	Continuous	Overall score from all themes	CDC

Appendix C: Research Question 1

Multicollinearity Test and Logistic Models Description

This Appendix C consists of the analyses related to selecting the independent variables in the three logistic models evaluated in Research Question 1(RQ1) and the models' description. Specifically, for each model, the selection of independent variables in the models, multicollinearity tests, and the model’s description tests are presented in tables and figures. The dependent variable for RQ1 is Anastomotic Leak (AL). The binomial logistic regression analysis results for each model are presented in Section 3, under the section for Research Question one. The models are labeled to present the research question number and the model number.

RQ1-Model-1

In RQ1-Model-1 were included single measurement ACS SDOH independent variables at the Zip code level with dependent variable AL. Based on the bivariate analyses, independent SDOH variables with significance 0.05 or below were initially included for multivariable analysis in RQ1-Model-1. After multicollinearity test the independent variable included in the final RQ1-Model-1 are shown in Figure C1.

Figure C1

Independent variables included for multivariable analyses in the final RQ1-Model-1 based on bivariate and multicollinearity test. Dependent Variable: AL

Variable Type		Variables in RQ1-Model-1
Biological Patient level		Age Sex
Clinical Patient level	Covariates	Principal Diagnosis Surgical Approach Surgical_Procedure_Site Anastomosis distal end Diverting Stoma APRSOI Severity of Illness risk Admission Type
SDOH Patient level	Social /Community Context Health Care Access Hospital Facility Used	Race Health Insurance Annual Hospital Volume
SDOH Zip code level	Language Proficiency	Limited English All Households
	Education level	Less than 9th grade High School GED Some College No degree Associate degree Bachelor Degree
	Employment Status Economic stability	Unemployment rate 16 year + No Vehicle OHU%
	Income	Median Household Income
	Poverty	All Families below poverty level Below Poverty age 65 and above
	Inequality	GINI index of inequality

Table C1 *Multicollinearity test RQ1-Model-1.*

	Collinearity Statistics	
	Tolerance*	VIF**
Age 4gr	0.693	1.443
Sex	0.984	1.016
Principal Diagnosis	0.784	1.275
Surgical_Procedure_Site	0.701	1.426
Surgical Approach	0.707	1.414
Anastomosis distal end	0.791	1.264
Diverting Stoma	0.784	1.276
APRSOI Severity of Illness risk	0.661	1.512
Admission Type	0.674	1.484
Race	0.762	1.312
Health Insurance	0.733	1.364
Annual Hospital Volume4	0.851	1.175
Speak English well	0.016	62.729
Speak English less than well	0.015	64.805
Speak Other than English	0.105	9.544
Limited English All Households	0.259	3.860
Less than 9th grade	0.170	5.867
Has 9th to 12th grade no Diploma	0.136	7.368
High School GED	0.276	3.622
Some College No degree	0.550	1.819
Associate degree	0.418	2.393
Bachelor Degree	0.117	8.547
Graduate/Professional degree	0.117	8.580
High School or Higher	0.086	11.689
Bachelor or Higher degree	0.063	15.956
Unemployment rate 16 yr +	0.482	2.073
Median Household Income	0.111	9.010
Median Family Income	0.099	10.056
Per Capita Income	0.139	7.211
All Families below poverty level	0.133	7.544
People below poverty level	0.065	15.370
Below Poverty age 18 to 64	0.086	11.630
Below Poverty age 65 and above	0.333	3.007
GINI index of inequality	0.238	4.198
GINI 4 categories	0.276	3.628
Medicaid only	0.067	14.940
Private insurance alone	0.157	6.359
No Vehicle OHU%	0.260	3.843

Note. cut-off points: *tolerance < 0.2 and **VIF > 5;
Independent variables initially selected for multivariable analysis in RQ1-Model-1,
Dependent Variable: AL=anastomotic Leak

Table C2

Multicollinearity test RQ1-Model-1 after *multicollinearity adjustment.*

	Collinearity Statistics	
	Tolerance	VIF
Age 4gr	0.694	1.440
Sex	0.985	1.016
Principal Diagnosis	0.784	1.275
Surgical_Procedure_Site	0.701	1.426
Surgical Approach	0.708	1.412
Anastomosis distal end	0.791	1.264
Diverting Stoma	0.784	1.275
APRSOI Severity of Illness risk	0.662	1.512
Admission Type	0.674	1.484
Race	0.774	1.292
Health Insurance	0.734	1.363
Annual Hospital Volume4	0.861	1.161
Limited English All Households	0.387	2.584
Less than 9th grade	0.279	3.579
Has 9th to 12th grade no Diploma	0.224	4.455
High School GED	0.336	2.976
Some College No degree	0.580	1.724
Associate degree	0.444	2.251
Bachelor Degree	0.217	4.606
Unemployment rate 16 yr +	0.497	2.010
Median Household Income	0.219	4.559
All Families below poverty level	0.215	4.645
Below Poverty age 65 and above	0.350	2.856
GINI index of inequality	0.247	4.052
GINI 4 categories	0.291	3.437
Private insurance alone	0.219	4.570
No Vehicle OHU%	0.275	3.630

Note. cut-off points: *tolerance < 0.2 and **VIF > 5; Dependent Variable: AL=anastomotic Leak

The independent variables included in the final RQ1-Model-1 based on the bivariate analysis and after multicollinearity test are listed on Figure C1.

Table C3

RQ1-Model-1 Model Description- Omnibus Tests

Omnibus Tests of Model Coefficients			
	Chi-square	*df*	*p*
Step	9111.991	65	0.0000
Block	9111.991	65	0.0000
Model	9111.991	65	0.0000

Table C4

RQ1-Model-1 Model Description- Model Summary

Model Summary			
Step	-2 Log likelihood	Cox & Snell *R* Square	Nagelkerke R Square
1	93517.022a	0.067	0.124

a Estimation terminated at iteration number 6 because parameter estimates changed by less than .001.

Table C5

RQ1-Model-1 Model Description- Hosmer and Lemeshow Test

Hosmer and Lemeshow Test			
Step	Chi-square	*df*	*Sig.*
1	8.836	8	0.356

Table C6

RQ1-Model-1 Model Description- Classification Table

Classification Table					
	Observed		Predicted ANASTOMOTIC LEAK		Percentage Correct
			no	yes	
Step 1	ANASTOMOTIC LEAK	no	113307	4	100
		yes	17408	12	0.1
	Overall Percentage				86.7

RQ1-Model-2a

In RQ1-Model-2a were included composite SDOH- Social Vulnerability Index (SVI) Overall Themes evaluation on contextual level (ZIP code and County code areas) with dependent variable AL (see Figure C2). Independent variables with significance 0.05 or below from Tables 1 and 2, were initially included for multivariable analysis in RQ1-Model-2a. After multicollinearity test (Tables C7) the independent variable included in the final RQ1-Model-2a are shown in Figure C2.

Figure C2

Independent variables selected for multivariable analysis in the final RQ1-Model-2a after multicollinearity test. Dependent Variable: AL

Variable Type		**Variables in RQ1-Model-2a**
Biological Patient level	Covariates	Age Sex
Clinical Patient level	Covariates	Principal Diagnosis Surgical Approach Surgical_Procedure_Site Anastomosis distal end Diverting Stoma APRSOI Severity of Illness risk Admission Type
SDOH Patient level	Social /Community Context	Race
	Health Care Access	Health Insurance
	Hospital Facility Used	Annual Hospital Volume
SDOH Zip code level	**Composite SDOH**	
	Social Vulnerability	Theme 0z Overall
	Extreme Social Vulnerability	Flags_T0z Overall
SDOH County level	Social Vulnerability	Theme 0ct Overall
	Extreme Social Vulnerability	Flags_T0ct Overall

Table C7

Multicollinearity test RQ1-Model-2a

	Collinearity Statistics	
	*Tolerance	*VIF***
Age 4gr	0.697	1.437
Sex	0.985	1.015
Principal Diagnosis	0.786	1.273
Surgical Approach	0.714	1.401
Surgical_Procedure_Site	0.702	1.423
Anastomosis distal end	0.792	1.263
Diverting Stoma	0.784	1.275
APRSOI Severity of Illness risk	0.662	1.511
Admission Type	0.675	1.482
Race	0.837	1.268
Health Insurance	0.736	1.361
Annual Hospital Volume4	0.89	1.124
T0z_Overal Themes SVI Summary score	0.626	1.582
T0ct Overall Themes SVI Summary score	0.722	1.486
Flags_TOTALz_SVI Themes Sum Flags3groups	0.72	1.748
Flags_TOTALct_SVI Themes Sum Flags3groups	0.764	2.089

Note. cut-off points: *tolerance < 0.2 and **VIF > 5; Dependent Variable: AL=anastomotic Leak

The independent variables included in the final RQ1-Model-2a are listed on Figure C2.

Table C8

RQ1-Model-2a Description Omnibus Tests

Omnibus Tests of Model Coefficients				
		Chi-square	*df*	*p*
Step 1	Step	9054.913	39	0.000
	Block	9054.913	39	0.000
	Model	9054.913	39	0.000

Table C9

RQ1-Model-2a Description Model Summary

Model Summary			
Step	-2 Log likelihood	Cox & Snell *R* Square	Nagelkerke *R* Square
1	93574.099a	0.067	0.123

Table C10

RQ1-Model-2a Description Hosmer and Lemeshow Test

Hosmer and Lemeshow Test			
Step	Chi-square	*df*	*p*
1	9.44	8	0.307

Table C11

RQ1-Model-2a Description Classification Table

Classification Table a					
	Observed		Predicted ANASTOMOTIC LEAK		Percentage Correct
			no	yes	
Step 1	ANASTOMOTIC LEAK	no	113307	4	100
		yes	17408	12	0.1
	Overall Percentage				86.7

RQ1_Model_2b

In RQ1-Model-2b *were* included SVI Themes with dependent variable AL (see Figure C3). Independent variables initially included for multivariable analysis in RQ1-Model-2b were selected based on $\chi 2$ test. After multicollinearity test the independent variable included in the final RQ1-Model-2b are shown in Figure C3.

Figure C3

Independent variables in the final RQ1-Model-2b after collinearity test

Variable Type		Variables in RQ1-Model-2b
Biological Patient level	Covariates	Age Sex
Clinical Patient level	Covariates	Principal Diagnosis Surgical Approach Surgical_Procedure_Site Anastomosis distal end Diverting Stoma APRSOI Severity of Illness risk Admission Type
SDOH Patient level	Social /Community Context	Race
	Health Care Access	Health Insurance
	Hospital Facility Used	Annual Hospital Volume
SDOH Zip code level		
	Composite SDOH	
	Social Vulnerability	Theme 1z_ Socioeconomic Status Theme 2z_ Household Composition and Disability Theme 3z _Minority Status and Language Theme 4z_ Housing and Transportation
	Extreme Social Vulnerability	Flags_T1z_Socioeconomic Status Flags_T2z_Household Composition & Disability Flags_T3z_Minority Status and Language Flags_T4z_Housing and Transportation
SDOH County level	Social Vulnerability	Theme 1ct Socioeconomic Status Theme 2ct Household Composition and Disability Theme 4ct Housing and Transportation
	Extreme Social Vulnerability	Flags_T1ct Socioeconomic Status Flags_T2ct Household Composition and Disability Flags_T4ct_Housing and Transportation

Note. SDOH=Social Determinants of Health, SVI=Social Vulnerability, Flags SVI = Extreme Vulnerability.

Table C12

Multicollinearity test RQ1-Model-2b

	Collinearity Statistics	
	Tolerance	*VIF*
Age 4gr	0.695	1.439
Sex	0.985	1.016
Principal Diagnosis	0.785	1.273
Surgical Approach	0.713	1.403
Surgical_Procedure_Site	0.703	1.423
Anastomosis distal end	0.792	1.263
Diverting Stoma	0.784	1.276
APRSOI Severity of Illness risk	0.662	1.511
Admission Type	0.673	1.485
Race	0.763	1.311
Health Insurance	0.734	1.362
Annual Hospital Volume4	0.867	1.153
T1z_Socioeconomic Status	0.446	2.242
T2z_Houshold Composition and Disability	0.618	1.618
T3z_Minority Status and Language	0.428	2.337
T4z_Housing and Transportation	0.578	1.731
Flags_T1z_Socioeconomic Status	0.53	1.887
Flags_T2z_Household Composition & Disability	0.687	1.455
Flags_T3z_ Minority Status and Language	0.608	1.645
Flags_T4z_Housing and Transportation	0.628	1.591
T1ct Socioeconomic Status	0.226	4.419
T2ct Household Composition and Disability	0.465	2.149
T4ct Housing and Transportation	0.419	2.387
Flags_T1ct Socioeconomic Status	0.288	3.468
Flags_T2ct Household Composition and Disability	0.365	2.739

Note. cut-off points: *tolerance < 0.2 and **VIF > 5; Dependent Variable:

AL=anastomotic Leak

The independent variables included in the final RQ1-Model-2b

are listed on Figure C3.

Table C13

RQ1-Model-2b Description Omnibus Tests

Omnibus Tests of Model Coefficients				
		Chi-square	*df*	*p*
Step 1	Step	9243.176	72	0.000
	Block	9243.176	72	0.000
	Model	9243.176	72	0.000

Table C14 *RQ1-Model-2b Description Model Summary*

Model Summary			
Step	-2 Log likelihood	Cox & Snell R Square	Nagelkerke R Square
1	93385.837a	0.068	0.126

Table C15

RQ1-Model-2b Description Hosmer and Lemeshow Test

Hosmer and Lemeshow Test			
Step	Chi-square	*df*	*p*
1	3.831	8	0.872

Table C16

RQ1-Model-2b Description Classification Table

Classification Table a					
	Observed		Predicted ANASTOMOTIC LEAK		Percentage Correct
			no	yes	
Step 1	ANASTOMOTIC LEAK	no	113303	8	100
		yes	17407	13	0.1
	Overall Percentage				86.7

a The cut value is .500

Appendix D: Research Question 2

Multicollinearity Test and Logistic Models Description

This Appendix D consists of the analyses related to selecting the independent variables in the three logistic models evaluated in Research Question 2(RQ2) and the models' description. Specifically, for each model, the selection of independent variables in the models, multicollinearity tests, and the model's description tests are presented in tables and figures. The dependent variable for RQ2 is Surgical Site Infection (SSI). The binomial logistic regression analysis results for each model are presented in Section 3, under the section for research question two. The models are labeled to present the research question number and the model number.

RQ2-Model-1

In RQ2-Model-1 were included single measurement ACS SDOH independent variables at the Zip code level with dependent variable SSI. Based on the bivariate analyses, independent SDOH variables with significance 0.05 or below were initially included for multivariable analysis in RQ2-Model-1. After multicollinearity test the independent variable included in the final RQ2-Model-1 are shown in Figure D1.

Figure D1

Independent variables included in RQ2-Model-1 after multicollinearity test in RQ2-Model-1, Dependent Variable: SSI

Variable Level	Variable Type	Variables in RQ2-Model-1
Biological Patient level		Age
		Sex
Clinical Patient level		Principal Diagnosis
		Surgical Approach
		Surgical_Procedure_Site
		Anastomosis distal end
		Diverting Stoma
		Admission Type
		APRSOI Severity of Illness risk
SDOH Patient level	Social /Community Context	Race
	Health Care Access	Health Insurance
	Hospital Facility Used	Annual Hospital Volume
SDOH Zip code level	Language Proficiency	Limited English All Households
	Education level	Less than 9th grade
		Has 9th to 12th grade no Diploma
		Some College No degree
		Associate degree
		Bachelor Degree
	Economic Stability	Employed Population Ratio16 yr+
		Unemployment rate 16 yr +
		No Vehicle OHU%
	Income	Median Household Income
	Poverty	All Families below poverty level
	Inequality	GINI index of inequality
	Health Care Access	Private insurance alone

Table D1 *Multicollinearity test RQ2-Model-1*

	Collinearity Statistics	
	Tolerance	*VIF*
Age in years	0.673	1.485
Sex	0.988	1.012
Principal Diagnosis	0.787	1.270
Surgical Approach	0.707	1.414
Surgical_Procedure_Site	0.701	1.426
Anastomosis distal end	0.792	1.263
Diverting Stoma	0.784	1.276
APRSOI Severity of Illness risk	0.666	1.501
Admission Type	0.673	1.486
Race	0.739	1.353
Health Insurance	0.692	1.445
Annual Hospital Volume4	0.849	1.178
US Native	0.001	1086.284
Foreign Born	0.001	1089.429
Speak English well	0.016	63.151
Speak English less than well	0.015	65.018
Speak Other than English	0.089	11.290
Limited English All Households	0.257	3.884
Less than 9th grade	0.168	5.956
Has 9th to 12th grade no Diploma	0.134	7.458
Some College No degree	0.553	1.809
Associate degree	0.402	2.487
Bachelor Degree	0.119	8.368
Graduate/Professional degree	0.122	8.193
High School or Higher	0.085	11.819
Bachelor or Higher degree	0.063	15.758
Employed Population Ratio 16 yr +	0.519	1.925
Unemployment rate 16 yr +	0.461	2.170
Median Household Income	0.107	9.321
Median Family Income	0.099	10.130
Per Capita Income	0.136	7.356
All Families below poverty level	0.133	7.536
People below poverty level	0.064	15.651
Below Poverty age 18 to 64	0.086	11.674
Below Poverty age 65 and above	0.332	3.014
GINI index of inequality	0.358	2.793
Public Health Insurance alone	0.061	16.264
Medicaid only	0.065	15.470
Private insurance alone	0.155	6.438
No Vehicle OHU%	0.254	3.929
All Families below poverty >20%	0.391	2.559
People below poverty level >20%	0.302	3.308

Note. cut-off points: *tolerance < 0.2 and **VIF > 5; Independent variables initially selected for multivariable analysis in RQ2-Model-1;Dependent Variable: SSI=Surgical Site Infection

Table D2

Multicollinearity RQ2-Model-1 after adjustment

	Collinearity Statistics	
	Tolerance	VIF
Age in years	0.674	1.483
Sex	0.989	1.012
Principal Diagnosis	0.787	1.270
Surgical Approach	0.709	1.411
Surgical_Procedure_Site	0.702	1.425
Anastomosis distal end	0.792	1.263
Diverting Stoma	0.784	1.275
APRSOI Severity of Illness risk	0.667	1.500
Admission Type	0.673	1.485
Race	0.770	1.299
Health Insurance	0.692	1.444
Annual Hospital Volume4	0.857	1.167
Limited English All Households	0.384	2.601
Less than 9th grade	0.278	3.597
Has 9th to 12th grade no Diploma	0.223	4.482
Some College No degree	0.586	1.707
Associate degree	0.430	2.325
Bachelor Degree	0.294	3.407
Employed Population Ratio 16 yr +	0.555	1.801
Unemployment rate 16 yr +	0.483	2.070
Median Household Income	0.203	4.919
All Families below poverty level	0.204	4.891
Below Poverty age 65 and above	0.350	2.859
GINI index of inequality	0.433	2.310
Private insurance alone	0.218	4.595
No Vehicle OHU%	0.280	3.565
All Families below poverty >20%	0.406	2.464
People below poverty level >20%	0.330	3.035

Note. cut-off points: *tolerance < 0.2 and **VIF > 5;
Dependent Variable: SSI= Surgical Site Infection

The independent variables included in the final RQ2-Model-1 are listed on Figure D1.

Table D3

RQ2-Model-1 Model Description- Omnibus Tests

Omnibus Tests of Model Coefficients				
		Chi-square	*df*	*p*
Step 1	Step	10028.091	69	0.000
	Block	10028.091	69	0.000
	Model	10028.091	69	0.000

Table D4 *RQ2-Model-1 Model Description- Model Summary*

Model Summary			
Step	-2 Log likelihood	Cox & Snell R Square	Nagelkerke R Square
1	106625.242a	0.074	0.125

Table D5 *RQ2-Model-1 Model Description- Hosmer and Lemeshow Test*

Hosmer and Lemeshow Test			
Step	Chi-square	*df*	*p*
1	2.069	8	0.979

Table D6 *RQ2-Model-1 Model Description- Classification Table*

Classification Table a					
	Observed		Predicted SSI (Surgical Site Infection)		Percentage Correct
			no	yes	
Step 1	SSI (Surgical Site Infection)	no	109253	45	100
		yes	21366	67	0.3
	Overall Percentage				83.6

RQ2-Model-2a

In RQ2-Model-2a were included single measurement patient level and composite SDOH- Social Vulnerability Index (SVI) Overall Themes evaluation on contextual level (ZIP code and County code areas) with dependent variable SSI (see Figure D2). Independent variables with significance 0.05 or below were initially included for multivariable analysis in RQ2-Model-2a. After multicollinearity test (Table D7) the independent variable included in the final RQ2-Model-2a are shown in Figure D2.

Figure D2

Independent variables in the final RQ2-Model- 2a after multicollinearity test,

Dependent Variable: SSI

Variable Type		Variables in RQ2-Model-2a
Biological Patient level	Covariates	Age Sex
Clinical Patient level	Covariates	Principal Diagnosis Surgical Approach Surgical_Procedure_Site Anastomosis distal end Diverting Stoma APRSOI Severity of Illness risk Admission Type
SDOH Patient level	Social /Community Context Health Care Access Hospital Facility Used	Race Health Insurance Annual Hospital Volume
SDOH Zip code level	**Composite SDOH**	
	Social Vulnerability Extreme Social Vulnerability	Theme 0z Overall Flags_T0zt Overall
SDOH County level	Social Vulnerability Extreme Social Vulnerability	Theme 0ct Overall Flags_T0ct Overall

Table D7

Multicollinearity test RQ2-Model-2a

	Collinearity Statistics	
	Tolerance	VIF
Age 4gr	0.697	1.434
Sex	0.985	1.015
Principal Diagnosis	0.786	1.273
Surgical Approach	0.714	1.402
Surgical_Procedure_Site	0.702	1.424
Anastomosis distal end	0.792	1.263
Diverting Stoma	0.784	1.275
APRSOI Severity of Illness risk	0.662	1.511
Admission Type	0.675	1.481
Race	0.837	1.195
Health Insurance	0.736	1.359
Annual Hospital Volume4	0.890	1.123
T0z_Overal Themes Summary score	0.626	1.597
T0ct Overall Themes Summary score	0.722	1.385
Flags_TOTALz_Themes Sum Flags3	0.720	1.390
Flags_TOTALct_Themes Sum Flags3	0.764	1.309

Note. cut-off points: *tolerance < 0.2 and **VIF > 5,

Dependent Variable: SSI=Surgical Site Infection

Table D8

RQ2-Model-2a Description Omnibus Tests

Omnibus Tests of Model Coefficients				
		Chi-square	*df*	*p*
Step 1	Step	10065.94	39	0.000
	Block	10065.94	39	0.000
	Model	10065.94	39	0.000

Table D9

RQ2-Model-2a Description Model Summary

Model Summary			
Step	-2 Log likelihood	Cox & Snell R Square	Nagelkerke R Square
1	106587.395a	0.074	0.126

Table D10

RQ2-Model-2a Description Hosmer and Lemeshow Test

Hosmer and Lemeshow Test			
Step	Chi-square	*df*	*p*
1	10.762	8	0.216

Table D11

RQ2-Model-2a Description Classification Table

Classification Table a					
	Observed		Predicted SSI (Surgical Site Infection)		Percentage Correct
			no	yes	
Step 1	SSI (Surgical Site Infection)	no	109257	41	100
		yes	21365	68	0.3
	Overall Percentage				83.6

RQ2-Model-2b

In RQ2-Model-2b were included *the* Social Vulnerability Themes with dependent variable SSI (see Figure D3). Independent variables initially included for multivariable analysis in RQ2-Model-2b were selected based on $\chi 2$ test. After multicollinearity test the independent variable included in the final RQ2-Model-2b are shown in Figure D3.

Figure D3

Independent variables in the final RQ2-Model- 2b after multicollinearity test,

Dependent Variable: SSI

Variable Type		**Variables in RQ2-Model-2b**
Biological Patient level	Covariates	Age Sex
Clinical Patient level	Covariates	Principal Diagnosis Surgical Approach Surgical_Procedure_Site Anastomosis distal end Diverting Stoma APRSOI Severity of Illness risk Admission Type
SDOH Patient level	Social /Community Context Health Care Access Hospital Facility Used	Race Health Insurance Annual Hospital Volume
SDOH Zip code level		
	Composite SDOH	
	Social Vulnerability	*Theme 1z_ Socioeconomic Status* *Theme 2z_Household Composition and Disability* *Theme 3z_Minority Status and Language* *Theme 4z_Housing and Transportation*
	Extreme Social Vulnerability	*Flags_T1z_Socioeconomic Status* *Flags_T2z_Household Composition & Disability* *Flags_T3z_Minority Status and Language* *Flags_T4z_Housing and Transportation*
SDOH County level	***Social Vulnerability***	*Theme 1ct Socioeconomic Status* *Theme 2ct Household Composition and Disability* *Theme 3ct Minority Status and Language* *Theme 4ct Housing and Transportation*
	Extreme Social Vulnerability	*Flags_T1ct Socioeconomic Status* *Flags_T2ct Household Composition and Disability*

Table D12

Multicollinearity test RQ2-Model-2b

	Collinearity Statistics	
	Tolerance	*VIF*
Age 4gr	0.693	1.442
Sex	0.984	1.016
Principal Diagnosis	0.785	1.273
Surgical Approach	0.713	1.403
Surgical_Procedure_Site	0.702	1.424
Anastomosis distal end	0.791	1.264
Diverting Stoma	0.784	1.276
APRSOI Severity of Illness risk	0.661	1.512
Admission Type	0.673	1.486
Race	0.751	1.331
Health Insurance	0.734	1.362
Annual Hospital Volume4	0.851	1.175
T1z_Socioeconomic Status	0.426	2.349
T2z_Houshold Composition and Disability	0.601	1.663
T3z_Minority Status and Language	0.311	3.221
T4z_Housing and Transportation	0.570	1.755
T1ct Socioeconomic Status	0.202	4.957
T2ct Household Composition and Disability	0.319	3.139
T3ct Minority Status and Language	0.077	12.991
T4ct Housing and Transportation	0.281	3.559
Flags_T1z_Socioeconomic Status	0.529	1.891
Flags_T2z_Household Composition & Disability	0.684	1.462
Flags_T3z_ Minority Status and Language	0.596	1.678
Flags_T4z_Housing and Transportation	0.583	1.716
Flags_T1ct Socioeconomic Status	0.259	3.856
Flags_T2ct Household Composition and Disability	0.329	3.039
Flags_T3ct Minority Status and Language	0.130	7.703
Flags_T4ct Housing and Transportation	0.129	7.736

Note. cut-off points: *tolerance < 0.2 and **VIF > 5; Dependent Variable:

SSI=Surgical Site Infection

Table D13

Multicollinearity test RQ2-Model-2b

	Collinearity Statistics	
	Tolerance	*VIF*
Age 4gr	0.694	1.441
Sex	0.984	1.016
Principal Diagnosis	0.785	1.273
Surgical Approach	0.713	1.403
Surgical_Procedure_Site	0.702	1.424
Anastomosis distal end	0.792	1.263
Diverting Stoma	0.784	1.276
APRSOI Severity of Illness risk	0.662	1.512
Admission Type	0.673	1.486
Race	0.754	1.327
Health Insurance	0.734	1.362
Annual Hospital Volume4	0.851	1.174
T1z_Socioeconomic Status	0.428	2.337
T2z_Houshold Composition and Disability	0.602	1.662
T3z_Minority Status and Language	0.314	3.189
T4z_Housing and Transportation	0.576	1.737
T1ct Socioeconomic Status	0.224	4.473
T2ct Household Composition and Disability	0.376	2.657
T3ct Minority Status and Language	0.223	4.477
T4ct Housing and Transportation	0.412	2.425
Flags_T1z_Socioeconomic Status	0.529	1.891
Flags_T2z_Household Composition & Disability	0.685	1.459
Flags_T3z_ Minority Status and Language	0.596	1.677
Flags_T4z_Housing and Transportation	0.613	1.632
Flags_T1ct Socioeconomic Status	0.265	3.773
Flags_T2ct Household Composition and Disability	0.342	2.923

Note. cut-off points: *tolerance < 0.2 and **VIF > 5; Dependent Variable:

SSI=Surgical Site Infection

The independent variables included in the final RQ2-Model-2b are listed on Figure D3

Table D14

RQ2-Model-2b Description Omnibus Tests

Omnibus Tests of Model Coefficients				
		Chi-square	*df*	*p*
Step 1	Step	10194.47	61	0.000
	Block	10194.47	61	0.000
	Model	10194.47	61	0.000

Table 15

RQ2-Model-2b Description Model Summary

Model Summary			
Step	-2 Log likelihood	Cox & Snell *R* Square	Nagelkerke *R* Square
1	106458.862a	0.075	0.127

Table 16

RQ2-Model-2b Description Hosmer and Lemeshow Test

Hosmer and Lemeshow Test			
Step	Chi-square	*df*	*p*
1	4.352	8	0.824

Table 17

RQ2-Model-2b Description Classification Table

Classification Table a Observed			Predicted SSI (Surgical Site Infection)		Percentage Correct
			no	yes	
Step 1	SSI (Surgical Site Infection)	no	109217	81	99.9
		yes	21330	103	0.5
	Overall Percentage				83.6

Appendix E: Research Question 3

Multicollinearity Test and Logistic Models Description

This Appendix E consists of the analyses related to selecting the independent variables in the three logistic models evaluated in Research Question 3(RQ3) and the models' description. Specifically, for each model, the selection of independent variables in the models, multicollinearity tests, and the model's description tests are presented in tables and figures. The dependent variable for RQ3 is overall complications (COMPL). The binomial logistic regression analysis results for each model are presented in Section 3, under the section for Research Question 3. The models are labeled to present the research question number and the model number.

RQ3-Model-1

In RQ3-Model-1 were included single measurement ACS SDOH independent variables at the Zip code level with dependent variable COMPL. Based on the bivariate analyses, independent SDOH variables with significance 0.05 or below were initially included for multivariable analysis in RQ3-Model-1. After multicollinearity test the independent variable included in the final RQ3-Model-1 are shown in Figure E1.

Figure E1

Independent variables included in the final RQ3-Model-1 after multicollinearity test;

Dependent Variable: COMPL

Variable Level	***Variable Type***	***Variables RQ3-Model-1***
Biological Patient level		Age
		Sex
Clinical Patient level		Principal Diagnosis
		Surgical Approach
		Surgical_Procedure_Site
		Anastomosis distal end
		Diverting Stoma
		Admission Type
		APRSOI Severity of Illness risk
SDOH Patient level	Social /Community Context	Race
	Health Care Access	Health Insurance
	Hospital Facility Used	Annual Hospital Volume
SDOH Zip code level	Language Proficiency	Limited English All Households
	Education level	Less than 9th grade
		High School GED
		Associate degree
		Bachelor Degree
	Economic Stability	Employed Population Ratio16 yr+
		Unemployment rate 16 yr +
		No Vehicle OHU%
	Income	Median Household Income
	Poverty	All Families below poverty level
		Below Poverty age 65 and above
	Inequality	GINI index of inequality
	Health Care Access	Medicare only
		Private insurance alone

Table E1

Multicollinearity test RQ3-Model-1

	Collinearity Statistics	
	*Tolerance	*VIF***
Age in years	0.673	1.486
Sex	0.988	1.012
Principal Diagnosis	0.787	1.27
Surgical Approach	0.707	1.414
Surgical_Procedure_Site	0.701	1.426
Anastomosis distal end	0.792	1.263
Diverting Stoma	0.784	1.276
APRSOI Severity of Illness risk	0.666	1.501
Admission Type	0.673	1.486
Race	0.744	1.344
Health Insurance	0.692	1.445
Annual Hospital Volume4	0.852	1.174
US Native	0.001	1086.613
Foreign Born	0.001	1089.848
Speak English well	0.016	62.918
Speak English less than well	0.015	64.868
Speak Other than English	0.089	11.276
Limited English All Households	0.258	3.869
Less than 9th grade	0.168	5.951
Has 9th to 12th grade no Diploma	0.135	7.432
High School GED	0.262	3.816
Some College No degree	0.554	1.807
Associate degree	0.413	2.423
Bachelor Degree	0.115	8.73
Graduate/Professional degree	0.115	8.677
High School or Higher	0.085	11.721
Bachelor or Higher degree	0.062	16.032
Employed Population Ratio 16 yr +	0.489	2.045
Unemployment rate 16 yr +	0.464	2.156
Median Household Income	0.108	9.299
Median Family Income	0.099	10.083
Per Capita Income	0.133	7.531
All Families below poverty level	0.132	7.554
People below poverty level	0.065	15.363
Below Poverty age 18 to 64	0.085	11.749
Below Poverty age 65 and above	0.332	3.012

GINI index of inequality	0.359	2.786
Public Health Insurance alone	0.058	17.339
Medicare only	0.716	1.397
Medicaid only	0.062	16.245
Private insurance alone	0.154	6.482
No Vehicle OHU%	0.249	4.016

Note. cut-off points: *tolerance < 0.2 and **VIF > 5;
Dependent Variable: COMPL=Overall Surgical Complications

Table E2

Multicollinearity test RQ3-Model-1 after adjustment

	Collinearity Statistics	
	*Tolerance	*VIF***
Age in years	0.674	1.483
Sex	0.989	1.012
Principal Diagnosis	0.788	1.270
Surgical Approach	0.709	1.410
Surgical_Procedure_Site	0.702	1.425
Anastomosis distal end	0.792	1.263
Diverting Stoma	0.784	1.275
APRSOI Severity of Illness risk	0.667	1.500
Admission Type	0.674	1.484
Race	0.777	1.287
Health Insurance	0.693	1.444
Annual Hospital Volume4	0.861	1.161
Limited English All Households	0.387	2.583
Less than 9th grade	0.301	3.325
High School GED	0.316	3.168
Some College No degree	0.584	1.713
Associate degree	0.451	2.218
Bachelor Degree	0.230	4.351
Employed Population Ratio 16 yr +	0.524	1.907
Unemployment rate 16 yr +	0.489	2.044
Median Household Income	0.214	4.684
All Families below poverty level	0.215	4.658
Below Poverty age 65 and above	0.350	2.861
GINI index of inequality	0.415	2.412
Medicare only	0.819	1.221
Private insurance alone	0.218	4.581
No Vehicle OHU%	0.271	3.684

Note. cut-off points: *tolerance < 0.2 and **VIF > 5;
Dependent Variable: COMPL=Overall Surgical Complications

Table E3

RQ3-Model-1 Model Description- Omnibus Tests

Omnibus Tests of Model Coefficients				
		Chi-square	*df*	*p*
Step 1	Step	21856.93	69	0.000
	Block	21856.93	69	0.000
	Model	21856.93	69	0.000

Table E4

RQ3-Model-1 Model Description- Model Summary

Model Summary			
Step	-2 Log likelihood	Cox & Snell R Square	Nagelkerke R Square
1	134889.723a	0.154	0.22

Table E5

RQ3-Model-1 Model Description- Hosmer and Lemeshow Test

Hosmer and Lemeshow Test			
Step	Chi-square	*df*	*p*
1	11.399	8	0.180

Table E6

RQ3-Model-1 Model Description- Classification Table

Classification Table a					
	Observed		Predicted		
			COMPL		Percentage Correct
			no	yes	
Step 1	COMPL	no	84921	8282	91.1
		yes	24446	13082	34.9
	Overall Percentage				75

RQ3-Model-2a

In RQ3-Model-2a were included single measurement patient level and composite SDOH- Social Vulnerability Index (SVI) Overall Themes evaluation on contextual level (ZIP code and County code areas) with dependent variable COMPL (see Figure E2). Independent variables with significance 0.05 or below were initially included for multivariable analysis in RQ3-Model-2a. After multicollinearity test (Table E7) the independent variable included in the final RQ3-Model-2a are shown in Figure E2.

Figure E2

Independent variables in the final RQ3-Model- 2a after multicollinearity test,

Dependent Variable: COMPL, Source: Original drawing

Variable Type		**Variables in RQ3-Model-2a**
Biological Patient level	Covariates	Age Sex
Clinical Patient level	Covariates	Principal Diagnosis Surgical Approach Surgical_Procedure_Site Anastomosis distal end Diverting Stoma APRSOI Severity of Illness risk Admission Type
SDOH Patient level	Social /Community Context	Race
	Health Care Access	Health Insurance
	Hospital Facility Used	Annual Hospital Volume
SDOH Zip code level	**Composite SDOH**	
	Social Vulnerability	*Theme 0z Overall*
	Extreme Social Vulnerability	*Flags_T0zt Overall*
SDOH County level	Social Vulnerability	*Theme 0ct Overall*
	Extreme Social Vulnerability	*Flags_T0ct Overall*

Table E7

Multicollinearity test RQ3-Model-2a

	Collinearity Statistics	
	*Tolerance	*VIF***
Age in years	0.677	1.476
Sex	0.989	1.011
Principal Diagnosis	0.789	1.268
Surgical Approach	0.714	1.401
Surgical_Procedure_Site	0.703	1.423
Anastomosis distal end	0.792	1.262
Diverting Stoma	0.784	1.275
APRSOI Severity of Illness risk	0.667	1.499
Admission Type	0.675	1.481
Race	0.839	1.192
Health Insurance	0.695	1.439
Annual Hospital Volume4	0.891	1.123
T0z_Overal Themes Summary score	0.626	1.597
Flags_TOTALz_Themes Sum Flags3	0.720	1.390
T0ct Overall Themes Summary score	0.722	1.385
Flags_TOTALct_Themes Sum Flags3	0.765	1.308

Note. cut-off points: *tolerance < 0.2 and **VIF > 5;
Dependent Variable: COMPL=Overall Surgical Complications

Table E8

RQ3-Model-2a Description Omnibus Tests

Omnibus Tests of Model Coefficients				
		Chi-square	*df*	*p*
Step 1	Step	21816.047	37	0.000
	Block	21816.047	37	0.000
	Model	21816.047	37	0.000

Table E9

RQ3-Model-2a Description Model Summary

Model Summary			
Step	-2 Log likelihood	Cox & Snell *R* Square	Nagelkerke *R* Square
1	134930.611a	0.154	0.22

Table E10

RQ3-Model-2a Description Hosmer and Lemeshow Test

Hosmer and Lemeshow Test			
Step	Chi-square	*df*	*p*
1	12.553	8	0.128

Table E11

RQ3-Model-2a Description Classification Table

Classification Table					
	Observed		Predicted		
			COMPL		Percentage Correct
			no	yes	
Step 1	COMPL	no	85019	8184	91.2
		yes	24499	13029	34.7
	Overall Percentage				75

RQ3-Model-2b

In RQ3-Model-2b were included *the* Social Vulnerability Themes with dependent variable COMPL (see Figure E3). Independent variables initially included for multivariable analysis in RQ3-Model-2b were selected based on $\chi 2$ test. After multicollinearity test the independent variables included in the final RQ3-Model-2b are shown in Figure E3.

Figure E3

Independent variables in the final RQ3-Model-2b after multicollinearity test, Dependent Variable: COMPL

Variable Type		Variables in RQ3-Model-2b
Biological Patient level	Covariates	Age Sex
Clinical Patient level	Covariates	Principal Diagnosis Surgical Approach Surgical_Procedure_Site Anastomosis distal end Diverting Stoma APRSOI Severity of Illness risk Admission Type
SDOH Patient level	Social /Community Context Health Care Access Hospital Facility Used	Race Health Insurance Annual Hospital Volume
SDOH Zip code level		
	Composite SDOH	
	Social Vulnerability	*Theme 1z_ Socioeconomic Status* *Theme 2z_Household Composition and Disability* *Theme 3z_Minority Status and Language* *Theme 4z_Housing and Transportation*
	Extreme Social Vulnerability	*Flags_T1z_Socioeconomic Status* *Flags_T2z_Household Composition & Disability* *Flags_T3z_Minority Status and Language* *Flags_T4z_Housing and Transportation*
SDOH County level	***Social Vulnerability***	*Theme 1ct_Socioeconomic Status* *Theme 2ct_Household Composition and Disability* *Theme 4ct_Housing and Transportation*
	Extreme Social Vulnerability	*Flags_T1ct_Socioeconomic Status* *Flags_T2ct_Household Composition and Disability* *Flags_T4ct_Housing and Transportation*

Note. Social Vulnerability Themes* variables composition is described on Table B4

Table E12

Multicollinearity test RQ3-Model-2b

	Collinearity Statistics	
	*Tolerance	VIF**
Age in years	0.675	1.482
Sex	0.989	1.012
Principal Diagnosis	0.788	1.269
Surgical Approach	0.713	1.403
Surgical_Procedure_Site	0.702	1.424
Anastomosis distal end	0.792	1.263
Diverting Stoma	0.784	1.276
APRSOI Severity of Illness risk	0.667	1.5
Admission Type	0.672	1.487
Race	0.754	1.327
Health Insurance	0.693	1.442
Annual Hospital Volume4	0.852	1.174
T1z_Socioeconomic Status	0.426	2.349
T2z_Houshold Composition and Disability	0.601	1.663
T3z_Minority Status and Language	0.311	3.22
T4z_Housing and Transportation	0.57	1.755
T1ct Socioeconomic Status	0.202	4.957
T2ct Household Composition and Disability	0.319	3.139
T3ct Minority Status and Language	0.077	12.991
T4ct Housing and Transportation	0.281	3.558
Flags_T1z_Socioeconomic Status	0.529	1.891
Flags_T2z_Household Composition & Disability	0.684	1.461
Flags_T3z_ Minority Status and Language	0.596	1.678
Flags_T4z_Housing and Transportation	0.583	1.716
Flags_T1ct Socioeconomic Status	0.259	3.857
Flags_T2ct Household Composition and Disability	0.329	3.039
Flags_T3ct Minority Status and Language	0.13	7.7
Flags_T4ct Housing and Transportation	0.129	7.735

Note. cut-off points: *tolerance < 0.2 and **VIF > 5;
Dependent Variable: COMPL=Overall Surgical Complications

Table E13

Multicollinearity RQ3-Model-2b after adjustment

	Collinearity Statistics	
	*Tolerance	*VIF***
Age in years	0.675	1.481
Sex	0.989	1.012
Principal Diagnosis	0.788	1.269
Surgical Approach	0.713	1.403
Surgical_Procedure_Site	0.703	1.423
Anastomosis distal end	0.792	1.262
Diverting Stoma	0.784	1.276
APRSOI Severity of Illness risk	0.667	1.500
Admission Type	0.673	1.487
Race	0.756	1.322
Health Insurance	0.693	1.442
Annual Hospital Volume4	0.852	1.174
T1z_Socioeconomic Status	0.428	2.336
T2z_Houshold Composition and Disability	0.602	1.662
T3z_Minority Status and Language	0.314	3.189
T4z_Housing and Transportation	0.576	1.737
T1ct Socioeconomic Status	0.224	4.473
T2ct Household Composition and Disability	0.376	2.657
T3ct Minority Status and Language	0.223	4.474
T4ct Housing and Transportation	0.412	2.425
Flags_T1z_Socioeconomic Status	0.529	1.890
Flags_T2z_Household Composition & Disability	0.685	1.459
Flags_T3z_ Minority Status and Language	0.596	1.676
Flags_T4z_Housing and Transportation	0.613	1.632
Flags_T1ct Socioeconomic Status	0.265	3.773
Flags_T2ct Household Composition and Disability	0.342	2.923

Note. cut-off points: *tolerance < 0.2 and **VIF > 5,
Dependent Variable: COMPL=Overall Surgical Complications

Table E14

RQ3-Model-2b Description Omnibus Tests

Omnibus Tests of Model Coefficients				
		Chi-square	*df*	*p*
Step 1	Step	21938.77	52	0.000
	Block	21938.77	52	0.000
	Model	21938.77	52	0.000

Table E15

RQ3-Model-2b Description Model Summary

Model Summary			
Step	-2 Log likelihood	Cox & Snell R Square	Nagelkerke R Square
1	134807.888a	0.154	0.221

Table E16

RQ3-Model-2b Description Hosmer and Lemeshow Test

Hosmer and Lemeshow Test			
Step	Chi-square	*df*	*p*
1	13.071	8	0.109

Table E17

RQ3-Model-2b Description Classification Table

Classification Table					
	Observed		Predicted COMPL		Percentage Correct
			no	yes	
Step 1	COMPL	no	84874	8329	91.1
		yes	24339	13189	35.1
	Overall Percentage				75

Appendix F: Research Question 4

Multicollinearity Test and Logistic Models Description

This Appendix F consists of the analyses related to selecting the independent variables in the three logistic models evaluated in Research Question 4(RQ4) and the models' description. Specifically, for each model, the selection of independent variables in the models, multicollinearity tests, and the model's description tests are presented in tables and figures. The dependent variable for RQ4 is Not_SSI (Not Surgical Site Infectious Complication). The binomial logistic regression analysis results for each model are presented in Section 3, under the section for Research Question four. The models are labeled to present the research question number and the model number.

RQ4-Model-1

In RQ4-Model-1 were included single measurement patient and ACS SDOH independent variables at the Zip code level with dependent variable Not_SSI. After multicollinearity test the independent variable included in the final RQ4-Model-1 are shown in Figure F1.

Figure F1

Independent variables included in the final RQ4-Model-1 after multicollinearity test;

Dependent Variable: Not_SSI

Variable Level	Variable Type	Variables in RQ4-Model-1
Biological Patient level		Age
		Sex
Clinical Patient level		Principal Diagnosis
		Surgical_Procedure_Site
		Surgical Approach
		Anastomosis distal end
		Diverting Stoma
		Admission Type
		APRSOI Severity of Illness risk
		LOSS_4gr
SDOH Patient level	Social /Community Context	Race
	Health Care Access	Health Insurance
	Hospital Facility Used	Annual Hospital Volume4
SDOH Zip code level	Language Proficiency	Limited English All Households
	Education level	Less than 9th grade
		Has 9th to 12th grade no Diploma
		High School GED
		Some College No degree
		Associate degree
		Bachelor Degree
	Economic Stability	Employed Population Ratio 16 yr +
		Unemployment rate 16 yr +
		No Vehicle OHU%
	Income	Median Household Income
	Poverty	All Families below poverty level
		Below Poverty age 65 and above
	Inequality	GINI index of inequality
	Health Care Access	Private insurance alone

Table F1

Multicollinearity test RQ4-Model-1

	Collinearity Statistics	
	*Tolerance	*VIF***
Age 4gr	0.688	1.454
Sex	0.984	1.016
Principal Diagnosis	0.784	1.275
Surgical_Procedure_Site	0.700	1.429
Surgical Approach	0.688	1.454
Anastomosis distal end	0.791	1.264
Diverting Stoma	0.780	1.283
APRSOI Severity of Illness risk	0.545	1.834
Admission Type	0.667	1.500
LOSS_4gr	0.617	1.620
Race	0.732	1.366
Health Insurance	0.732	1.366
Annual Hospital Volume4	0.847	1.181
US Native	0.001	1086.407
Foreign Born	0.001	1089.726
Speak English well	0.016	63.291
Speak English less than well	0.015	65.068
Speak Other than English	0.088	11.318
Limited English All Households	0.257	3.884
Less than 9th grade	0.168	5.964
Has 9th to 12th grade no Diploma	0.134	7.468
High School GED	0.251	3.990
Some College No degree	0.553	1.809
Associate degree	0.399	2.504
Bachelor Degree	0.115	8.706
Graduate/Professional degree	0.116	8.648
High School or Higher	0.085	11.824
Bachelor or Higher degree	0.062	16.091
Employed Population Ratio 16 yr +	0.510	1.959
Unemployment rate 16 yr +	0.460	2.172
Median Household Income	0.107	9.322
Median Family Income	0.099	10.139
Per Capita Income	0.136	7.357
All Families below poverty level	0.132	7.576
People below poverty level	0.064	15.651
Below Poverty age 18 to 64	0.085	11.708

Below Poverty age 65 and above	0.331	3.019
GINI index of inequality	0.352	2.841
Public Health Insurance alone	0.061	16.284
Medicaid only	0.065	15.479
Private insurance alone	0.155	6.438
No Vehicle OHU%	0.254	3.931
All Families below poverty >20%	0.373	2.678
People below poverty level >20%	0.302	3.311

Note. cut-off points: *tolerance < 0.2 and **VIF > 5;
Dependent Variable: Not_SSI=Not Surgical Site Infectious Complications

Table F2.

Multicollinearity RQ4-Model-1 after adjustment

	Collinearity Statistics	
	*Tolerance	*VIF***
Age 4gr	0.690	1.450
Sex	0.984	1.016
Principal Diagnosis	0.784	1.275
Surgical_Procedure_Site	0.700	1.428
Surgical Approach	0.689	1.452
Anastomosis distal end	0.791	1.264
Diverting Stoma	0.780	1.282
APRSOI Severity of Illness risk	0.546	1.832
Admission Type	0.667	1.498
LOSS_4gr	0.618	1.619
Race	0.773	1.293
Health Insurance	0.733	1.365
Annual Hospital Volume4	0.860	1.163
Limited English All Households	0.387	2.582
Less than 9th grade	0.280	3.574
Has 9th to 12th grade no Diploma	0.224	4.456
High School GED	0.333	3.006
Some College No degree	0.584	1.714
Associate degree	0.444	2.255
Bachelor Degree	0.217	4.607
Employed Population Ratio 16 yr +	0.552	1.813
Unemployment rate 16 yr +	0.486	2.059
Median Household Income	0.211	4.740
All Families below poverty level	0.217	4.615
Below Poverty age 65 and above	0.349	2.862
GINI index of inequality	0.410	2.437
Private insurance alone	0.217	4.599
No Vehicle OHU%	0.283	3.530

Note. cut-off points: *tolerance < 0.2 and **VIF > 5;
Dependent Variable: Not_SSI=Not Surgical Site Infectious Complication

Table F3

RQ4-Model-1 Model Description- Omnibus Tests

Omnibus Tests of Model Coefficients				
		Chi-square	*df*	*p*
Step 1	Step	18256.819	77	0.000
	Block	18256.819	77	0.000
	Model	18256.819	77	0.000

Table F4

RQ4-Model-1 Model Description- Model Summary

Model Summary			
Step	-2 Log likelihood	Cox & Snell R Square	Nagelkerke R Square
1	86800.733a	0.13	0.236

Table F5

RQ4-Model-1 Model Description- Hosmer and Lemeshow Test

Hosmer and Lemeshow Test			
Step	Chi-square	df	*p*
1	6.275	8	0.616

Table F6

RQ4-Model-1 Model Description- Classification Table

Classification Table a					
	Observed		Predicted Not_SSI (Not Surgical Site Infectious Complications)		Percentage Correct
			no	yes	
Step 1	Not_SSI (Not Surgical Site Infectious Compl)	no	111507	1148	99
		yes	16598	1478	8.2
	Overall Percentage				86.4

RQ4-Model-2a

In RQ4-Model-2a were included single measurement patient level and composite SDOH- Social Vulnerability Index (SVI) Overall Themes evaluation on contextual level (ZIP code and County code areas) with dependent variable Not_SSI (see Figure F2). Independent variables with significance 0.05 or below were initially included for multivariable analysis in RQ4-Model-2a. After multicollinearity test (Table F7) the independent variable included in the final RQ4-Model-2a are shown in Figure F2.

Figure F2

Independent variables in the final RQ4-Model-2a after multicollinearity test,

Dependent Variable: Not_SSI

Variable Level	Variable Type	Variables in RQ4-Model-2a
Biological Patient level		Age
		Sex
Clinical Patient level		Principal Diagnosis
		Surgical Approach
		Surgical_Procedure_Site
		Anastomosis distal end
		Diverting Stoma
		Admission Type
		APRSOI Severity of Illness risk
		LOSS_4gr
SDOH Patient level	Social /Community Context	Race
	Health Care Access	Health Insurance
	Hospital Facility Used	Annual Hospital Volume4
SDOH Zip Code level	Social Vulnerability	Theme 0z_Overall Themes Summary Score
	Extreme Social Vulnerability	Flags_T0z_Overall Themes Sum Flags
SDOH County level	Social Vulnerability	Theme 0ct_Overall Themes Summary Score
	Extreme Social Vulnerability	Flags_T0ct_Overall Themes Sum Flags

Note. Social Vulnerability Themes* variables composition is described on Table B4.

Table F7

Multicollinearity test RQ4-Model-2a

	Collinearity Statistics	
	*Tolerance	VIF**
Age 4gr	0.693	1.442
Sex	0.985	1.016
Principal Diagnosis	0.785	1.273
Surgical_Procedure_Site	0.701	1.426
Surgical Approach	0.693	1.443
Anastomosis distal end	0.791	1.264
Diverting Stoma	0.780	1.282
APRSOI Severity of Illness risk	0.546	1.831
Admission Type	0.669	1.496
LOSS_4gr	0.619	1.616
Race	0.835	1.198
Health Insurance	0.735	1.361
Annual Hospital Volume4	0.889	1.124
T0z_Overal Themes Summary score	0.626	1.597
T0ct Overall Themes Summary score	0.722	1.385
Flags_TOTALz_Themes Sum Flags3	0.720	1.390
Flags_TOTALct_Themes Sum Flags3	0.764	1.309

Note: cut-off points: *tolerance < 0.2 and **VIF > 5,
Dependent Variable: Not_SSI=Not Surgical Site Infectious Complications

Table F8

RQ4-Model-2a Description Omnibus Tests

Omnibus Tests of Model Coefficients		Chi-square	df	*p*
Step 1	Step	18154.84	42	0.000
	Block	18154.84	42	0.000
	Model	18154.84	42	0.000

Table F9

RQ4-Model-2a Description Model Summary

Model Summary			
Step	-2 Log likelihood	Cox & Snell R Square	Nagelkerke R Square
1	86902.707a	0.13	0.235

Table F10 *RQ4-Model-2a Description Hosmer and Lemeshow Test*

Hosmer and Lemeshow Test			
Step	Chi-square	df	*p*
1	6.026	8	0.644

Table F11 *RQ4-Model-2a Description Classification Table*

Classification Table	Observed		Predicted Not_SSI (Not Surgical Site Infectious Compl)		Percentage Correct
			no	yes	
Step 1	Not_SSI (Not Surgical Site Infectious Compl)	no	111691	964	99.1
		yes	16790	1286	7.1
	Overall Percentage			86.4	

RQ4-Model-2b

In RQ4-Model-2b were included the Social Vulnerability Themes with dependent variable Not_SSI (see Figure F3). Independent variables initially included for multivariable analysis in RQ4-Model-2b were selected based on $\chi 2$ test. After multicollinearity test the independent variables included in the final RQ4-Model-2b are shown in Figure F3.

Figure F3

Independent variables in the final RQ4-Model-2b after multicollinearity test,

Dependent Variable: Not_SSI

Variable Level	Variable Type	Variables in RQ4-Model-2b
Biological Patient level		Age
		Sex
Clinical Patient level		Principal Diagnosis
		Surgical Approach
		Surgical_Procedure_Site
		Anastomosis distal end
		Diverting Stoma
		Admission Type
		APRSOI Severity of Illness risk
		LOSS_4gr
SDOH Patient level	Social /Community Context	Race
	Health Care Access	Health Insurance
SDOH Zip code level	Hospital Facility Used	Annual Hospital Volume4
	Social Vulnerability	Theme 1z_Socioeconomic Status
		Theme 2z_Houshold Composition and Disability
		Theme 3z_Minority Status and Language
		Theme 4z_Housing and Transportation
		Flags_T1z_Socioeconomic Status
		Flags_T2z_Household Composition & Disability
		Flags_T3z_Minority Status and Language
		Flags_T4z_Housing and Transportation
SDOH County level	Social Vulnerability	Theme 1ct Socioeconomic Status
		Theme 2ct Household Composition and Disability
		Theme 3ct_Minority Status and Language
		Theme 4ct Housing and Transportation
		Flags_T1ct Socioeconomic Status
		Flags_T2ct Household Composition and Disability

Note. Social Vulnerability Themes* variables composition is described on Table B4.

Table F12

Multicollinearity test RQ4-Model-2b

	Collinearity Statistics	
	*Tolerance	*VIF**
Age 4gr	0.69	1.45
Sex	0.98	1.02
Principal Diagnosis	0.79	1.27
Surgical_Procedure_Site	0.70	1.43
Surgical Approach	0.70	1.44
Anastomosis distal end	0.79	1.26
Diverting Stoma	0.78	1.28
APRSOI Severity of Illness risk	0.55	1.82
Admission Type	0.61	1.65
Length of Hospital Stay /days	0.53	1.91
Race	0.75	1.33
Health Insurance	0.73	1.37
Annual Hospital Volume4	0.85	1.18
T1z_Socioeconomic Status	0.43	2.35
T2z_Houshold Composition and Disability	0.60	1.66
T3z_Minority Status and Language	0.31	3.22
T4z_Housing and Transportation	0.57	1.76
T1ct Socioeconomic Status	0.20	4.96
T2ct Household Composition and Disability	0.32	3.14
T3ct Minority Status and Language	0.08	12.99
T4ct Housing and Transportation	0.28	3.56
Flags_T1z_Socioeconomic Status	0.53	1.89
Flags_T2z_Household Composition & Disability	0.68	1.46
Flags_T3z_ Minority Status and Language	0.60	1.68
Flags_T4z_Housing and Transportation	0.58	1.72
Flags_T1ct Socioeconomic Status	0.26	3.86
Flags_T2ct Household Composition and Disability	0.33	3.04
Flags_T3ct Minority Status and Language	0.13	7.70
Flags_T4ct Housing and Transportation	0.13	7.74

Note. cut-off points: *tolerance < 0.2 and **VIF > 5,
Dependent Variable: Not_SSI =Not Surgical Site Infectious Complication

Table F13

Multicollinearity RQ4-Model-2b after adjustment

	Collinearity Statistics	
	*Tolerance	*VIF***
Age 4gr	0.689	1.452
Sex	0.984	1.016
Principal Diagnosis	0.785	1.274
Surgical_Procedure_Site	0.702	1.425
Surgical Approach	0.695	1.439
Anastomosis distal end	0.791	1.263
Diverting Stoma	0.784	1.276
APRSOI Severity of Illness risk	0.549	1.822
Admission Type	0.606	1.651
Length of Hospital Stay /days	0.525	1.906
Race	0.753	1.328
Health Insurance	0.733	1.364
Annual Hospital Volume4	0.850	1.176
T1z_Socioeconomic Status	0.428	2.338
T2z_Houshold Composition and Disability	0.602	1.662
T3z_Minority Status and Language	0.314	3.190
T4z_Housing and Transportation	0.575	1.738
T1ct Socioeconomic Status	0.224	4.473
T2ct Household Composition and Disability	0.376	2.657
T3ct Minority Status and Language	0.223	4.478
T4ct Housing and Transportation	0.412	2.425
Flags_T1z_Socioeconomic Status	0.529	1.891
Flags_T2z_Household Composition & Disability	0.685	1.459
Flags_T3z_ Minority Status and Language	0.596	1.677
Flags_T4z_Housing and Transportation	0.613	1.632
Flags_T1ct Socioeconomic Status	0.265	3.773
Flags_T2ct Household Composition and Disability	0.342	2.923

Note. cut-off points: *tolerance < 0.2 and **VIF > 5,
Dependent Variable: Not_SSI=Not Surgical Site Infectious Complication

Table F14

RQ4-Model-2b Description Omnibus Tests

Omnibus Tests of Model Coefficients				
		Chi-square	*df*	*p*
Step 1	Step	18247.115	73	0.000
	Block	18247.115	73	0.000
	Model	18247.115	73	0.000

Table F15

RQ4-Model-2b Description Model Summary

Model Summary Step	-2 Log likelihood	Cox & Snell R Square	Nagelkerke R Square
1	86810.436a	0.13	0.236

Table F16 *RQ4-Model-2b Description Hosmer and Lemeshow Test*

Hosmer and Lemeshow Test Step	Chi-square	*df*	*p*
1	6.675	8	0.572

Table F17

RQ4-Model-2b Description Classification Table

Classification Table a					
	Observed		Predicted		
			Not_SSI no	yes	Percentage Correct
Step 1	Not_SSI	no	111503	1152	99
		yes	16585	1491	8.2
	Overall Percentage				86.4