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Containing Contamination From Human Sources in the Surgical Suite with Fabrics and Garment Design

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CONTAINING CONTAMINATION FROM HUMAN SOURCES

IN THE SURGICAL SUITE

WITH FABRICS AND GARMENT DESIGN

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ABSTRACT

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by

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A Dissertation Submitted in Partial Fulfillment of

the Requirements for the Degree of

Doctor of Philosophy

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ABSTRACT

When compared to surgical environments of the 19th Century, today's hospitals are paradigms of sterility. The bacterial counts from the air of uninhabited rooms are now virtually nil. The count begins to rise as soon as human activity begins, with levels of contamination being proportionate to the activity.

Although the question remains as to the pathogenicity of these organisms, they cannot be ignored as potential infectors and may well be of particular importance in patients in whom host resistance has been diminished for whatever cause.

Much has been written in the literature about the role of airborne contamination in surgical infection. Many methods have been used in an attempt to cope with the potential vectors, including ultra-violet irradiation and most recently the controversial laminar flow rooms.

Researchers have found that bacteria shed from human skin constitute a major portion of those found in the air of the surgical suite. This dissertation describes a method of reducing the number of bacteria transferred to the environment from these sources. The approach uses a densely woven material fabricated into an occlusive design garment which encapsulates those areas of the body identified as the primary source of shedding of skin bacteria. The tests conducted demonstrated that an occlusive design garment, when worn properly, significantly reduces the bacterial air count.

The elimination of these sources of environmental bacterial contamination may well be vital to the safe performance of many surgical procedures, and to the prevention of exogenous infection in unusually susceptible patients.

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CHAPTER I

ENVIRONMENTAL CONTAMINATION IN THE SURGICAL SUITE

Introduction

Much has been written about the role of airborne contamination in surgical infection and many methods have been used in an attempt to cope with potential vectors, including ultra-violet irradiation and, most recently, the controversial laminar flow rooms (Williams, R.E.O., 1966).

The classification of some humans as "carriers" and potential disseminators of certain types of infectious organisms is well known and has long been recognized (Maibach, H.I., 1965).

Since it is not always practical or possible to restrict or remove the carrier from the surgical suite, precautions should be taken which could prevent or minimize the transmission of these viable organisms to the ambient atmosphere.

The objective of this study is to investigate the approaches aimed at effectively reducing the number of bacteria transferred to the environment from human skin. The study examines the use of a special fabric for a garment designed to encapsulate those areas of the body identified as the primary source of skin bacteria.

The reduction in the number of bacteria within the surgical environment may be of particular importance in patients whose host resistance has been diminished for whatever cause.

Modes of Transmission of Infection

There are essentially three modes of transmission of contamination or infection in surgical wounds: 1) contact, 2) endogenous, and 3) airborne. Adoption of aseptic practices such as surgical scrub, gloves, mask, gown and the use of sterile supplies is an acknowledgment of the importance of contact as a major source of contamination. There is also agreement in terms of endogenous bacteria being another major contributor to surgical infection, especially in those situations when the viscera is entered. However, since the era of Lister, there has been virtually no agreement, whatsoever, about the importance of airborne contamination and its role in the infection of surgical wounds (Coriell, L., 1970).

Airborne Contamination

Certain modern aseptic practices, when carefully followed, control, if not minimize, the possibility of infection by contact. By the same token, improved procedures and supportive measures such as, discipline of the surgical team, availability of numerous antibiotics, and quality of supplies further reduce the possibility of endogenous infections. However, under some circumstances, airborne contamination may well be the major factor leading to surgical infection. The issue is certainly controversial. In point of fact, the relative importance of airborne contamination in a clean surgical wound is not known. Nevertheless, airborne contamination is a potential source of infection and evidence does indicate this possibility (Laufman, H., 1978).

The airborne route of infection exemplifies the cyclical path of the theory of infectious diseases. For several hundred years, air was thought to be a major route of infection. Control of the spread of epidemics was promoted by developing air barriers such as burning sulphur, camphor and tar. The airborne route became of less concern when other modes of transmission were identified with a fair degree of certainty. By the middle of the 19th Century, lack of concern of airborne contamination had led researchers away from this avenue of investigation. Then Pasteur's demonstration of 1861, followed by Lister's work in 1867, resulted in a re-emergence of interest in the airborne route of transmission. Lister reported on the control of post-operative wound infection. However, subsequent work in the 1880's indicated the spread by contact to be the more prominent influence in terms of disease. This resulted in the discontinuance of the practice of spraying of the operating room. Several years later, at the turn of the century, additional emphasis and importance was given to the role of spread by contact which further downgraded the significance of airborne sources (Burke, J.F., 1963).

After World War I, interest in the airborne route emerged once again with studies of the spread of disease in experimental animals (Walter, C.W., 1963). Further reports dealing with measles outbreaks in schools, respiratory disease epidemics among military recruits, and nosocomial infections in pediatric and surgical wards, were all contributory factors to the reawakening of interest in the airborne route (Brachman, P.S., 1971).

Bourdillon and Colebrook (1946) advocated that hospitals exclude contaminated air from the outside. They suggested certain precautions for the movements and activities of persons in the operating room, and described the rapid removal of despensed air as it became contaminated. The legitimate role of disease spread via the airborne route actually began to be studied in the late 1920's and 1930's and was continued into the 50's by investigators such as Wells, Hart, Walter, Hare, Ridley, Bethune, Williams and Shooter (Wells, W.F., 1955).

Clean Rooms

In the 1960's, "clean rooms" were being put into use by industry. These rooms were used to assemble small parts that had to be kept free from dust particles (Daniel, D., 1964). Before the laminar flow concept was developed the air handling engineers had produced the "Class 100,000" room (Whitfield, W.J., 1962). Such a room contained no more than 100,000 particles $.5_{u}$m or greater, per cubic foot of air. By the end of 1961, the first laminar flow clean room was built and tested (Whitfield, W.J., 1963). These rooms, with little restriction of personnel, could be maintained with levels of fewer than 50 particles of $.5_{u}$m or larger per cubic foot. With the passing of time, a clean bench and a Class 100 clean room were applied to the manufacturing technology and handling of pharmaceuticals. Federal Standard 209 was issued in 1963, and the National Aeronautics and Space Administration (NASA) specified laminar flow clean rooms for the manufacture and assembly of spacecraft (NASA Standard, 1963). Rooms with vertical flow were compared with those of horizontal flow (Marsh, 1964). Both types were also put into use. A laminar flow clean stall for operating room use was tested and reported on in 1965 (Whitcomb, J.G., 1966).

Ultra-Violet Irradiation

The use of ultra-violet irradiation had been suggested as a means of controlling airborne contamination in operating rooms. One hospital (Hart, D., 1936, 1960) installed equipment to give an irradiation intensity of 28-

34 micro-watts per square centimeter in the operating area and reported a dramatic reduction in the frequency of the heretofore unaccountable sepsis. However, in a large scale use of the same system, (National Research Council, 1964) there was a 2 to 4 fold reduction of airborne contamination. However, the general wound sepsis rate remained unchanged, being 7.5 percent in non-irradiated, and 7.4 percent in irradiated operating rooms.

These somewhat disappointing results were difficult to understand, because similar reductions in the number of airborne contaminants by ventilation had strikingly reduced the rates of sepsis. A possible explanation may be that ventilation removes many large as well as small airborne particles, while the activity of ultra-violet irradiation is mainly focused against bacteria that are embedded in small particles. Those bacteria in the larger particles are shielded from irradiation. Therefore, the larger particles contain enough organisms to initiate sepsis (Williams, 1966).

In addition, the practical application and usefulness of ultra-violet irradiation is furthermore limited due to the fact that direct contact with the organisms is required for the agent to be effective. Micro-organisms are in a constant state of motion in the air currents of the conventional ventilating system, and in moving across the ray of ultra-violet light, the pathogens could conceivably be exposed for only a fraction of a second. This is too minimal a time for effective contact with the radiant energy (Atkinson, L.J., 1978). Against the apparently slight advantage that may be derived from the use of ultra-violet irradiation in the surgical suite is the risk of burning the unconscious patient by accidental exposure. The need for members of the surgical team to wear eyeshields, special headgear, and other special clothing to protect the skin are some of the discomforts which must be reckoned with and/or tolerated.

Exhaust Ventilation

In England in the meantime, Blowers and Wallace (1960) found that with exhaust ventilation, an air particle count of 750-1000/m^3 could be attained; that by adding positive pressure ventilation, the count could be reduced to 200-300/m^3 ; and that by adding some improved procedures, the count could be further lowered to 15-100/m^3 (Blowers, R., 1960).

Laminar Flow

About this same time, J. A. Charnley (1964) at the Wrightington Hip Centre near Wigan, England, was attempting to achieve a cleaner environment for his new operation for total hip joint replacement. The air in his operating rooms was relatively untreated when compared with most operating rooms in the United States. He instituted many measures to correct this situation, one of which was installing a glass-walled chamber with a vertical flow air system in the operating room.

As the great success of Charnley's hip replacement operation became known to more and more orthopedic surgeons throughout the world, visitors came from far and near to observe the technique first hand. The incidence of deep wound infection rate (9 percent in 1958) had been declining steadily until it reached one percent (Charnley, J., 1970, DuPont, J.A., 1972). With this impressive record, Charnley convinced a large segment of the orthopedic community, that the reduction was due mostly to the use of the "green house." Visiting surgeons returned home and demanded "green houses" in their operating rooms. This set the stage for the argument and controversy related to the benefits of laminar flow. The concerns continue to prevail even today.

With the advent of horizontal modular blowers, a minor controversy soon arose as to whether vertical airflow was better than horizontal. Some hospitals compromised by installing diagonal airflow units in their surgical suites. A state of confusion arose on the part of both surgeons and administrators as to the real benefit to be derived from these expensive air handling systems. The clamor rose to the point that some orthopedic surgeons were said to have joined in on the chant of the manufacturers, who maintained that, unless a laminar flow chamber was installed, infection rates would be high and lawsuits would surely follow (Laufman, H., 1973).

Air Filtering Systems

For the most part, U. S. hospitals today have operating rooms with well filtered, humidified, temperature controlled, properly disperse air with an air handling plant that has been properly engineered and designed and, if well maintained and kept in good repair, will function as intended. These surgical suites are usually ventilated by efficient bag-filtered HEPA (high efficiency particulate air) system.

The environment of these operating rooms, especially when air flow rates provide over 25 changes per hour, has been shown to be virtually as clean as that produced in special chambers. If such ventilating systems are in good working order, the bioparticulate matter in the air is virtually nil untilthe room is occupied by members of the surgical team.

This is essentially Lidwell's (1963) observation to the effect that no matter what the system of airflow, the presence of personnel never permit maintenance of zero particles over an extended period of time.

Statement of Provision

For the purposes of this study, the research will focus on a certain aspect of clothing and the hypothesis that the air in the operating room can be kept clean with proper containment of the team through the use of apparel. The researcher recognizes the role of numerous other factors that may influence the contribution of contamination from humans (such as age, sex, race, shedding characteristics, personal hygienic habits, time of day and function) but this study does not deal with them.

Definitions of Terms

Selected terms are defined in the study as follows:

1. Clean Room: A room which incorporates high standards of control of humidity, temperature, and all forms of particulate matter and contamination. The rooms are classified as Class 100, 10,000 or 100,000 depending on the level of cleanliness which can range from 100 to 100,000 particles 0.5 microns and larger per cubic foot (NASA Standard MSFC - STD 246 - Design and Operational Criteria of Controlled Environment Areas, July 29, 1963).

2. Laminar Flow: A special air-handling system for improving the filtration, dilution and distribution of air. It is a controlled uni-directional positive pressure stream of air that moves either horizontally or vertically across an enclosed room. A rate of 100 to 400 air changes per hour is possible, with most systems delivering about 240 per hour

(Marsh, R. C., et al, Standard tests for laminar flow devices, Technical Memorandum, SC-TM-64-637, Sandia Corp., Albuquerque, N. M., 1964).

3. Operating Room: That place in the hospital where the patient undergoes a special diagnostic or operative procedure essential to his treatment. Set aside from the rest of the hospital so that the special precautions required may be taken. An operating suite consists of more than one operating room and may be called surgery department (Hoeller, 1965).

In the next chapter the use of operating room apparel will be explored in greater depth.

Summary

The role of airborne contamination in surgical infections has been addressed by several researchers. Many methods have been used in an attempt to cope with the potential vectors, including various types of air filtering systems, sophisticated laminar flow air circulatory systems, and ultra-violet irradiation. Although each of the systems has its own distinctive advantages and disadvantages, each has proven to be effective in achieving microbiologically clean air up to a point when the operating room is occupied by members of the surgical team.

CHAPTER II

OPERATING ROOM APPAREL:

PAST AND PRESENT

Its History and Purpose

The evolution of special attire for the operating room has been an integral part of aseptic practices introduced in the latter half of the nineteenth century. Consideration for these practices are a comparatively recent event in contrast to the total history of medicine and health care. One of the earliest mentions of specific OR attire appeared in a nurses' training handbook recommending that the nurse bathe before operations and wear a garment with long sleeves plus a clean apron during the procedure. (Hartford Hospital, circa 1900).

In some operating theaters, the bacteria-laden, infection-causing woolen suits and Prince Albert's were replaced by OR garb made of a sterilizable material to lessen the introduction of pathogenic organisms into the wound. The two-piece suits covered the entire body and the arms to the elbow (Beck, C., 1895). Operating room apparel was first introduced during the last quarter of the nineteenth century. Items such as special surgical clothing, head coverings, gloves and masks were brought into use during this period. A German surgeon, Gustav Neuber, is credited with being the first to insist on absolute cleanliness in the operating room in 1883. He required surgeons and their assistants to wear sterile gowns and caps (Castaneda, 1961). In the United States, a photograph of an operation in an 1888 text on the practical application of asepsis shows the surgeon, a well-bearded man, wearing an apron to cover his clothes, while the nurse wears a dark, long sleeved dress, a white apron and kerchief tied over her hair (Gerster, 1888).

Innovators in aseptic techniques insisted on operating room cleanliness and on the wearing of caps and sterile gowns (Castaneda, 1961). In spite of the advances in technique and the profession in general, many surgeons in the 1890's continued to operate in street clothes under a pus and blood encrusted apron (Atkinson, L.J., 1978).

One of the early American advocates of asepsis was Doctor Hunter Robb of Johns Hopkins University. In his book, Aseptic Surgical Techniques, (1894), Dr. Robb recommended suits especially adapted for surgery be made of material that could easily be sterilized. Robb explained that, during an operation, the sleeve or some other portion of the garment could come in contact with the sterile field or one of the surgeons could accidentally touch the clothing of one of his colleagues. He continued to explain that, if the garments are not sterile, pathogenic microorganisms could readily be introduced into the wound. Robb further suggested that the suits should be made of some white material that could be easily washed.

Apparel in the Twentieth Century

As surgeons adopted the use of the surgical gown, so did the nurse who handed him his instruments. A nurses' guide published in 1905 (Senn) instructed the nurse to wear a calico dress covered with an aseptic (sterile) gown.

By 1914, gowns, caps, masks and gloves were gaining acceptance for surgeons, assistants and the sterile (scrubbed) nurse. The gowns had long sleeves, belted fronts and fastened down the back. Although no mention is made of the surgeon's (male) scrub apparel, it is indicated that nurses (women) on duty in the operating room wore white dresses made of linen or cotton. They put on a fresh gown every day or more often if necessary (Felter, R.K., 1914).

But then, just as today, there was resistance to principles attempting to advance aseptic practices. Few surgeons were properly gowned and some continued to operate in their undershirt. Nevertheless, insistence and special clothing was repeatedly emphasized in textbooks for OR nurses. One such book published in 1924 stated that "the circulating nurse should be easily picked out, wearing an operating room cap, but no mask, and a gown with special pockets for pencil and pad." The text continues to describe the scrub nurse as wearing a mask and donning a gown after scrubbing (Smith, A.A., 1924). Another text observed that a most stringent rule in the modern operating room should be not to permit the surgeon, his assistants and the nurse to wear street clothes in the operating room (Falk, H.C., 1925).

For many years, nurses simply wore their regular nurse uniforms in the operating room, with the sterile or instrument nurse wearing a sterile surgical gown over it. The adoption of today's traditional scrub apparel apparently took place over a number of years. Researchers' attempts to find documentation as to when all surgical personnel, male and female began to wear these type of garments have not been successful. However, from personal conversations and communications with a number of people who worked in ORs years ago, it was found that, in some geographic areas, the garments were being used in the thirties and in other areas not until the forties (Personal communication).

In the fifties, colors were introduced into operating room apparel primarily to reduce the glare. This had a welcomed side effect of improving the atmosphere of the operating room. In the sixties, pantsuits for OR nurses arrived on the scene. Even before they became high fashion for women, their use was suggested by a Scottish anesthetist who commented that the nurses' skirts sent out a cloud of bacteria. He recommended that nurses wear tight, close-fitting slacks and a tight, short jacket as a means of controlling bacteria and preventing infection (American Hospital Asssociation, 1970).

Materials Used

As previously stated, the original material that was suggested for use in operating room apparel seemed to have two standards (white and washable). In the 1880-1890 period, although there were a relatively limited number of qualities of fabrics available, they all had one thing in common. They were all made of one hundred percent carded cotton. These fabrics were known as either "muslin" or "sheeting." Muslin had a higher thread count, but was not quite as strong. So, the heavier weight, one hundred thread count sheetings soon became the standard. Over the years, another more expensive all cotton fabric was used by those that preferred a fabric with better surface quality. Technically known as "jean twill", it had a higher thread count than either the muslin or sheeting, but was considered desirable for both its better appearance and durability.

With the passing of time, the requirements for laundering of hospital linens were established. They called for the use of very hot water, alkali, bleach and anti-chlor. The all cotton, loosely woven, readily permeable apparel fabrics proved to be most satisfactory in terms of their durability. Although they admittedly left much to be desired aesthetically, the only major change that was made was the addition and availability of two surgical colors, jade green and misty green. The colors were desirable, since they had a tendency to somewhat subdue the appearance of blood stains while at the same time reduce the glare from the powerful, overhead surgical lights.

In the mid-1960's, the retail textile market was introduced to permanent press. No longer would a garment have to be ironed to have a neat, wrinkle-free look. However, there was a safety factor to be reckoned with in an operating room environment. These new fabrics were generally made of a blend of sixty-five percent polyester and thirty-five percent cotton. Since the man-made polyester fiber had been known to be capable of generating static electricity under certain conditions, the question of compliance with existing safety codes had to be reviewed. Most hospitals at that time were using flammable anesthetics, and the safety of surgical textiles was determined by the requirements for surface resistivity and static decay, as clearly defined in the National Fire Protection Association (NFPA) Code No. 56A. (Code for Use of Flammable Anesthetics, 1954). A testing facility recognized by hospitals and insurance underwriters - Underwriters Laboratories (UL), Chicago, Illinois - investigated the matter and found, in fact, that the conventional permanent press fabrics did not meet the NFPA's rigid standard.

Shortly thereafter, a new permanent press fabric was brought to market which had a fiber content of sixty-five percent polyester, thirty-four percent combed cotton and one percent stainless steel fiber. This fabric was submitted to UL for evaluation. The stainless steel fiber was found effective in terms of resisting and dissipating a static charge. The fabric was approved for use and was listed with UL in the Recognized Component Index (1970). Another blended fabric having a fiber content of fifty percent polyester and fifty percent combed cotton with a permanent anti-static finish subsequently became very popular. As time progressed, hospitals began to refrain from the use of flammable anesthetics. This eliminated the hazards of static electricity. Today, for example, it is estimated that less than five percent of all surgical procedures are performed with flammable anesthetics (Laufman, H., 1981). Basically, however, the rigorous laundering requirements for surgical apparel still prevails, and whether it be a fabric made of all cotton or one of the polyester/cotton blends, they are all regarded as being of suitable quality.

The stainless steel content fabric has a thread count of approximately one hundred and ten, which is fairly close to that of the all cotton sheeting. The other commonly used polyester/cotton blend is known as a "percale" having a thread count of approximately one hundred and eighty. Although the percale is not as loosely woven as the sheeting, its interstices are comparatively large and both are considered readily permeable. They are available today in a variety of colors and in a number of attractive prints as well.

OR Apparel Today

It was not until 1975 that the Association of Operating Room Nurses (AORN) published their "Standards for OR Wearing Apparel" (AORN Standards, 1975). These standards were applicable to all types of body covers: scrub dresses, jumpsuits, pant-suits, shirts and trousers, headcovers, masks and shoe covers. Each item was regarded as having an appropriate purpose in terms of combating sources of exogenous contamination to the surgical environment. With the publishing of these standards, apparel became further recognized as an important facet of environmental control. The standards indicated that scrub pants with ankle closure were preferable to scrub dresses. No specific mention was made of the quality or capability of the material from which they should be made/or of the particulars of their design. However, the standard did further acknowledge the need for research in this area by stating that, "Further investigation regarding scrub pants versus dresses is being requested." This, of course, accounts for the very purpose and objective of this study, which investigated ways and means of effectively reducing the number of bacteria transferred to the environment from human skin. The study tested the use of a special garment fabric designed to encapsulate those areas of the body identified as the primary source of skin bacteria.

People as Shedders

In spite of the fact that there are many variables associated with sepsis, people remain the major source of contamination. Everything on or about a human being is contaminated by him or her in some way. Additionally, the action and interaction of personnel and patients contribute to the prevalence of organisms (Walter, C.W., Kundsin, R.B., Brubaker, M.M. et al,1963; Walter, C.W. and Kundsin, R.B., 1973).

Although many mechanisms of dispersal of microorganisms exist, probably the most common in the hospital environment is dispersal of organisms carried on the skin, or derived from some other carrier site, on small particles of desquamated epithelium. The "carrier" of *Staphylococcus aureus* has received the most attention. But there may well be "carriers" of other infectious bacteria which are not recognized as such at this time. Not to be overlooked is the quantitative differences in the number of bacteria present. The throat and nasal "carrier" have always been a matter of concern, and the identification and disposition of the skin "carrier" only tends to complicate matters further.

Organisms shed by these "carriers" on small particles of desquamated epithelium have a very small equivalent particle diameter and can remain airborne for long periods. Such airborne organisms may be inhaled, resulting in nasal acquisition, or may settle onto one of many items or solid surfaces in the surgical environment and thereby be acquired by contact.

Effects of Showering

Another phenomenom is the effect of showering on dispersal of skin bacteria. Although contrary to what would be normally expected, an increase in dispersal of bacteria following a showerbath has been demonstrated. It would have been normal to assume that showering would reduce the number of bacteria dispersed, but in some individuals dispersal was considerably increased for as long as two hours following the shower (Bethune, D.W.,1965; Spears, R., Jr., 1966). This occurred despite the fact that recently acquired "contaminant" bacteria were removed by showering (Clifton, R.J., 1968). Similar observations of an apparent increase of bacteria on freshly washed hands was made by Colebrook (1930). An explanation for this may be that, while many bacteria are removed in washing the skin, those that remain are spread over the skin surface. This results in a higher surface count of viable particles even though each viable unit may consist of fewer organisms.

Primary Reservoirs of Organisms

It has been established that apertures in the apparel at the waist, neck and arms are apparently not important as sites for the escape of skin organisms (Blowers, R., 1965). Dissemination of skin bacteria probably occurs as a result of friction between areas of heavy skin contamination and many more bacteria are liberated involving the lower extremities (Bernard, H.R., 1965b).

Thus, the perineum, thighs and feet are isolated as the primary sources of viable organisms which may become airborne in the course of normal activity. Substantiating evidence has confirmed the importance of the perineal area as a source of bacteria shedding from the skin (Hare, R., 1958; Ridley, M., 1959).

It has been shown that the conventional clothing made of loosely woven cotton sheetings, and worn by surgeons and nurses in the operating room, does not prevent the liberation of skin bacteria from the body to the air (Bethune, et al, 1948). Researchers studying contamination of the air in ward dressing rooms and operating theaters found that many of the organisms present were derived from infected burns, blankets and the clothes of surgical and nursing staff. Movement of the staff about the room increased the number of airborne organisms, partly by raising contaminated particles that had settled to the floor and partly by liberating fresh ones. Duguid and Wallace (1948) found that even slight movement increased the output of organisms and that a loosely woven cotton gown worn over ordinary clothing did not prevent this scatter.

Subsequently, it was demonstrated that conventional operating room apparel did little or nothing to reduce airborne dispersal of skin organisms during vigorous movement in experimental air sampling chambers (Bernard, H.R., 1965; Blowers, R., 1965). The organisms were thought to probably be on skin scales which escaped partly through the interstices of the fabric and partly through the normal dress apertures, of which open trouser ends were most important. It had also been shown that dispersal of bacteria bearing skin particles was almost eliminated by wearing suits of impermeable polyethylene with closed trouser ends (Williams, 1966). However, long continued wearing of such an outfit would be intolerable.

Nevertheless, this did confirm the theory that restriction of dispersal of bacteria bearing skin particles to the atmosphere was a function of both the design of the apparel and the material from which it was made (Litsky, 1974). If the organisms shed from the lower extremities were to be restricted or confined, it would seem essential that this area of the torso be encapsulated by wearing apparel that is 1) made of an essentially impervious type of fabric, and 2) that this apparel be so designed so as to render it occlusive.

In the next chapter the methods used in the study are described.

Summary

The evolution of special attire for operating room personnel has been an integral part of aseptic practices since the latter part of the nineteenth century. Attention initially focused on the surgeon and sometime later on the nurse. Although the basic design and function of the garments has not changed dramatically, these materials, in terms of fiber content and color have advanced considerably. With the passing of time has also come an awareness of the role of apparel in containing dispersal of skin bacteria.

CHAPTER III

METHODS FOR EVALUATING GARMENT EFFECTIVENESS

Factors considered and accounted for in establishing the parameters of this investigation were:

1) qualities of materials used,
2) design of the garments, and
3) environmental conditions.

Qualities of Materials Used for Garments

Two types or qualities of materials were used.

The first was a traditional, loosely-woven, all cotton sheeting made of carded yarns, having a thread count of approximately one hundred and weight of 2.65 yards per pound. This quality of fabric is also available in blends of polyester and cotton. Although thread counts may be the same, the blends are a bit lighter due to the lighter weight of the polyester yarns compared to that of the cotton yarns. However, its general attributes in terms of air permeability and interstices are similar to that of the all cotton fabric.

The second fabric utilized has a thread count of approximately 270 threads per square inch and is woven of all combed Pima cotton yarns that are exceptionally long and tightly twisted (two ply warp) for strength and smoothness in hand. Its attributes and capabilities in terms of air permeability and bacteria permeation have been examined and documented in earlier studies (Bernard, H. R., 1965a, 1965b).

The fabric was originally developed during World War II, when a need arose for a suit for aircraft personnel on naval escort assignments - personnel who might be downed and have to spend prolonged periods of time in cold ocean waters. The suit was designed to protect the pilot from the elements without impairing his mobility or contributing to his general fatigue or discomfort. Known as an "immersion suit", it performed quite satisfactorily.

Since that time, the fabric has been used for Biological Isolation Garments (BIG) worn by the returning lunar astronauts, to keep lunar microorganisms on the astronauts' bodies from contaminating the earth's atmosphere. According to both U. S. Army and NASA officials, the outfits restrained more than ninety-nine percent of an aerosol of bacterial spores (Ref.: Report N68-16237, U.S. Dept. of Commerce, 1968).

Design of Garments Examined

The first set of garments studied were made of the loosely-woven, all cotton sheeting and consisted of the conventional shirt and pants for men and a scrub dress for women. The second outfit examined included a pair of trousers made of the densely-woven, all combed Pima cotton fabric. In this instance, the trousers were worn by both the men and women. The waist closure was secured with a usual cloth tie. However, the bottoms of the trousers continued at the ankles into a pair of boots of the same material, with soles formed of impermeable conductive rubber. Stitching of seams was carefully done to provide minimal leakage of air through the needle holes. The boot portion of the trousers was additionally secured at the ankles by cloth ties. The shirt was worn by both men and women in this instance, and was made of the same loosely-woven material as used for the first uniform.

For the studies done in the operating room, there were also two sets of garments worn the same as those as described above. In addition, all members of the surgical team were provided with a standard style surgical gown which had been sterilized. In those situations where the garments worn were made of the all cotton loosely-woven fabric, the gowns were similarly made of that quality fabric. When the trousers made of the densely-woven material were worn, the personnel again wore a gown of standard design into which inserts of the Pima cotton fabric were placed between the wrists and elbow and front of the gown to cover the area of the chest and abdomen.

Environmental Conditions

These tests were carried out in:

1) an environmental sampling chamber (Tests 1 and 2)

2) a general operating room (Test 3)

The physical details of the environmental sampling chamber were as follows:

Dimensions - 8 ft. X 8 ft. x 8 ft.

Ventilation - 10 room changes per hour,
no recirculation

Air conditioning - direct expansion coils
83,500 BTU

Humidity control - none

Room sterilization - 15 minutes of ventilation
plus ultra-violet irradiation
from four equally spaced 30 watt

ultra-violet tubes between

each experiment.

The physical details of the operating room were as follows:

Dimensions - 20 ft. X 20 ft. X 10 ft.

Ventilation - 9 room changes per hour,

no recirculation.

Air conditioning system - chilled water through

cooling coils.

Humidity control - none.

Room sterilization - housekeeping and ventilation

only.

Miscellaneous - instrument sterilization performed

outside the room, access through one

double swinging door, ceramic tile

walls, built-in stainless steel

cabinets, ceramic conductive tile

flooring and aluminum ceilings.

It is to be noted that the ventilation rates (room changes per hour) in both the environmentally controlled chamber and the operating room were ten and nine respectively. These rates are lower than the recommended rate of ventilation of fifteen to twenty-five changes per hour.

Methodology of Investigation

For the pilot study (Test 1) in the environmental chamber, five subjects - three male and two female - were tested on an individual basis. A subject was placed in the chamber, alternately wearing conventional apparel and the occlusive trouser design. When the conventional pants were worn, the shoes were covered with canvas type shoe covers. Caps were worn, but no masks. The subjects remained silent while in the experimental room, and moved about in the same manner as he or she would in normal operating room activity.

In additional studies in the environmentally controlled chamber, (Test 2), seventeen "volunteers" selected at random were again individually tested under comparable conditions while wearing either the loosely or the densely woven outfits. The subjects walked at a measured pace of about ninety steps per minute while in the experimental room to simulate maximum activity and to theoretically produce maximum contamination.

Air sampling in the chamber was done with the generally accepted Anderson multi-stage air samplers (Hall, L.B., 1962) (Cole, W.R., Bernard, H.R., and Gravens, D.L., 1965) positioned on a 42 inch high (waist level) table placed in the center of the room. Air samples were collected at ten minute intervals, and were examined after overnight incubation for bacterial content on petri dishes containing blood agar.

In the operating room, no pre-test measurements were made. The studies were carried out during the course of eight operations of comparable length and type while the subjects performed their normal duties. An attempt was made to limit entrance and exit of personnel not involved in the investigation. The same personnel -- twelve in all -- participated in each run and alternately wore the conventional apparel and the occlusive trouser design. Each of the operations was performed in the same operating room to insure consistency of air ventilation, humidity and temperature. An Andersen multi-stage air sampler was placed one and one-half feet from the left arm of the patient at table (waist) level. Air samples were collected at ten minute intervals for a ninety minute period and were examined after over-night incubation for bacterial content.

Statistical Treatment

In order to test the hypothesis, a "t" test of the difference between two means for correlated samples was applied (Ferguson, G. A., 1959).

The variance of the (D's) is given by:

$$\sigma^2 = \frac{\Sigma D^2}{N} - \bar{D}^2$$

The estimate of the variance of sampling distribution of $\bar{D}$ is

$$SD^2 = \frac{\sigma^2}{N-1}$$

The "t" ratio equals:

$$"t" = \frac{\bar{D}}{\sqrt{SD^2/(N-1)}}$$

Where: N = Sample size

D = Difference of any paired observation

$\bar{D}$ = Mean differences over all pairs

SD^2 = Estimate of the sampling distribution of $\bar{D}$

σ^2 = Variance of the D's

A confidence criterion of .05 was applied. Since the tests for small samples are not very sensitive, normalty and homogeneity of variance were assumed.

The critical values for specific degrees of freedom were as follows:

Test	Degrees of Freedom	Critical Values *		
		.05	.01	.001
1	4	2.776	4.604	8.610
2	16	2.120	2.921	4.015
3	3	3.182	5.841	12.941

* Critical values of t (Ferguson, G.A., 1959)

Summary

Factors considered and accounted for in establishing the parameters of this investigation were 1) qualities of the materials used, 2) design of the garments and 3) environmental conditions. These variables were initially examined in a pilot study with repeated runs with a limited number of subjects. The results were then confirmed on a larger scale with randomly selected "volunteers," and ultimately in a series of actual surgical procedures. The statistical treatment for testing the hypothesis is included.

CHAPTER IV

RESULTS OF INVESTIGATION

Hypothesis Tested

The results of the tests of the hypothesis, that the air in the operating room can be kept clean with proper containment of contamination from human sources through the use of apparel, are presented in this chapter. The tests were conducted in both a controlled environmental chamber and a general operating room. In addition, the tests were performed with personnel alternately wearing garments made of a loosely-woven fabric in a conventional design and others made of a densely-woven material in an occlusive configuration.

Controlled Environmental Chamber

In the controlled environmental chamber, the subjects were tested individually. The subjects alternately wore garments made of the loosely-woven fabric in the traditional design as well as those made of the densely-woven material in the encapsulating configuration. Each subject wore each of the outfits a total of ten times. The bacteria counts are presented in Table 1.

The data revealed that there were marked differences in the bacteria counts among the five individual subjects when the conventional garments were worn. However, these differences were significantly reduced with the use of the occlusive design apparel. The mean bacteria count per cubic foot was reduced from 11.6 to 1.3., significant at the .05 level.

TABLE 1

COMPARISON OF MEAN BACTERIA PER CUBIC FOOT BETWEEN CONVENTIONAL AND OCCLUSIVE APPAREL IN CONTROLLED ENVIRONMENT TEST

SUBJECT	CONVENTIONAL APPAREL	OCCLUSIVE APPAREL
1	11.7	1.0
2	6.5	1.9
3	7.5	.9
4	23.8	1.4
5	8.4	1.2
MEAN	11.6	1.3

$t = 3.238 \quad p < .05$

NOTE: Each subject wore both conventional and occlusive apparel ten times. The measures alone represent the average bacterial count for those occurrences.

In an attempt to replicate these results, the seventeen "volunteers," selected at random, again alternately wore either the loosely-woven garments or the densely-woven outfits. Each subject was tested one time in each suit with the results recorded in terms of the number of bacteria per cubic foot of air (see Table 2). The test revealed a significant difference at .01 level. Table 3 presents the findings obtained from an actual operating room during eight procedures. The counts are recorded in a descending range.

TABLE 2

COMPARISON OF BACTERIA PER CUBIC FOOT

BETWEEN CONVENTIONAL AND OCCLUSIVE APPAREL

	CONVENTIONAL APPAREL	OCCLUSIVE APPAREL
	24	2.5
	23	2.0
	15	1.8
	13	1.6
	12	1.6
	9	1.5
	8	1.4
	7.5	1.2
	7	1.2
	7	1.1
	6.5	1.0
	4.8	1.0
	4.3	.7
	2.9	.5
	2.5	.4
	1.9	.39
	1.8	.3
MEAN	8.835	1.188

$t = 3.459$ $\underline{P} < .01$ $N = 17$

NOTE: Each reading was taken one time for conventional as well as occlusive.

TABLE 3

NUMBERS OF BACTERIA PER CUBIC FOOT OF AIR FOUND IN CONSECUTIVE TEN (10) MINUTE AIR SAMPLES DURING TOTAL OF EIGHT (8) OPERATIONS

Consecutive ten (10) minute samples

	1	2	3	4	5	6	7	8	9	10	11	$\bar{X}$
<u>OCCLUSIVE APPAREL</u>												
Operation 1	.8	1.6	.6	.3	.7	.7	1.2	1.3	1.3	.8	—	.93
3	1.0	2.4**	2.3**	.5	.1	.6	.7	.3	1.5**	.2	1.0	.96
5	1.4	.9	.4	1.0	.9	.8	.7	.7	1.0	—	—	.867
7	1.5	1.9**	1.2	.8	.6	—	—	—	—	—	—	1.2
$\bar{X}$	1.5	1.7	1.1	.65	.6	.7	.9	.8	1.3	.5	1.0	.989
<u>CONVENTIONAL APPAREL</u>												
Operation 2	2.8*	3.0*	3.3*	3.5*	3.0	1.8	2.5*	4.1	4.3	3.9	2.9	3.19
4	4.2	3.6*	2.5	3.5	3.0*	1.8*	—	3.9	1.8	1.7	2.4	2.66
6	4.3	5.0	5.2	4.0*	3.5*	—	—	—	—	—	—	4.4
8	5.3	2.8	4.3	2.7	2.0	2.5*	1.8	2.8	3.2	2.7	2.8	2.99
$\bar{X}$	4.1	3.6	2.8	3.4	2.9	2.0	2.1	3.6	3.1	2.8	2.7	3.31

* - Staphylococcus aureus cultured　　$t = 5.479$　　$\underline{P} < .05$　　$\bar{X}$ = mean

** - Improperly clothed personnel present

Operating Room

The occlusive design garments performed equally as well in the invivo comparison. Comparing the data from each of the eight operations, the mean bacteria count per cubic foot was reduced significantly.

It was noted that when the conventional garments were worn, coagulose positive *Staphylococcus aureus* were recovered in three of the four operations. No *S. auereus* were recovered in the four procedures during which time the occlusive garments were worn (see Table 3). As tested, the utilization of the densely-woven fabric in the occlusive design garment again reduced the number of bacteria shed into the air from the subjects. Again the null hypothesis was rejected at $P < .05$.

Data gathered as a result of these tests appears to confirm that the use of occlusive garments may result in a significant reduction in the bacteria count within an operating room or other environment where such conditions are important, ie., selected manufacturing. Table 4 summarizes the results of the "t" test.

TABLE 4

SUMMARY OF THE FINDINGS

Test	Sample	"t"	Sig
1	5	3.238	*
2	17	3.459	**
3	4	5.479	*

NOTE: * = $P < .05$
** = $P < .01$

In the next chapter, conclusions and implications are reported.

Summary

The results of the tests of the hypothesis are presented. Although there were marked differences in the bacteria counts in all instances when the conventional garments were worn, these differences were significantly reduced with the use of the occlusive design apparel.

CHAPTER V

SUMMARY; CONCLUSION; IMPLICATIONS AND REEVALUATIONS

Overview

Hospital associated infections have been recognized since the beginning of organized health care. Indeed, at one time they created an atmosphere of foreboding for almost every patient. In the hospital of today, infection is no longer an overwhelming fear, yet it is still more than an annoyance, causing deaths and suffering, and adding to the expense of health care.

Post-operative wound infections reportedly account for approximately twenty percent of all nosocomial infections (Dixon, 1978). The time of discovery of post-operative wound infections is affected by the duration of hospital stay, and the use of antibiotics either prophylactically or therapeutically. As a result, the post-operative infections may not occur until the patient has been discharged from the hospital. While the patient is hospitalized, the post-operative wound infections create the need for longer stays and more expensive medical care. However, if the infection is discovered after discharge, the recovery period may be prolonged and rehospitalization may become a necessity and add still further to the already expensive health care cost.

An enormous amount of literature has been written on control of surgical infection and most examine only one or a few facets of the problem (Laufman, H., 1978). Although the incidence of infection following certain operations has fallen in recent years, overall statistics appear unchanged despite great advances in aseptic techniques and drug therapy (Nichols, R., 1982). This situation appears related to extended indications for surgery, advances in surgical techniques, and changes in the predominant microbiologic flora affecting surgical patients in recent years.

Infections in surgical procedures are considered to be a direct result of exposure and susceptibility. Both of these factors have greatly increased in recent years. Patients are on the operating table for longer periods as more radical procedures are carried out. As the frequency of organ transplants and other complex techniques increases, the possibilities of surgical infection will similarly increase.

The role of airborne bacteria in surgical infections has led to numerous attempts to evaluate the importance of this route of transmission. Several studies have already shown that operating room personnel are a major source of airborne staphylococcal contamination and infections (Walter, C.W., 1963, Burke, J., 1963, Duguid, J.P., 1948). The elimination of this source of environmental bacterial contamination may well be vital to the sate performance of many surgical procedures, and to the prevention of exogenous infection in unusually susceptible patients. How does one assess a value to a reduction in bacterial transfer? Theoretically, the advantage is obvious. To the extent to which there is a reduction of airborne bacteria, the possibility of infection from these bacteria should be proportionately reduced.

Aseptic technique can best be described as an aggregation of reasonable practices performed in the surgical suite as part of the overall methodology in controlling or minimizing the possibility of infection. Surgical asepsis concerns itself with protecting the patient from the environment and encompasses a broad spectrum of practices. The principles of aseptic technique as we know them were not simple to accomplish for any one of their individual advocates. Special wearing apparel in surgery seems like a good idea and has become a standard practice. However, if there is to be any progress made in this practice, it is quite apparent that a change or departure from traditional is in order so that the objective of the apparel will be achieved — that namely being to package people for the protection of the patient.

Many surgical devices contribute to the control of contamination, including air-handling equipment, surgical drapes and apparel, hundreds of disposable and reusable items, and surgical furniture and equipment. No one device or combination of devices can entirely contain surgical contamination hazards since most devices depend upon human manipulation and judgment in use (Laufman, H., 1978).

Nevertheless, the effect of infection on any patient, and more particularly on those whose survival depends on a narrow margin of safety, was never important as it is today. Certainly any and all measures which do not hamper the surgeon in the performance of his technical maneuvers should be worthy of serious consideration.

Although attempts to control airborne bacteria were a part of Lister's antiseptic routine in the earlier years, it was not too long before air was considered insignificant in comparison to direct contact as the means of spread of bacteria to the wound. Through general improvements in operating room design and procedures, reductions in the air borne contamination have obviously been achieved. However, it is not surprising that we have so far failed to measure the benefit of operating room ventilation. This results from the complexity of the task in trying to determine how much wound infection is contracted in the operating room, how often the bacteria are conveyed to the wound through the air, and how much this can be changed by apparel design and personnel behavior. There are several possible routes of transfer, and no one preventive routine is likely to be completely effective. It may well be too that airborne spread constitutes a serious risk in only a few situations, such as when there is an active disperser within the operating room.

The bacteriologist can demonstrate how infection spreads and present evidence which proves beyond any reasonable doubt that each of the routes has, on occasion, been the culprit. In the absence of quantitative comparison of risks, perhaps steps should be taken to prevent as many risks as possible. Avoidance of some hazards are simple; but to prevent all staff from dispersing their skin bacteria into the air around the wound could involve substantial cost and/or inconvenience. But before concluding that the cost or inconvenience of preventing the occasional greater risk are too great, it should be remembered that trying to protect against an apparently small risk of airborne infection is similar to sterilization of surgical tools. The risk of performing an operation with a scalpel that had merely been well washed in hot soap and water might well be very small, but we do prefer to sterilize.

It has been stated that "the development of post-operative wound sepsis is an important event that cannot always be prevented. It can, however, be minimized by careful, exacting surgical technique, by judicious use of prophylactic antibiotics, and perhaps by other preventive measures when they are shown to be of value in thoughtfully conducted clinical studies" (Nichols, R.L., 1982).

At this point in time, there appears to be ample demonstration that contamination in the form of skin scales with accompanying bacteria is generated through the very presence and physical activity of humans. In those situations where a clean environment is desirable, such as in hospital operating rooms, this contamination seems to provide the majority of airborne bacteria. A sensible approach to preventing these organisms from passing from personnel to the patient seems to be through the use of clothing or apparel.

Conclusions

The purpose of this research was to test the hypothesis that the level of airborne contamination from human sources in the surgical suite could be contained through the use of fabrics and garment design. In order to test the hypothesis, three experiments were conducted to determine the difference between conventional apparel made of loosely woven fabric and garments made of a densely woven material in an occlusive design. The researchers uncovered significant differences in all cases.

Therefore, the null hypothesis is rejected. The research concludes that it appears that the use of occlusive designed apparel within the surgical suite can indeed significantly reduce the bacteria count in that environment.

The American College of Surgeons' definition of surgical microbiologic clean air established three classifications of clean air based upon the number of viable particle counts (colony forming units) present (Committee on the Operating Room Environment (CORE), 1976). A Class 1 level of microbiologic cleanliness is defined as one in which the viable microbiologic airborne particle counts do not exceed one particle per cubic foot of air; Class 5 - more than one and up to five; and Class 20 - more than five and up to twenty. Based on this definition or standard, it can be stated that the use of the occlusive design garments made of the densely woven material virtually achieved a Class 1 level of microbiologic cleanliness.

The results of this investigation tend to support previous investigations which demonstrated that airborne bacterial contamination results from the shedding of skin scales may be reduced by wearing tightly woven or impervious clothing, tightly occluded at the ankles and the waist (Bernard, H.R., 1967; Davies, R.R., 1962). Clothing these lower extremities is important as the majority of the bacteria shed into the air arise from that area (Speers, R.Jr., 1965) (Bethune, D.W., 1965) (Whyte, N., 1976) (Whyte, W., 1978). This also tends to support the principle that restriction of dispersal of bacteria-bearing skin particles to the atmosphere is a function of both design of the apparel or clothing and the material of which the garments are made (Litsky, B.Y., 1974) (Whyte, W., 1976) (Whyte, W., 1978). The organisms, probably on skin scales, escape partly through the interstices of the woven fabric and partly through the normal dress apertures, for example, open-ended trousers.

In summarizing the results of another investigation, "aerial dispersal of skin bacteria was reduced by about eighty percent in male subjects wearing an experimental operating suit made of close weave fabric" (Mitchell, N.J., 1974). The researchers also found that drawers made of the same fabric similarly reduced dispersal by eighty percent in the unclothed subject, but the drawers were found to be less effective when worn under other clothing. This further tends to confirm the earlier findings as reported herewith with regard to the importance of encapsulating the lower extremities.

A more recent study (Dankert, J., 1979) reports on the reduction -- fifty to seventy-five percent-- in the number of bacteria carrying particles in the air of a test chamber and in an operating room when everyone present wore a suit made of a material said to have a fiber content of sixty-five percent polyester and thirty-five percent cotton. No other specific information about the cloth in terms of its thread count, weight, etc. was provided. However, the study did state that a suit, when worn in conjunction with knee high boots, showed even a further reduction in the dispersal of colony forming units. Again, the role and importance of the encapsulating principle was demonstrated.

It should be noted at this point that this principle has been applied in a practical situation by a group of clinical investigators. The team (Michaelsen, G.S., 1967) successfully adopted the use of occlusively designed apparel, made of the densely-woven cloth worn by nursing and other attendant personnel providing care to exceptionally susceptible patients being protected from airborne contamination in a unidirectional (ventilation) air flow patient isolation room.

Recently, a series of studies were completed in which eleven fabrics were evaluated in relationship to their use as protective garments in nursing and surgery. Physical measurements from bench tests and in a test chamber were obtained (Lidwell, O.M., 1978). Hopefully, this will stimulate others to address themselves to further study the matter as well. These studies suggest a need to initiate a change away from the use of conventional apparel made of the loosely-woven, readily permeable materials which are so commonplace today to occlusive garments.

Unfortunately, there are no universally accepted standards at the moment that specifically relate to hospital operating room apparel and surgical infection, bacterial penetration or dispersion. Standards for comfort, similarly, have left much to be desired. At a conference on Medical Applications of Textiles, (Department of Textile Industries, 1981), it was agreed that a priority need was the development of specific and meaningful standards. Certainly, without standards, there will be great difficulty in deciding the relative advantages of all the protective wear that may become available in the future.

Not to be overlooked, as well, is the fact that the effectiveness of any fabric can be reduced or completely lost by poor design or construction of the finished garment (Mackintosh, C.A., 1982). The fabrics that are currently available do not appear to work as well when examined as complete garments. This might well be due to the escape of contamination around seams or garment reinforcements such as bartacks.

Implications and Suggestions for Further Research

Although the influence of airborne contamination on surgical infections has yet to be determined, a number of methods have been used in an attempt to cope with the potential vectors. Ultra-violet lights and laminar-flow air circulating systems have demonstrated their capability of reducing the level of contamination in the surgical environment. If it is to be assumed from this study that the use of occlusive designed apparel can produce similar reductions, then other factors should be considered.

For example, ultra-violet lights can be harmful to members of the surgical team and the turbulence of air in a laminar-flow room has been found to be disturbing to the surgeon. On the other hand, occlusive designed apparel involves a simple departure from traditional practice and can very easily become an integral part of the surgeon's armamentarium.

In terms of cost, whether short term or long term, the economics of implementing a change from conventional to occlusive apparel are minimal compared to those for either the ultra-violet or laminar-flow systems.

Whereas reductions in infection rates have been clinically documented in studies utilizing ultra-violet and laminar-flow systems, this has not been done as of this date with occlusive designed apparel.

To those that question why a change in apparel is needed, the data is suggesting that the time has long past since the need for such a change has been evident.

Practical Applications Today

As noted earlier, the Association of Operating Room Nurses' (AORN) Standards for OR Wearing Apparel (1975) stated that:

> "Available data indicates scrub pants with ankle closures are superior to the scrub dress. (Further investigation regarding scrub pants versus dresses is being requested.)"

Since the publication of that Standard in 1975, there have been those that have maintained that wearing of pantyhose constitutes encapsulating the lower extremities and thereby restricts bacteria shed from this area from becoming airborne. Interestingly enough, Mitchell and Gamble in their study (1974) found that "the wearing of stockings increased the dissemination by young women of skin bacteria from the legs."

There is little doubt, that whatever the nature of a surgical procedure, today's patient is the beneficiary of a vast amount of knowledge and technology that has been developed by medical science over the span of time. However, it is highly unlikely that all the sources of contamination and the related possibilities of surgical infection will ever be totally eradicated.

Nevertheless, the role or influence of air-borne contamination in surgical infections has been duly documented. A practical (and economical) means of reducing the bacteria counts in the surgical environment by simply containing the contamination from human sources with fabrics and garment design has also been demonstrated. On this basis, there is no reason why this apparel, along with the mask and gloves, should not be considered to be an integral part of the surgeons' armamentarium.

Summary

This dissertation describes a method of reducing the number of bacteria transferred from human sources to the surgical environment. The approach uses a densely woven material fabricated into an occlusive design garment which encapsulates those areas of the body identified as the primary source of shedding skin bacteria. The elimination of these sources of environmental bacterial contamination may well be vital to the safe performance of many surgical procedures, and to the prevention of exogenous infection in unusually susceptible patients.

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