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Surgical attire in relation to asepsis :bits history and effectiveness with modern suggestions and including a bacteriological study of operating room shoes

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SURGICAL ATTIRE IN RELATION TO ASEPSIS

Its history and effectiveness with
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TABLE OF CONTENTS

INTRODUCTION

For the past seven or eight decades physicians have searched for methods and procedures to achieve absolute cleanliness of surgical wounds. Directly related to contamination and infection are the surgeon's attire and conduct in performing operations of any type.

It is the purpose of this paper to present a history of surgical attire and its evolution to the present day with comments on recent developments. Also included will be a special bacteriological study of shoes as a source of contamination in today's operating rooms.

We are all aware that maximum precautions for achieving sterile operative fields are not always taken. Effective but simple procedures will have to be developed before routine "aseptic surgery" can become a reality. The attitude of operating room personnel is extremely important. In this regard I would like to quote Sir Berkely Moynihan from his article published in 1920, "The Ritual of a Surgical Procedure". (28)

> "Every operation in surgery is an experiment in bacteriology. The success of the experiment in respect to the salvation of the patient, the quality of healing in the wound, the amount of local or constitutional reaction, the discomfort during the days following operation, and the severity of any possible sequels, depend not only on the skill but also on the care exercised by the surgeon in the ritual of the operation. The 'ritualist' must not be a man unduly concerned with fixed forms and ceremonies, with carrying out the rigidly prescribed ordinances to the surgical sect to which he owes allegiance; but a man who, while observing with unfaltering

> loyalty those practices which experience and experiment have together imposed upon him, refuses to be merely a mimic bound by custom and routine. He must set endeavor in continual motion, and seek always and earnestly for simpler methods and a better way."

The fact that there is so much information available and so many opportunities for help in the area of aseptic surgery, coupled with the growing threat of hospital infections, leaves no justification for any hospital or physician to continue outmoded or dangerous technics. Change must come with understanding, and unless information resulting in this understanding is sought and accepted, lives of patients will be threatened.

ERAS IN SURGERY

In the following few pages an attempt will be made to review some of the past principles in clean surgical procedure. Some of the major landmarks and achievements will be presented in a partially chronological form. It is rather difficult to attach specific dates to some of the great advances in surgical "aseptic technic", not only because records were not always kept but because many great steps were not realized until a number of years after their introduction. Then as now it took time for better technics to be accepted because of the diversities of opinion by different leaders in the field. To illustrate this fact there is no written record of when alcohol was first acclaimed for its germ killing properties.

Pre-Listerian Era.

This era includes the years from the beginning of surgery until about 1865, and is the longest of the eras. During this period of time there were no striking achievements in antisepsis until the last years prior to 1862. Probably one of the first recorded uses of any antiseptic solution, whether recognized or not, dates back to Biblical times when the Good Samaritan poured oil and wine into the wounds of the man by the wayside.

In surgery, the discovery of the antiseptic principle was of such significance that centuries of tradition and experience which preceded it appear as nothing compared with the rapid advances made in the decades which followed. It is difficult for us, in possession of the benefits of asepsis, to visualize the terrible and tragic conditions prevailing only a century ago in the pre-antiseptic era.

The earliest reference to any attempt at cleanliness prior to operations, that I could find, was reported by Dr. Fishbein in one of his articles. (11) He mentioned John of Arderne who was some semblance of a surgeon about 1350. He, John of Arderne, recommended that "they have clean hands, well shaped nails, cleaned of all blackness and filth."

From about 1300 to 1800 Barber-Surgeons reigned. Not until 1540 did the Barbers and Surgeons unite. Even after this time, they were more or less separated within their own ranks. In 1800 the Royal College of Surgeons was established. During the 500-year period, from 1300 to 1800, nothing very beneficial to wound healing was stumbled upon. I do think it worthy of mention, however, that about 1550 Ambrose Paré, a "barber turned surgeon", accidentally found that turpentine, with added ingredients such as herb juices and rose petals, was less damaging to bullet wounds than the previously used boiling oil poured into such wounds. This advance was achieved only because during the war they ran out of boiling oil. Paré also used ligatures to control arterial bleeding instead of cautery. Ligatures were mentioned years earlier but never became popular.

In the pre-Listerian era actually no specific precautions were taken with respect to cleanliness in operations. Surgeons might have worn anything from derby hats and street clothes to blood-encrusted operating jackets hung in the operating room between operations. (2) (See Fig. 3 and 4) It was not uncommon to have a pin cushion hanging in the operating room where needles were placed until used again in the next operation. Often a surgeon would place ligatures through his lapel buttonhole so they would be handy during operations. (14)

Not until 1843 was the issue of puerperal fever brought squarely before the medical profession in America. That year Oliver Wendell Holmes published his famous essay on "The Contagiousness of Puerperal Fever", maintaining that the "disease known as Puerperal Fever is so far contagious as to be frequently carried from patient to patient by physicians and nurses." In 1847 a similar debate was excited in Europe by Ignaz Philipp Semmelweis. He showed that the transmission could be prevented by such simple measures as washing the hands before examining, assisting or in any way touching a patient. Semmelweis for years prior to this had wondered why so many expectant mothers developed fevers and died. Expectant mothers of that time pleaded not to be taken to the hospitals for fear of contracting the "childbirth fever." In the hospital where Semmelweis worked the dissecting laboratory was close to the delivery ward but not until one of Semmelweis' close friends, and a fellow physician, died of sepsis following a laceration on the hand did he realize the similarity of symptoms. Even after seemingly convincing proof that the disease was spread by the attendants, he was severely criticised by other high ranking physicians of the time. Semmelweis died a brokenhearted man because of the lack of acceptance of his ideas. (36)

After Semmelweis' death it was realized that it was necessary to wash the hands between examinations of women but no antiseptics were in use at this time. As early as 1860, Jules Lemaire extolled the virtues of carbolic acid in preventing wound infections but not until Lister's work in 1862 was it generally accepted as good treatment. (36)

Prior to 1862, and even later, erysipelas, pyemia, septicemia, hospital gangrene and tetanus were never absent from the wards, and every operative wound was infected. It is a small wonder that "pure" creamy pus, without the telltale odor of incipient gangrene, was referred to as "laudable." Because of sepsis, little progress had been made in extending the scope of, and indications for surgery. Abdominal surgery was hardly thought of and drainage of empyema was the extent of thoracic surgery. The central nervous system was virtually unexplored. In the pre-antiseptic era amputation, lithotomy, vascular surgery and the drainage of abscesses made up the bulk of a surgeon's practice. Surgical results were judged by the mortality statistics of amputation: 25% was considered a "very low" rate, 50% was a more normal figure. (36)

Listerian Era (Antiseptic Era).

This era began about 1862 or 1865 and extended for only a few years and merged into the Aseptic Era about 1885. The literature does not completely agree as to the time Lister began practicing antiseptic technic. The discrepancy probably arises as to whether one considers his first use of carbolic acid as the beginning or whether it began with the germ theory. One source (5) stated that in 1862 Lister developed antisepsis but this hardly seems probable because at that time he was not yet familiar with the work of Pasteur. Pasteur was not a surgeon seeking the cause of infections but rather was a chemist seeking a method to preserve his wines. (21)

In 1865 Dr. Thomas Anderson, professor of chemistry at Glasgow University became familiar with Pasteur's work and called it to the attention of Joseph Lister of the Surgery Department at Glasgow. Lister was intensely interested in inflammation and suppuration of wounds at the time and Pasteur's work supplied the missing link as to their causes, that is: putrefaction was fermentation and due to micro-organisms, carried in the air and in wound material. Lister found it was possible to free the air of these germs by heat, filtration or chemical means and he chose the latter as the most practicable. The chemical substance he used was carbolic acid (German creosote). He first used this in March of 1865 on a compound fracture of the tibia but not until August of that same year did he have successful results with a similar case.

As early as 1752 different antiseptics were used including mercurial salts, alcohol and sulfates with reports of effectiveness. None of these antiseptics, however, became generally accepted as prime treatment for infected wounds. Lister is given the credit for antiseptic technic because he brought forward and maintained a scientific principle in accordance with which methods of procedure might be devised. For him carbolic acid was simply a means to an end, and not an end in itself, as was thought earlier of the different antiseptic solutions.

Lister's factors necessary for "per primum" healing of clean wounds were: (36) 1) The germs must be destroyed on the patient's skin, on the surgeon's hands, on the instruments used, and on everything surrounding the area of operation; 2) Germs must be prevented from entering the wound during operation, and 3) Germs must be prevented from spreading into the wound after operation.

This concept was difficult for the profession to grasp and it met with considerable opposition. Many lost sight of the principle and called it "carbolic acid treatment."

The Listerian technic caught on slowly at first but spread more rapidly once its merits were proved and other leaders in the field found success with it, if it was followed as Lister suggested. As time progressed, of course, some minor changes were made.

On October 12, 1865 Lister first used carbolic acid spray in the operating room, employing a crude atomizer, to engulf the area around the operative field with droplets of carbolic acid. (5) Not until August 10, 1871, however, did Lister publicly recommend this carbolic acid spray technic. (36) Volkman in 1872 used Lister's technic with success but others were more skeptical. Billroth, the German surgeon, was one of the skeptics as there had been reported cases of carbolic acid poisoning with its use. Von Bergmann, in Virchow's Krahhenhaus, also used the spray technic quite early.

As the carbolic acid spray did not prove highly effective and was used with some apprehension, Lister himself abandoned its use about 1887. Many other eminent surgeons had discontinued using it a few years earlier. Many are the tales of how the operating room floor was covered with six to eight inches of carbolic acid mixed with blood and how surgeons had, on occasion, slipped and fallen in the pool surrounding the table. (37)

About 1870 antiseptic technic was brought from Edinburgh by Henry House, and practiced at Guy's Hospital afterward. Arbuthnot Lane introduced the principle and practice that anything that touched the hand should not be allowed in the wound (forceps technic). Lane was a very gentle operator and had excellent results with the Listerian technic, probably because tissues were not damaged as much during the operation and therefore healed better and with less drainage from dying tissues following the operation. (29)

Dr. Moritz Schuppert, a German surgeon, was probably the first to adopt the Listerian method in America. He was a great admirer of

Volkman who was following with good results Lister's technic in Germany. Dr. Schuppert, practicing at the time in New Orleans, had such excellent results, with only 4% mortality in 120 cases, that Listerism finally began to blossom here in America.

<u>Aseptic Era</u> (Modern Aseptic Era). Beginning approximately in 1885.

It would be difficult to attach a specific date to the beginning of aseptic or modern technic as it began with modifications from the well established Listerian technic. The middle-1880's was the approximate beginning of aseptic surgery; thus one can see that the Listerian Era was only about twenty years long. It is interesting to note that once the principle of antisepsis was established, surgical technique rapidly advanced into our modern day technic, hence probably the most important of all eras in surgery was also the shortest.

As the antiseptic system spread, constant improvements in technics were made. The transition from the "wet" or antiseptic treatment of wounds to the "dry" or aseptic method was largely dependent upon the work of two German surgeons, Gustav Neuber of Kiel and Ernst von Bergmann of Berlin. Neuber realized that progress would be slowed unless caustic antiseptics could be dispensed with.

In 1886 Neuber had published details on aseptic technic:

1. Separation of "clean" and "dirty" cases.

2. Sterilization of the air entering the operating room by heat and filtration.

3. Cleansing the entire body of the patient and the operative site itself with mercuric bichloride.

4. Washing of the hands and arms of the operating team with soap and water.

5. Sterilization of instruments and drapes by boiling.

6. Closure of the wound without drainage.

A year or so later Ernst von Bergmann improved and simplified this technic by devising a method of sterilizing linen and instruments by using steam. (36)

The universal adoption of this aseptic technic followed rapidly. Despite the effectiveness of this technic in preventing most infections, there remained several possible sources of wound contamination. These remaining sources seem quite obvious to us today, but at that time, without the benefits of good bacteriological studies, the operator's bare hands, droplets from the nose and throat and the patient's own skin as sources of contamination were not so obvious.

EVOLUTION OF SURGICAL ATTIRE

The preceding portion of this paper has dealt with the development of basic antiseptic and aseptic principles. The following few pages will be devoted to the history of surgical attire and its part in improving aseptic technic to the present day level.

Surgical attire is probably more intimately related to sterile technic and prevention of wound infection than any other single entity concerned with operative cleanliness. Prior to 1885 very little attention was paid to the clothing worn by operating room personnel and before 1865 deliberate and planned preoperative cleanliness was practically unknown.

<u>Body Coverings</u> (Gowns and Undergarments).

Surgical gowns as known and used today were unheard of until the late 1880's; even then they were anything but adequate. In the pre-antiseptic era there was no specific apparel worn for operative procedures. Some surgeons wore jackets and others removed their coats and rolled up their shirt sleeves. The latter procedure was probably followed if the operation was expected to be somewhat more bloody than usual. If a special coat was worn, it was most likely to protect the surgeon's own garments from spattering blood, pus and fluids. The only specific data of early reference to attire in the operating room was recorded in the form of pictures from artists' concepts. (See the accompanying reprints, Figs. 1, 2, 3, 4, 5, 6.)

The earliest reference I could find of gowns for operating was in a textbook by Robb, first published in 1894 and entitled Aseptic Surgical Technic. (33) I think it is safe to assume that he had recommended gowns earlier if one considers the delays in recording and printing. I would imagine that von Bergmann was instrumental in their origin from Robb's reference to the "German School." (See below) You will recall that von Bergmann devised steam sterilization of drapes and instruments in the late 1880's. To quote from Robb's text: "For now that we know the dangers of infection by contact, it would seem essential that not only the surgeon but all of his assistants should wear at every operation thoroughly clean sterilized suits. It is safer and better that all should put on a complete change of costume rather than simply draw on a sterilized coat and pair of trousers over ordinary clothes, as has been recommended by the German School...... The former plan also offers many advantages, for not only are the warm out-door clothes exchanged for thin, cool garments, which are far better suited for the temperature of the operating room, but the ordinary clothes run no risk of being soiled or of carrying away on them the disagreeable odor of the fumes of the anesthetic. These are also less cumbersome and awkward to work in as a sheet or rubber apron." (33) From this last statement by Robb, I think it is safe to assume that rubber aprons were worn a few years earlier to protect the operator's own clothing.

Robb further describes the type of gown as fitting comfortably and fairly loosely with buttons down the front or back and the sleeves extending to just above the elbows. One-piece or two-piece garments could be worn but the trousers should not drag the floor. He recommended that all ordinary clothing be removed and the suits put on; the shoes being adjusted last. (33)

About 1900 von Esmarch and Kowalzig recommended washed and ironed white linen suits and gowns and that the coats must be changed previous to each new aseptic operation, if they had become soiled during any preceding operation. They also preferred sleeves above the elbows with the arms below the elbow being disinfected or covered with disinfected rubber sleeves. (38)

Berkeley Moynihan, about 1920, advised white sterile trousers, clean white shoes or overshoes, sterile coat, cap and mask, all necessary for the perfect outfit. (28) About this time at the Mayo Clinic, linen suits were used with separate sleeves and towels, these being applied to the arms after scrubbing. (37)

Approximately 1922, T. L. Deavor of New York advocated long sleeves with the cuffs tucked under the cuff of the rubber gloves used at that time. (9)

By 1924 garments very similar to those in use today were recommended by J. Renfrew White in A Textbook of Surgical Handicraft, published in that same year. He also recommended a sterile apron be worn where the operation was likely to result in soiling of clothes with blood, pus, lotions, etc. For the non-sterile assistants he advocated clean, short-sleeved gowns, their hands and forearms being clean and free from sores or abrasions. If the latter were present the assistants should be barred from the operating room. (39)

In the middle-1940's Wallace and Duguid of England conducted studies on air contamination and found dust-borne bacteria from clothing could be controlled by proper attire. They found a conventional loose-fitting sterile gown reduced dust-borne bacteria of the air by only 50%. By modifying a "boiler suit" to entirely cover the body and feet the count could be reduced to one-tenth or one-twentieth of that observed for street clothing. They realized, however, that for practical purposes these were too cumbersome for general acceptance and use. (10)

More recently, Adams and others devised a new quick-change, double-breasted gown which proved satisfactory for personnel entering and leaving the operating room during operations. (1)

From the foregoing discussion one may deduce that in the relatively short life of operating gowns and suits many advances have been made. None of these improvements in style have proved ideal from the aseptic standpoint. This includes the conventional loose-fitting gowns worn today.

<u>Headdress</u> (Masks and Caps).

Masks and caps as such came into use about the turn of the century. A type of mouth and nose covering was first recommended in 1897 by Mikulicz and modified in 1898 by Hubener.

As early as 1881 Pasteur and Sternberg found that the human mouth was a perfect breeding place for all types of bacteria. In 1897 Carl Flugge proved that the human nose, throat, and mouth contained pathogenic bacteria and that these were spread by speaking, coughing and breathing. He called this to the attention of Dr. Mikulicz who began tests and in 1897 published his results. (36) To quote Dr. Mikulicz:

> "We have, indeed, at Breslau the custom of hardly speaking at all at operations; communications are easily conveyed through signs with the hands. But a word must be said here and there. If the surgeon has a cold which causes him to sneeze at inconvenient moments, then he must, according to Flugge, be entirely excluded from operating. All of these dangers will be wholly avoided if one wears during the operation a mouth bandage covering the mouth and also the nostrils. A piece of mull serves the purpose and can be used also to cover the beard. The mask is of course sterilized."

Mikulicz later felt that these original mull masks were not satisfactory either germ-wise or for comfort. He asked a colleague, W. Hubener, to check on the efficiency of the masks and to improve the design. In 1898 Hubener demonstrated that Mikulicz' simple cloth mask was not at all adequate and he devised a metal frame -- modified from an Esmarch chloroform mask with spectacle earpieces -- carrying a double layer of close-meshed muslin.

The wearing of masks received much criticism when the practice was initiated. In 1901, John Poland spoke of Mikulicz's use of masks as a somewhat ridiculous and extreme measure. From 1900 on, however, numerous articles appeared advocating various modifications of the original masks. Nearly all of these modifications have been tested and found ineffective, but only in the past few years are seemingly effective masks being developed. These new masks are of the filter type, one such mask being advocated by Adams _et al_. of Huggins Hospital. (1) They maintain that the patient as well as the staff should be masked while in the operating room.

In the late 1940's Byrne and Okeke at Boston City Hospital, after studying the effectiveness of masks, recommended silence in the operating room. (6) This merely repeats the suggested policy of Mikulicz forty years earlier.

From the above review of the history of masks it is obvious that masks routinely worn in the operating rooms today are only modifications of the first ones in use.

Caps used for operating room personnel have no definite date as to their institution. Actually caps are probably one of the oldest pieces of surgical attire, however, not with the intention of bacteriological cleanliness. Artists' pictures depicting the earliest operations in almost all cases showed the operator wearing some sort of head covering. (See appendix for illustrations.)

The wearing of caps for bacteriological reasons probably followed the introduction of masks in the operating room. J. Renfrew White in his textbook published in 1924 (39), recommended that all personnel should have their hair completely covered with a tightly-fitting cap. Hair coverings have, in contrast to masks, undergone very little change since their introduction. As long as the hair was covered, the manner in which it was achieved seemed of little concern.

Gloves.

Gloves, like many other inventions in medicine, underwent immediate criticism with their initial use but today are accepted without thought. The history of the introduction of gloves is very interesting. To present their introduction as it actually took place, I will quote Dr. Halsted who was responsible for their vital role in surgery. This monumental advance in sterile procedure was instituted by Halsted about 1889, however it is reported that Jalaquier, a European surgeon, used a type of rubber glove a year or so earlier because his skin was sensitive to antiseptic solutions. This may be an error of recording data; however, our best source of information is from Dr. Halsted himself. As he writes:

> "In the winter of 1889 and 1890 -- I cannot recall the month -- the nurse in charge of my operating room complained that the solutions of mercuric chloride produced a dermatitis of her arms and hands. As she was an unusually efficient woman, I gave the matter my consideration and one day in New York requested the Goodyear Rubber Company to make as an experiment two pair of thin rubber gloves with gauntlets. On trial these proved to be so satisfactory that additional gloves were ordered. In the autumn, on my return to town, the assistant who passed the instruments and threaded the needles was also provided with rubber gloves to wear at the operations. At first the operator wore them only when exploratory incisions into joints were made. After a time the assistants became so accustomed to working with gloves that they seemed to be less expert with the bare hand than with the gloved hand.
>
> "I think it was Dr. Bloodgood, my house surgeon, who first made this comment and that he was the first to wear them, invariably, when operating.
>
> "Dr. Hunter Robb in 1894, in his book on aseptic technic, recommended that the operator wear rubber gloves. Dr. Robb was, at that time, resident gynecologist of the Johns

Hopkins Hospital and had frequent opportunities to observe the technic of the surgical clinics.

"This incidental reference by Robb in 1894 to the wearing of rubber gloves, and the fact that a photograph of an operation for breast cancer taken late in the year 1893 shows that gloves were not being regularly worn by us at that time, serve to establish approximately the date of their definite introduction.

"Dr. Joseph C. Bloodgood, in his elaborate report on Hernia makes the following statements with reference to the wearing of gloves:

' The writer was the first as operator to wear gloves invariably in December, 1896; before this date he had operated in twenty cases of hernia with four suppurations, all late infections; wounds were closed with silver wire. Since wearing gloves he has operated in 100 cases of inguinal hernia. In one case (recent) the wound suppurated.

'Rubber gloves were introduced by Professor Halsted soon after the hospital opened in 1889. They were invariably worn by the assistant who handed instruments and by the assistant at the wound, usually the nurse in charge of the operating room'

"Thus the operating in gloves was an evolution rather than an inspiration or happy thought, and it is remarkable that during the four or five years when as operator I wore them only occasionally, we could have been so blind as not to have perceived the necessity for wearing them invariably at the operating table.

"It is also noteworthy that none of the many surgeons, foreign and American, who visited our clinic in those years should have recognized the desirability of eliminating the hands as a source of infection, by the wearing of gloves.

"We did not realize how slightly the sense of touch is obtuned by the rubber or how unessential it is in most operations that the greatest delicacy of finger perception be preserved. Furthermore we were delighted with the results in healing already obtainable, so vivid were the memories of infections in the recent past." (15)

Many top ranked surgeons condemned gloves because they believed that the surgeon's delicate sense of touch was impaired. Some even stated that first rate surgeons began doing second and third rate operations when they used gloves. Dr. Nicholas Senn in 1901, writing on the sterilization of the hands, said:

> "Perhaps one of the best proofs that all known methods of hand sterilization have their defects is the present quite extensive use of rubber gloves, advocated by Halsted, Mickulicz, Fenger and other surgeons.......It is easy to foresee that this practice will never become general, even in clinical amphitheaters.....The rubber gloves impair the delicate tactile sense of the fingers, are expensive, easily torn, and furnish a soothing poultice for the conscience when the surgeon fails to prepare his hands properly." (36)

Originally gloves were put on while wet and therefore with some difficulty. The main disadvantage was the chance of puncture with resulting spilling of sweat containing bacteria into the operative wound. With the introduction of powder and dry gloves, this danger was lessened. For practical purposes, the powder would absorb perspiration in most gloved hands.

By about 1920 gloves were almost universally worn after twenty years of criticism and controversy. Gloves in the past six decades have not undergone any radical modifications except for improvements in quality; they have become stronger and thinner.

<u>Footwear</u> (Shoes, Boots, and Booties).

Shoes worn in the operating room have never seemed to arouse much concern as a possible source of contamination. Actually whatever type of shoe was in vogue for general wear was considered appropriate for the operating amphitheater. Little bacteriological significance was attached to shoes until the turn of the century.

With the introduction of Lister's carbolic acid atomizer into the operating room some type of water-resistant shoe was needed. This led to the popular use, at that time, of rubber boots, more for the protection of the wearer than for the patient's sake.

In 1894 Hunter Robb suggested that the operator and assistants should wear white canvas shoes with low tops and with rubber soles. He said that these were clean and noiseless and prevented street shoes from being soiled. Also, they were easily cleansed with hot soap and water and made to look neat with a coating of pipe-clay. (33)

By 1920 or possibly earlier, Moynihan wrote of some of his ideas in the Journal of the American Medical Association of that same year. He mentioned that every visitor to an operating room took part, however remote, in the operation. "He is gowned, masked and his head is covered nowadays in all clinics. But dirty boots and soiled trouser legs, conveying mud, dust and fecal matter from the streets are often unnoticed. If the wearer of them moves about the theatre freely, or goes from one theatre to another, the organisms carried in the drying filth are scattered broadcast, as the simplest experiment will prove. Large canvas overalls for the boots and lower legs, tying just below the knee, as a sort of legging will afford ample and secure covering to this possible source of contamination and subsequent infections." (28)

About 1925 canvas boots to cover conventional shoes were available for all surgeons. Indeed an advertisement for such boots appeared in the September 5 issue of The Lancet in 1925. (18)

For the past three or four decades various forms of booties have been recommended and available, but very few hospitals required these to be worn in the operating rooms despite their accepted value. Even today shoes no longer satisfactory for public wear are worn in the operating rooms without any coverings.

CONTAMINATION IN THE OPERATING ROOM

Although the aseptic technic presently employed in the operating rooms would have astounded physicians of Lister's time, many improvements yet must be made before the ultimate in aseptic surgery can be acclaimed.

In the past few years there has been a reported increase of staphylococcal infections, 75% of which are resistant to one or more of the antibiotics. Rates frequently reported now are approximately 5% in clean surgical wounds. (23, 24) Granted this is a tremendous advance from the commonly reported 50% mortality for amputations about 1850; most of these dying from infection, not to mention the nonfatal infections of that time. Nonetheless, until post-operative infections cease to exist, much work must be directed to improving our aseptic technic of today. Adams and others of Boston University feel that 0.5% wound infection is the lowest that can be hoped for; however, this rate has been as high as 10% in isolated outbreaks in the past few years in this country. (2)

For the past twenty years the approach to this problem has been to rely upon internal saturation with the new antibiotics and upon external mopping with detergents. Other policies of asepsis are often delegated to nurses, administrators and laymen who are not prepared to evaluate accurately the various factors involved.

General Sources of Contamination.

Infections are acquired in two principle ways: 1) Directly through the handling of various patients and patients' supplies by doctors, nurses and other personnel and, 2) Indirectly by the contamination of circulating air. (23) These two factors apply both within the operating room and in the surgical wards.

As to the effectiveness of prophylactic drug therapy postoperatively, Meleney (24) found that the use of sulfonamides either locally, systemically or combined did not reduce the incidence or the severity of local infections. The same facts are true for penicillin. J. P. Sanford, et al. in 1957 (34) found that systemic therapy with the newer antibiotics did not decrease the incidence of wound infection in experimental non-debrided wounds of animals and actually increased the difficulties because of drug-resistant organisms.

Nearly all surgical wounds are contaminated. There is a tendency for physicians to regard contamination and infection as synonymous terms. Whether infection occurs depends on such factors as: 1) Resistance of the host; 2) Type of tissue involved; 3) The amount of contamination; 4) Presence of foreign bodies, and 5) Availability of culture media (devitalized tissues within the wound). Only number 3 (the amount of contamination) will be dealt with specifically herein.

Contamination of the air surrounding the operative field has been considered since Lister employed his carbolic acid spray in 1866. Unfortunately, however, not until the past ten or twenty years has this again become a real concern to physicians. Meleney in 1935 (25) showed that the sterile field in an ordinary operating room may be seeded with from 30,000 to 60,000 bacteria per hour from the air alone. This did not include sources from direct contact.

Pathogenic micro-organisms can enter the air in two ways: 1) In droplet spray produced by speaking, coughing, talking and breathing, or 2) in dust particles liberated as a result of friction and movement from the skin and clothing of infected persons, from their bedding, or from the floor and furniture of rooms. Air pollution is related to the amount of dust about any one area. Clean areas become contaminated rapidly by the presence of people. Substantial studies show that where there are large numbers of patients present and people in attendance on these patients the level of air pollution rises markedly. (2) For this reason it is desirable to have only the needed personnel in the operating room during operations. Duguid and Wallace of England (10) showed that one person doing vigorous activity may release up to 10,000 bacteria per minute into the air and that 10% of these bacteria-carrying dust particles may remain air-borne for 30 minutes or more.

In extensive bacteriological studies at Minneapolis General Hospital by H. I. Harder and M. Panaska in 1958 (16) it was found that the usual air contaminants were diphtheroids, <u>Staphylococcus</u>

albus, gram-positive rods and *Staphylococcus aureus*; the latter were frequently found to be pathogenic. The presence of *Staphylococcus aureus* in the operating room air could nearly always be traced to hospitalized patients or personnel who had previously been in the operating rooms.

Ventilation in the operating room is directly related to air pollution and proper ventilation is imperative for maintaining clean air in the operating room. Ventilating systems of the past and even some modern air conditioning is responsible for air contamination. R. H. Shooter, *et al.* (35) found that air was often pulled in from the surgical ward corridors and even from other remote areas in the hospital. The latter was especially true where a common blower system was connected by ducts to all parts of the hospital.

Sterile air can be delivered to any operating room by proper filtration. (1, 16) A positive pressure must be maintained in the room to move air outward into the corridors at all times. Practically speaking, contamination of a clean room, receiving only clean air, is introduced by exhalations of personnel entering the room and by fomites from clothing, shoes, or objects brought into that room.

Adams *et al.* found that ordinary cleaning of an operating room would not keep the bacterial count of the air reduced for any appreciable time. By a procedure of frequently repeated, intelligently directed, and vigorously applied mechanical effort in combination with a good detergent-disinfectant, any surface or area whatever can be rendered clean or even sterile. Some detergents had an 8-hour residual effect. These measures repeated daily would maintain almost sterile air in the operating rooms, however strict self discipline and supervision must be followed. (1)

In some areas ultra-violet lighting has been used as an adjunct to ordinary cleaning of rooms for the destruction of bacteria in the air. Its merits were established as early as 1934, being shown effective against bacteria up to 6 and 10 feet away. It was used at Duke Hospital and was reported to have all but eliminated infections, and not one infection that did occur was severe. (17) This system requires overhead lights and the personnel must wear special visors and cover all exposed skin surfaces to avoid burns. This inconvenience has probably prevented the routine acceptance of ultra-violet lights. (See Figure 14.)

Some operating rooms employ ultra-violet lights behind metal shields to prevent the direct rays from reaching the personnel or the operative site. This arrangement has proved somewhat less effective. If ultra-violet lighting is used, the effectiveness of the bulbs must be checked periodically as bulbs lose their effectiveness over a period of time. Ultra-violet lighting is only a supplement to other procedures and technics.

From the foregoing discussion it is evident that even though air is a prime source of wound contamination this source can be almost completely removed by filtered air ventilating systems, ultra-violet lighting and daily mechanical and chemical cleansing of the operating room. With air thus rendered sterile, or almost so, the source of contamination of this air then remains with the personnel, patients and fomites brought into the operating rooms. These sources of contamination will be discussed in the following portion of this paper.

Surgical Attire as a Source of Contamination.

Body Coverings. (Gowns and Scrub Suits) As mentioned earlier, personnel may contaminate the air of the operating room by either droplet spray or by bacteria-carrying dust particles liberated from their clothing. In experiments with nasal carriers of *S. aureus* it was found that the air was infected more regularly and to a greater degree by the liberation of dust particles from clothing than by sneezing. (10) This serves to illustrate the importance of the operating personnel wearing clean or sterile garments on entering the operating room. If this source of contamination is eliminated, the amount of air contamination can be substantially reduced.

In an extensive study by Duguid and Wallace of London (10) it was found that air is readily infected with dust-borne pathogenic organisms. In this study, measurements were made of the bacterial contamination of the air produced by liberation of dust from the skin and clothing during bodily movement, also of the duration of air carriage of the bacteria-laden dust particles, and of the effectiveness of gowning as a means of preventing such contamination of the air. In movements such as leaning forward with the arms outstretched, they found bacteria-carrying dust particles being liberated into the air at a rate of 1,000 per minute. More vigorous activity as "marking time" liberated up to 10,000 per minute. These are values for street clothing. By wearing a conventional long, loose-fitting, sterile operating gown, the liberation of bacteria was reduced by 50% while the subject carried out the same movements. The authors then devised a special type of body covering by modifying a "boiler suit", which completely covered the body and feet and fastened in the back. This, they conceded, was cumbersome to put on, however it reduced air contamination to one-tenth or one-twentieth of that found for street clothes. This suit was also of heavier material which may have added to its effectiveness. It is an established fact that bacteria may readily penetrate cotton garments, especially if the material is damp or wet. Documented cases of post-operative infections have been traced to skin lesions which the operator himself had. Colebrook and Ross in 1947 (10) demonstrated infection of the air of a burn-dressing room with S. aureus, which was proved by typing to be derived from a small sore on a surgeon's elbow; apparently this contamination was due to the dissemination of infected dust particles from that area of the gown overlying the wound.

Beck, Collette, and Propst (3, 23, 32) in 1954 did extensive work on determining the effectiveness of draping material. They showed that a single layer of properly treated linen is essentially impervious to bacteria even when wet; whereas even multiple layers of untreated linen when wet through with a few cubic centimeters of liquid are permeated at once by bacteria.

With this information one wonders why better methods have not been used. If you have ever watched any surgeon or nurse scrub their hands, it is obvious that the front of the scrub suit is spattered with water, soap and bacteria, removed from the hands and arms. Under these conditions the scrub suit, when wet, actually makes for better transmission of bacteria from the surgeon's skin through the scrub suit onto the sterile gown. The front of the sterile gown often becomes moistened with solutions and blood, thereby becoming readily contaminated from the scrub suit beneath. The same holds true for the wound drapes and towels. This entire situation could be improved simply by wearing a plastic apron while scrubbing. Such an apron could easily be removed before entering the operating room without hand contamination.

To improve the technic even more, a sterile plastic apron could be worn between the sterile operating gown and the scrub suit. This would prevent soaking through in either direction. Such a simple precaution would require one or two more minutes of time, at the most, and eliminate a very real source of contamination of the operative field. Granted this would not remove the possibility of bacterial transmission through the sleeves of the gown, but any procedure to decrease a source of contamination is a step in the right direction. It is very possible that a sterile plastic sleeve could be drawn on prior to the sterile gown or even incorporated into the sleeve of the gown permanently.

Similarly, it is obvious that drying of the hands and arms prior to donning the sterile gown is of paramount importance. All of us have observed excellent surgeons and nurses dry their hands and arms to the elbow and then place their arms into a sterile gown with droplets of water still on the arm above the elbow. This represents pure carelessness on the part of any such individual. This breach in procedure can, without much effort or intellectual exercise, be prevented.

It is obvious that clean clothes are required to maintain a low level of air contamination. Adams, et al. (1) accumulated proof that all clothing worn in a nonclean room, for however brief a time, is almost surely contaminated by fomites and that such clothing will introduce contamination into any operating room.

The bottoms of men's scrub suit trousers are one of the worst sources of contamination and bacterial dissemination because of their flopping along the floor and over dirty shoes. Nearly all of these trousers are inches too long for the average male and maintaining a cuff is next to the impossible, as anyone having worn them will testify. For practical purposes and convenience, scrub suits and dresses may be worn unless contaminated for a series of operations, but at no time should such attire be worn outside the operating room area and then be allowed to re-enter the operating room. Ideally, scrub suits should be changed for each operation but this is inconvenient. After contaminated cases, however, a complete change is absolutely necessary. This simple precaution is frequently overlooked or neglected.

Nine-tenths of the causes of wound infections are believed to arise in the operating pavilion area from entry of bacteria into the wound from the air or from fomites about the personnel and patient, including the patient's own skin. (6) This presents a real problem where personnel leave and re-enter the operating room during the operation. To prevent some of this contamination, Adams _et al_. (1) devised a sexless, sizeless, sideless, quick-change, double-breasted gown which proved quite satisfactory for personnel entering and leaving the room to change into upon each re-entry. These men also made some suggestions regarding the physical plant which will be included below under Modern Aseptic Technic. These suggestions by R. Adams _et al_. of Boston can be recommended without reservation for all interested. (See the _Journal of the American Medical Association of_ April 4, 1959, pages 1557-1567.)

Masks. Like all other major advancements in surgical attire, masks were not introduced until the late 1890's although it was known that bacteria were present in the mouth as early as 1881. (36) The conventional present day operating room mask is only a modification of the original ones recommended by Mickulicz in 1897, and I doubt if they are very much more effective.

Extensive studies presently under way report varying values for the effectiveness of masks. Findings by different groups are not always parallel in their conclusions.

Adams _et al_. (1, 2) in 1959 state that exhalation droplets from the operating personnel are known to be the number one source of wound infection. Wells and Wells in 1934 stated, "As regards droplet spray, the larger droplets fall out of the air in 1 to 2 seconds, while smaller droplets (under 0.1 mm. in diameter) evaporate immediately to form minute solid residues, "droplet nuclei", which may remain air-borne for several minutes or hours." (10) Along this line of thought, Duguid and Wallace attached the major cause of air pollution to bacteria-carrying dust particles. From this, one would conclude that the larger droplets contaminate the wound directly by falling into it while the smaller particles become air-borne and as such may eventually settle into the wound also.

Wells and Wells in 1936, and Duguid in 1945 bring out that it is well established that sneezing, coughing, and speaking contaminate the air with very large numbers of droplet nuclei containing salivary commensal organisms -- e.g. 10,000 to 1,000,000 per sneeze; 10 to 1,000 per cough, and 10 to 100 per 100 spoken words. They believed, however, that the importance of droplet spray as a cause of air contamination should not be overestimated, since it appeared that pathogenic organisms are contained in only a small portion, if any, of the droplet nuclei, i.e. most of the organisms are non-pathogenic.(10)

Byrne and Okeke at Boston City Hospital found that five of ten operating rooms studied were contaminated with S. aureus. (6) Such bacteria, they felt, were no doubt introduced into the room by patients and professional personnel either because they were nasal carriers or their skin, clothes, blankets, and linen were contaminated.

Therefore they recommended that all personnel should be properly attired. On studying masks, they found that there appeared to be no advantage in wearing two masks over one nor was one mask much of an improvement over none. (These tests were compared by having the subject hold an open blood agar plate at 18 inches while talking. This method, however, has questionable validity.) If talking was permitted, the total count was cut in half with one mask but these counts were still higher than when no talking was permitted without masks. When silence was the rule, the lowest counts were obtained and masking did not seem to improve the situation. From these tests they concluded that silence was more important than masking. These same conclusions agree with the recommendations of Mickulicz as early as 1897. Byrne and Okeke also found that S. aureus was present on the skin or in the naso-pharynx of 49% of patients and 74% of the hospital staff studied. They recommended masks for both the patients and the staff.

Adams, et al. in 1958, on studying the effectiveness of masks, found S. aureus to be the most common bacteria exhaled by nasal carriers. They reported finding 20% of incoming patients as nasal carriers and 34% of the hospital personnel as nasal carriers. (2) From these two recent sources it is obvious that the hospital personnel is a greater potential hazard to air contamination than are the patients. The authors also stressed that both the nose and mouth be covered and found that masks were effective only up to one hour and totally ineffective after two hours. In their most recent work, however, Adams and co-workers found that ordinary gauze masks keep air contamination down for only 20 minutes. They found that unrestrained laughter and conversation and unrestricted movement about a room caused a very rapid rise in the bacterial content of the air in that room. (1)

This group, after testing some 196 different types of masks, developed a filter mask which was effective and could be autoclaved. They found that a mask made as a common gauze mask and simply containing a filter instead of a piece of gauze was really only little better than an ordinary gauze mask. It will stop direct passage of bacteria but the billowing out effect is unchanged. In fact it is worse if the mask is impervious or solid because the spill-over is then increased. An essential feature of a filter type of mask is that it fit tightly against the skin but have a sufficient reservoir of exchange. An effective mask will accumulate moisture and therefore must be sufficiently absorbent. It must also be light, economical and effective for many hours. With these requirements as a goal they devised a filter type of mask which would maintain 98% effectiveness against human exhalation as determined by air samples of the operating room air. This microstatic filter mask has a foam rubber base which easily molds to the face for airtight contact with the skin. Two layers of copper mesh sandwich a fiberglass filter whose many small openings permit easy breathing yet stop passage of bacteria. They withstand months of frequent autoclaving.

The Adams group believed that the patient should also be masked and that masks should be worn at all times in the operating room, both prior to and following the operation. It was deemed essential that everyone entering the operating rooms be masked, including the maids and janitors. Along with the mask these personnel were required to attire themselves in sterile external gowns and booties for the shoes.

It appears that after many years of neglect and delay, an effective mask is finally being devised. The remaining problem is the universal acceptance of its use.

Head Coverings. There has been no specific work done toward devising a better covering for the hair nor have there been any studies yet done to evaluate our presently used models. The ordinary conventional caps are apparently considered satisfactory if used properly. This is a greater problem for feminine personnel than for men due to the extra length and bulk of their hair. Today, however, with the trend toward shorter hair for both sexes and absence of the formerly popular beards, contamination from hair can be adequately controlled. One aspect which could be improved would be a cap for the patient, especially for operations on the face. One can conceive of dust particles being dislodged from the hair by the anesthetic mask with the array of tubes connected to it, but a cap covering the hair would alleviate this source somewhat.

Footwear. Shoes worn in today's operating suite, as previously mentioned, have not experienced any great change in style since the beginning of surgery, except that of keeping up with models in vogue for street wear. In the past, various methods for cleaning, as well as special covering (as booties) have been recommended. Apparently because of the distance of shoes from the operative field, surgeons have not attached any appreciable significance to the part shoes play in air contamination.

That many shoes worn in today's operating rooms are filthy with blood, plaster and dust is no secret. With our present knowledge of air contamination by bacteria-carrying dust particles, it is obvious that these filthy shoes do contribute substantially to air pollution and something needs to be done to correct this deplorable situation. The reason for any special clothing and strict sterile technic is to decrease air pollution, thereby reducing the amount of contamination of the wound itself. Why then is this objective overlooked or ignored in the case of shoes?

In the past, when apparently improved footwear had been introduced, the use of such appliances was scattered and only short lived even in these scattered areas. This attitude has probably developed because of the slight inconvenience and consumption of time required in making use of such improvements.

Shoes by nature of their function are always bacteriologically contaminated and the only method to prevent this is a ten-minute scrubbing with disinfectant-detergent solution prior to entering an operating room. (6) This is of course unobtainable for practical reasons. Only recently has any concentrated research been directed toward this problem. (1, 7) As mentioned above, shoes cannot be decontaminated by any practical means and even freshly autoclaved shoes worn into a public corridor or ward, and then into a sterile room will introduce contamination into that room. Use of protective clean covering for the entire shoe before the wearer is admitted to a "sterile" area is the only feasible and practical method yet found for eliminating contamination from shoes. (1)

Recently Adams and colleagues (1) found that a shoe cultured without any treatment showed a massive growth of a mixed flora of bacteria. Another shoe that was soaked in 10% phenol detergent solution for 1 minute showed a relatively high number of bacteria from a single swab drawn over the shoe. If shoes soaked 1 minute in phenol were scrubbed vigorously with a brush for 30 seconds, the number of viable bacteria remaining markedly decreased. Ten minutes of scrubbing, however, was required to render dirty shoes sterile. A further finding was that antiseptic-detergent solutions were fully active in their bacteriocidal effect, insofar as they were able to come into contact with organisms present. If there was a layer of dirt present the action was inhibited and cultures showed growth. This illustrates the absurdity of occasionally wiping shoes with an antiseptic cloth. Actual mechanical cleaning is required to remove bacteria and dirt from shoes.

Another recent source of information dealing with shoes worn in the operating and delivery suites of a hospital can be reviewed in the April 1959 issue of the Southern Medical Journal. In this article, A. E. Casey, et al. of Alabama cultured thirty different shoes of physicians in the operating and delivery suites. They took a single swab from the sole and one across the top of the shoes for culturing. These swabs were placed in thioglycollate broth and from these cultures blood agar plates were streaked.

In this study, every shoe demonstrated multiple colonies. More than 70 different strains were isolated including some 23 strains of hemolytic staphylococci; 5 strains of Proteus; 1 strain of Neisseria; 50 beta hemolytic gram-positive rods; and numerous fungi.

Five strains of the hemolytic staphylococcus were penicillin-resistant and all were coagulase-negative. The authors felt that this did not negate the possibility of pathogenicity of these strains, but merely indicated that they had not immediately been associated with an acute or fulminating human infection. They believed that the resistance of these staphylococci to antibiotics indicated that they were recently associated with clinical infections treated with antibiotics during which resistance had developed. (7)

They also found most of the shoes in terrible outward appearance and concluded that with the decrease in humidity from present day air conditioners, colonies of bacteria on such shoes could very well be thrown into the air and circulated in the operating room as well as carried to other areas of the hospital. They suggested washable shoe coverings equipped with proper grounding devices and that ultra-violet lights be installed in locker rooms to help decrease bacterial counts in the air.

The group from Boston (Adams _et al_.) also had some definite suggestions and took steps to develop acceptable and effective shoe coverings. (1) They developed a washable, flexible, slip-on, wrap-around, cloth-type, conductive rubber soled bootie that met all requirements. This bootie was to be worn by all personnel while they were in the operating room and adjacent rooms. They could be worn outside the operating room but could not be worn upon re-entry. They could be worn only to the dressing room and then, on re-entering the operating room, had to be wiped on an antiseptic-detergent soaked blanket placed in the doorway of the operating room. The authors felt that this seemed a reasonable compromise for practical purposes thereby minimizing inconvenience to surgeons doing a series of operations.

From the above findings it seems well documented that shoes are a potential source of contamination in the operating rooms of today. Recent developments have produced an apparently satisfactory and effective shoe covering which can be used with only minimal inconvenience to all operating room personnel. Now acceptance of such improvements remains the thorn in the flesh.

SPECIAL BACTERIOLOGICAL STUDY OF OPERATING ROOM FOOTWEAR

The following paragraphs will contain recent information regarding shoes worn in various Omaha hospital operating rooms. This work was done in cooperation with the Microbiology Department of the University of Nebraska, and under the supervision and guidance of Doctor H. W. McFadden, Chairman of the Department.

The purpose of this study was to evaluate bacteriologically the condition of shoes worn in the operating rooms regarding potential sources of contamination to surgical wounds. This study, although in some respects similar to those mentioned just previously, differs mainly in that bacteriological contamination is evaluated on both a qualitative and a quantitative basis.

Technique.

In this study 58 different shoes were picked at random from four different hospitals. These shoes were then swabbed and cultured. For a quantitative study a 16-square-centimeter area was swabbed from each shoe, in most instances from the top of the toe. For this procedure a swab was moistened in a sterile peptone broth medium and after swabbing the area vigorously was placed into 10 ml. of broth. This solution was violently shaken to disperse evenly the bacteria picked up by the swab. Serial dilutions were then made from this solution. Dilutions of 1:10, 1:100, and 1:1000 were made and then 1 ml. of each was transferred to Petri dishes to which an enrichment agar was added and then incubated. Duplicates were run in each case to insure against human error and to obtain a more accurate average count. Tryptone Glucose Extract Agar was used for the enrichment media; this supports growth of many bacterial species. A second medium, Violet Red Bile Agar, was used to suppress growth of colonies other than the coliform group. Two blood agar plates were also streaked, one for anaerobic incubation and the other for aerobic incubation. These blood agar plates were incubated and read after 24- and 48-hour intervals to determine the type of colony growth and their hemolytic activity.

In the qualitative study, special emphasis was directed toward staphylococcal colonies. All colonies appearing to be staphylococcus were smeared and studied microscopically by the Gram stain method. Staphylococcal colonies with hemolytic activity were then incubated in serum (Coagulase Test) to determine pathogenicity.

Qualitative Analysis.

On nearly every shoe studied the bacterial flora was of a mixed type. On only three of the 58 shoes swabbed and cultured was there no growth on blood agar; however, on the serial dilution plates every shoe showed growth of some type. In nearly every case micrococci including staphylococci were found. Many, of course, were common contaminants of skin and soil, but S. aureus was grown from a high percentage of shoes and therefore represents a potential source of contamination to the air and indirectly to the surgical wound.

Forty-two of the 58 shoes showed micrococcal growth and all but 7 of these were hemolytic. Of these 35 strains of hemolytic micrococci, 2 were coagulase-positive and a third questionably positive. These were identified as coagulase-positive S. aureus. From 37 of the 58 shoes gram-positive bacilli were isolated, 4 of which were shown by staining to be spore formers. These were presumed to be contaminants of soil and air. Gram-negative rods of the enteric type were grown from 9 shoes.

In general, the majority of shoes carried fungi commonly found in the soil and air. Species ranged from Streptomyces, Alternaria, Aspergillus and Penicillium. As this study was directed primarily toward a quantitative analysis, bacteria isolated were not specifically typed nor was antibiotic sensitivity determined. (See Table 1.)

Quantitative Analysis.

As was originally suspected, all shoes in general carried a high number of bacteria and fungi of mixed species. The number of bacteria per square centimeter varied greatly from shoe to shoe, i.e. 37/sq. cm. for a low to 25,390/sq. cm. for the high count. The majority (37 in all) had counts below 1,000 bacteria per square centimeter and only 6 shoes had counts greater than 10,000 bacteria per square centimeter. From these data it is obvious that shoes are grossly contaminated and as such remain a definite source of air contamination and indirectly a hazard to clean surgical wounds. The overall average number of bacteria per square centimeter of all shoes studied was 2,554; this becomes alarming when compared to the average for street shoes; 1,527. From this one would conclude that ordinary street shoes are almost twice as clean as shoes presently worn in the operating rooms.

It is interesting to note that averages from the four different hospitals in the study differed considerably. This was evident by the figures compiled showing that in one hospital the average per square centimeter of shoe surface was as low as 1,596, while in another hospital, the highest, average count was 4,070/sq. cm. (See Table 2.); Hospital A, 2,825; Hospital B, 4,070; Hospital C, 1,596; Hospital D, 2,179. None of these hospitals have specific requirements regarding cleaning of shoes worn in the operating rooms nor do the methods of storage differ greatly. Two of the four hospitals have separate cabinets with pigeonholes for the shoes. The other two hospitals have shoe racks attached to the wall beneath the lockers. There seemed to be no difference in the methods of storage regarding the amount of dust observed.

Although shoes were picked at random, an attempt was made to compare the different surgical sub-specialties regarding the bacterial counts obtained. (See Table 3.) Mention should be made of the number of shoes swabbed from each sub-speciality. Counts might have been better compared if an equal number from each sub-speciality had been swabbed. This is especially true in cases where only two or three shoes from a sub-speciality were swabbed and one proved especially high. There seemed to be no particular pattern developed because there were very high and very low counts within each sub-speciality. (See Tables 1 and 3.)

As brought out by two cases, I believe that the significance of mechanical cleansing should be noted. Of two shoes known to have regular cleaning by the wearers the counts were both below 200 bacteria per square centimeter. (See Table 1., shoes number 46 and 47) Their sequence in the chart is purely coincidental as this knowledge was not obtained prior to swabbing these shoes. These two shoes are worn almost daily in the operating room, one pair by a registered nurse, the other by a surgeon. The surgeon in this case, after I commented to him about his clean appearing shoes, confessed he had recently scrubbed them when he heard I was conducting this study. The nurse stated that she washed her shoes every two weeks in an automatic washing machine. Her shoes were of the canvas type with rubber soles. From these two isolated cases it appears that mechanical cleansing has definite merit.

TABLE 1.

#	Hosp.	Bacteria per cm.^{2}	Specialty	Morphology on Bld. A	Hem	G+ cocci	G+ Bact.	G- Bact.	G+ Spore
1	A	703	Ob-Gyn	sg	*	*			
2	A	375	G. Surg.	sg	*	*			
3	A	906	Intern	sg	*	*			
4	A	1,562	Urol.	sg	*	*			
5	A	453	Intern	sg	*&o	*			
6	B	25,390	G.P.	sg	o	*			
7	B	66	Proct.	sg	*	*	*		
8	B	5,708	Ortho.	sg	*	*	*		*
9	B	779	Urol.	sg & sw	*part	*			
10	B	881	Proct.	sg	*	*			
11	B	2,070	G.P.	sg-lg	*-	o	*		*
12	B	1,905	Ob-Gyn	sg	*	*			
13	B	1,158	G. Surg.	sg	*	*			
14	B	929	Ortho.	sg	*	*	*		
15	B	268	Urol.	sg	*	*			
16	B	255	Ob-Gyn	sg-lg	*-o	*			
17	B	405	G. Surg.	sg	*	*	*		
18	B	13,093	Anesth.	sg	*	*	*	*	
19	C	37	G. Surg.	sg	o	*			
20	C	422	Ob-Gyn	sg	*comp	o		*	
21	C	178	Ortho.	sg	*	o		*	
22	C	691	G.P.	sg	*comp	*	*	*	
23	C	1,086	Ob-Gyn	sw	*	*			
24	C	776	G. Surg.	sg	*	*			
25	C	125	G. Surg.	sg	*	o	*		
26	C	108	Ob-Gyn	sg	*	*			
27	C	4,430	G. Surg.	sw	*	*	*		
28	C	100	Ortho	sw	o	*			
29	C	13,558	G.P.	sw	o	o	*		
30	C	2,148	Ortho	sg	*	*	*		

<u>Key to Chart</u>

sg - small gray
sw - small white
lg - large gray
lw - large white
part. - partial
comp. - complete
S - street shoe

TABLE 1. (Continued)

#	Hosp.	Bacteria per cm.^{2}	Specialty	Morphology on Bld. A	Hem.	G+ cocci	G+ Bact.	G- Bact.	G+ Spore
31	C	449	G. Surg.	o	o	o			
32	C	3,221	G. Surg.	sg	*comp.	*			
33	C	43	Ob-Gyn	o	o	o			
34	C	602	Ob-Gyn	sg	*	o	*		
35	C	553	Intern	sg	*	*	*		
36	C	193	G. Surg.	sw-lw	o	*	*		
37	A	3,365	RN	sg	*	o	*		
38	A	21,109	RN	sw	o	*			
39	A	10,538	G. Surg.	sg-lw	*	*			*
40	A	309	Ob-Gyn	sg	*	*	*		
41	A	809	Intern	sg	*	*	*		
42	A	1,072	Ob-Gyn	sg-lg-lw	*	o	*		
43	A	182	G. Surg.	sg	*	*	*		
44	A	812	G. Surg.	lg-lw	*	o	*	*	
45	S	816	Street	sg-lg	*	*	*		
46	A	66	G. Surg.	o	o	o			
47	A	118	RN	lw	o	*			
48	S	2,900	Street	s&l pink	*	*	*	*	*
49	S	1,821	Street	lg	*	*	*		
50	S	571	Street	sg-lg	*	*	*		
51	D	721	G. Surg.	sg-lg	*	o	*		
52	D	157	G. Surg.	sg-lg	*	o	*		
53	D	10,593	G. Surg.	sg-lg-sw	*	*	*		
54	D	147	G. Surg.	sg-lg-sw	*	*			
55	D	608	G. Surg.	sg-lw	*	o	*	*	
56	D	2,458	Ortho.	lw-lg	*	*		*	
57	D	859	Ortho.	sw-lw-tan	*	*			
58	D	1,891	G. Surg.	lg-lw	*	o		*	
		Average-2,554			48	42	27	9	4

<u>Key to Chart</u>

sg - small gray
sw - small white
lg - large gray
lw - large white
part. - partial
comp. - complete
S - street shoe

TABLE 2.

HOSPITAL	AVERAGE NUMBER BACTERIA PER SQ. CM. SHOE SURFACE	METHOD OF SHOE STORAGE
A	2,852	Pigeonhole cabinet
B	4,070	Racks below lockers
C	1,596	Pigeonhole cabinet
D	2,179	Racks below lockers

TABLE 3.

Surgical Sub-speciality	No. shoes Swabbed	Average Count	Highest Count	Lowest Count
Proctologists	2	474	881	66
Ob-Gyn.	10	650	1,905	43
Interns	4	680	906	453
Urologists	3	870	1,562	268
Street Shoes	4	1,527	2,900	571
Orthopedists	7	1,770	5,708	100
General Surgeons	20	1,844	10,593	37
Registered Nurses	3	8,197	21,109	118
General Practitioners	4	10,428	25,390	691

SUGGESTIONS FOR MODERN ASEPTIC TECHNIC

In the following paragraphs a plan is presented to cope with the problem of operating room contamination and subsequent post-operative infections. Many of the sources of contamination mentioned above can be eliminated and others greatly reduced. Some of the following suggestions have been made and practiced with excellent results by Adams and his co-workers at Huggins Hospital in Wolfeboro, New Hampshire. Specifically, they have reduced their incidence of staphylococcal infections from 1.4% (a figure well below the national average) to 0.25%. (1)

The arrangement of the physical plant plays a major role in fighting contamination. The operating room pavilion itself must be scrupulously clean. Every morning and evening, preferably, the entire operating room complex should undergo a top-to-bottom scrubbing and sterilizing. After each operation, all walls should be re-scrubbed to a height of six feet, floors sluiced with germicide, and excess water removed by a filter-protected, wet pickup vacuum cleaner. All furniture and equipment should be re-disinfected. Personnel carrying out this task must be gowned, masked and wearing protective shoe coverings to prevent re-contamination of cleaned surfaces. An area so cleaned will remain clean until contamination is introduced into it.

This group suggests zoning of the operating room pavilion into three major zones. Zone One, contiguous to the hospital corridor, should be scrupulously clean and here the staff washes and changes into sterile scrub suits. The surgeon's and nurses' dressing rooms would be included in this zone. Here complete cleanliness as regards the room, floor and furniture should be maintained but masks can be dispensed with. Booties for the shoes may or may not be worn in this area, but the soles of the booties must be wiped on an antiseptic soaked towel or blanket before entry or re-entry into the operating room itself. This plan seems satisfactory for surgeons doing more than one operation as well as for nurses.

Zone Two, or Exchange Area, comprises the area where all aseptic criteria are fulfilled. Here, all ambulatory persons should put on freshly laundered or autoclaved conductive booties over their footgear; also they put on face-fitting filter masks and sterile wrap-around gowns. (Adams and his group devised apparently effective booties, masks, and quick-change gowns.) Then, wearing special plastic protective aprons, the operating team should do their 10-minute scrub, preferably changing brushes one time in the process. This plastic apron is then removed by a nurse prior to admission to the operating room itself. Once in this Exchange Area (Zone Two), leaving it for a less clean area requires the same rigid technic upon re-entry. Patients brought to this area on ordinary stretchers are transferred to a clean stretcher that never leaves the operating suite. The patient should be capped and masked with a filter mask and changed into a sterile gown after the operative site receives a

10-minute scrub with a good detergent-disinfectant.

Zone Three (Operating Room Proper), may now be entered. The operating team now dons their sterile gowns and gloves. The patient then is put on the table and the operative site painted with antiseptic. A new type of adhesive plastic used by some surgeons is recommended over the area of incision, the plastic being incised when the skin incision is made. This gives added protection from the patient's own skin. In the near future possibly a sterile plastic sleeve could be devised to put on before the sterile operating gown or an autoclavable-impervious lining permanently sewn into the sleeve for convenience. This would prevent transfer of any bacteria through a sleeve that becomes wet during the operation or from improper drying of the arms. Also a sterile plastic apron might well be worn between the scrub suit and the sterile gown. This would prevent bacterial transfer from the operator's skin to the sterile gown surface should it become wet through during the operation.

A fourth zone would include any part of the hospital outside of the operating pavilion complex.

In Zones One, Two and Three air conditioning should deliver air through microstatic filters to prevent bacterial feedback. In these areas air must be delivered to maintain a positive pressure to force all air outward into the hospital corridors, thereby preventing contaminated hospital air from entering the operating room complex. Ultra-violet lights in these three zones can be used as a supplementary precaution. These bulbs should be replaced whenever their effectiveness drops to a low level.

If such a system as described above is employed and operating room personnel use every possible precaution against contamination, operations can be carried out in a nearly sterile atmosphere. This regimen is comparatively practical from every standpoint except for the extra time and effort required in the daily cleaning of the pavilion. This cleaning plan also requires additional training for janitors and maids working in this area. Dependable and comparatively intelligent persons must fill these jobs which in most hospitals are filled by not such conscientious persons. This plan also requires staff cooperation and self discipline for all partaking in it. If, however, personnel are shown the value of such a plan by improved end results they begin to take added pride in their efforts. It must also be remembered that suggested changes are sometimes over-rated, especially if such changes have not been given the test of time. Following any change in procedure, some apparent improvement may occur due to the incidental focusing of attention upon better aseptic technic generally or even due to natural remissions in epidemiology. Cooperation, self discipline and awareness are paramount requirements for such a program.

SUMMARY

Although the art of surgery is almost as old as man himself, our presently practiced modern aseptic technic has evolved to its present level only during the past one-hundred years. This evolution actually began with Lister's principles and technic introduced about 1865.

For sake of reference, surgery and its practice may be conveniently divided into three main eras: 1) The pre-Listerian Era, from the first operation to about 1862 or 1865; 2) The Listerian Era or Antiseptic Era, 1865 to 1885, and 3) Modern or Aseptic Era, from 1885 to the present day. The distinction between the latter two is the transition from the "wet" or antiseptic treatment of surgical wounds to the "dry" or aseptic treatment employed today.

As surgical attire has played an intimate role in achieving aseptic operating conditions, its evolution is interesting as well as enlightening.

Gowns. The surgical gown came into use in the late 1880's after the German surgeon, Von Bergmann introduced steam sterilization of linens and instruments. Prior to this time ordinary street clothing was worn in the operating room; the surgeon often removed his jacket and rolled up his shirt sleeves mainly to prevent soiling of them. Some surgeons, however, had a special coat or smock for operating which hung without washing in the operating room until the next operation. With the first gown came variations in design, some being two-pieced and buttoning either in front or back. Long sleeves did not appear until the early twentieth century. These latter modifications were quite similar to ours of today.

Masks. Masks originated about 1897, Mikulicz being given the credit. These were modified in the next two or three years and were probably very similar in design and effectiveness to our present day models routinely used. New filter masks are not available and recommended.

Gloves. Gloves marked a revolutionary change in 1889, being introduced by Halsted because of his concern for the hands of his nurse who passed instruments (and who later became Mrs. Halsted). They were not worn routinely until about 1894 or 1896 after Joseph Bloodgood, Halsted's House Surgeon, proved their merits statistically.

Caps. Caps were recommended about the turn of the century, but, like masks, never became well accepted until about 1910 or 1915.

Footwear. Footwear in the form of rubber boots became a necessity for the surgeon's comfort following the introduction of Lister's carbolic acid atomizer about 1866, which drenched the area about the table. With the transition to "dry" or aseptic technic about 1885, their necessity and popularity vanished. Again about 1890 a new type of canvas overshoe was recommended by some surgeons to prevent dirt and fecal material from the street from contaminating the operating room. This form of foot covering waxed and waned in popularity until about 1925 or 1930, but never has been and still is not popular or deemed a necessary precaution against contamination.

Only recently has concern again been directed specifically toward the development of a shoe covering satisfactory for safe wear in the operating room.

Contamination in the Operating Room. Nearly all surgical wounds are contaminated, the amount of contamination being the important factor. It has been shown that the sterile field in an ordinary operating room may be seeded with from 30,000 to 60,000 bacteria per hour from the air alone.

Contamination occurs by two principle routes: 1) Directly through the handling of patients and patients' supplies by doctors, nurses, and other personnel or, 2) Indirectly by contamination of the circulating air.

Pathogenic bacteria enter the air in two main ways: 1) In droplet spray produced by speaking, coughing, talking and breathing, or 2) In dust particles liberated as a result of friction and movement from the skin and clothing of infected persons, from their bedding, or from the floor and furniture in the room.

Air pollution is related to the amount of dust about any one area. Clean areas become contaminated rapidly by the presence of people. Usual air contaminants are diphtheroids, *Staphylococcus albus*, gram-positive rods, and *Staphylooococcus aureus*, the latter frequently found to be pathogenic. Also numerous fungus species are commonly found in the air.

Air conditioning and ventilating systems are frequently contributory to air pollution, but by using microstatic filters and maintaining an outward flow of air from the rooms this source can be curbed greatly. Ultra-violet lights are supplementary in decreasing air-borne organisms. These devices, however, are negated by bacteria brought into the rooms from other sources and hence circulated by the ventilating system.

Ordinary cleaning will not maintain low levels of air-borne bacteria, but rooms may be kept comparatively sterile by frequently repeated, intelligently directed, and vigorously applied mechanical scrubbing using a detergent-disinfectant repeated once or twice daily. Even this is not effective alone because a sterile room receives various bacterial contaminations from exhalations of personnel and from dust from fomites such as clothing and other objects brought into the room.

Improper and presently used clothing is responsible for a high degree of contamination of the air in operating rooms. Our routinely used loose-fitting gowns have been shown to decrease the air-borne bacteria count by only 50% over that of ordinary street clothing, the latter having been shown to disseminate into the surrounding air 1,000 bacteria-carrying dust particles per minute during moderate activity by the wearer. Scrub suit cuffs flopping along the floor and over dirty shoes literally throw bacteria into the air. These should be changed frequently. Circulating personnel or observers not covered with sterile gowns are nearly as bad as wearers of street clothes in the operating room.

Bacteria rapidly penetrate numerous thicknesses of cotton muslin if wet, but it has been shown that a single thickness of properly treated linen is essentially impervious to bacteria even when wet. Along this line of thought, it is obvious that even though "the scrub" removes bacteria from the arms and hands, these bacteria along with numerous water droplets are transferred to the scrub suit in the process by droplet spray. This could be prevented by wearing plastic aprons while scrubbing. Thorough drying of the hands and arms is therefore also extremely important before donning a sterile gown. Impervious sleeves would provide a barrier against wetting of the sleeves and hence prevent transfer of bacteria through the gown sleeves. A sterile plastic apron put on before the sterile gown would provide the same protection for the front of the sterile gown. The patient should wear a sterile gown as well as a cap and mask while in the operating room.

Conventional masks are ineffective after only a few minutes of use, and talking should be limited and laughter prohibited in the operating room. Nasal carriers of staphylococcus show a higher percentage in hospital personnel and physicians than in patients; 34% and 20% respectively. Newly devised filter-type masks have shown 98% effectiveness after several hours of continuous use.

Shoes presently worn in most operating rooms are grossly contaminated with mixed species of bacteria and fungi. In my recent study of this deplorable condition of shoes, I found that shoes worn in the operating rooms of four Omaha hospitals average approximately 2,500 bacteria per square centimeter of shoe surface. Ordinary street shoes that had been worn in and around hospitals averaged only 1,500 bacteria per square centimeter surface area; quite a contrast! From the 58 shoes studied, the range was from 37 to 25,390 bacteria per square centimeter surface area. Forty-two of the 58 carried micrococci including staphylococcus, 35 of these being hemolytic and 2 being coagulase-positive. Gram-positive bacilli were found on 37 shoes, 4 strains showing spore production. Gram-negative bacilli of the enteric type were carried by 9 shoes. These shoes represent a very real source of air contamination.

Our present day routinely worn surgical attire is not as effective as has been thought. This attire is contributing greatly to air contamination of our operating rooms. With many modern air conditioning systems actively circulating air, bacteria-carrying dust particles liberated from clothing and fomites are wildly circulated in the operating rooms and hospital. Under these conditions, the amount of contamination of surgical wounds is enhanced, thus setting the stage for post-operative wound infections.

Sources of operating room contamination can be greatly minimized by proper planning of the physical plant and wearing of effective surgical attire.

Post-operative wound infections can be reduced in number.

CONCLUSIONS

There exist in operating rooms numerous sources of contamination to the surgical field. Many of these sources can be eliminated and others greatly reduced.

Contamination of surgical wounds occurs in two principle ways: 1) Directly through the handling of various patients and patients' supplies by doctors, nurses and other personnel, and 2) Indirectly by contamination of the circulating air. Pathogenic bacteria enter the air by two main routes: 1) In droplet spray produced by speaking, coughing, talking and breathing, and 2) In dust particles liberated as a result of friction and movement from the skin and clothing of infected persons, from their bedding, or from the floor and furniture in rooms.

Air conditioning and ventilating systems are frequently contributory to air contamination, but this source can be eliminated or greatly minimized by microstatic filtration of the air entering the operating rooms and by maintaining the flow of air outward into the corridors by achieving positive pressure within the room.

Surgical attire worn in today's operating pavilions constitutes a potential source of contamination to the operative field, hence post-operative wound infections. Bacteria readily penetrate gowns which have become wet with fluids. Presently worn masks are quite ineffective after only a few minutes of use. Unrestricted talking, laughter, and motion disseminate bacteria-carrying dust particles and salivary commensals into the air surrounding the surgical field. Gowns are only 50% effective in reducing air contamination when compared to street clothing. Scrub suits, not frequently changed, collect bacteria and disseminate these on dust particles liberated by friction and motion. Shoes are grossly contaminated with bacteria and fungi of mixed type, and as such are a potential source of contamination to operating room air. Common street shoes carry less bacteria per square centimeter surface area than routinely worn operating room shoes!

Ordinary cleaning of operating rooms as presently performed will not maintain low bacterial counts of the air in these rooms.

Poor attitudes and mediocre performance of operating room personnel make the present day procedures and technics even worse.

The above sources of contamination can be reduced greatly by employing some of the suggestions listed below:

A. Rooms may be kept comparatively sterile by:

1. Frequently repeated, intelligently directed and vigorously applied mechanical scrubbing with a good detergent-disinfectant solution (at least one time daily).

2. Microstatic filtration of air delivered to the rooms.

3. Positive pressure maintained in the operating rooms.

4. Ultra-violet lighting as supplementary measures.

B. Attire can be made effective by:

1. Preventing gowns from becoming wet from poor scrub

technic and improper drying of arms and hands. Also sterile plastic aprons and sleeves.

2. Frequent changing of scrub suits.

3. Restriction of talking, laughing and motion while in the operating room.

4. Wearing newly devised, 98% effective, filter-type face masks.

5. Canvas wrap-around booties or washable shoes, washed and sterilized daily. A clean pair used for each new operation.

6. Sterile quick-change wrap-around gowns changed for a fresh one each time a non-sterile person enters or re-enters the operating room.

C. Masking and gowning of the patients entering the rooms.

D. Cleaning with antiseptic-detergent solution all articles taken into the operating room.

E. Restricting the number of persons present at any operation.

F. Strict self discipline and proper habit formation as regards technic of scrubbing and gowning.

G. Constructive criticism directed toward offenders of sterile procedures.

H. Frequent re-evaluation of the overall program as to its effectiveness and practicality.

There is no reason for the incidence of post-operative infections to remain over 1%. Surgical procedures can be carried out under almost sterile conditions.

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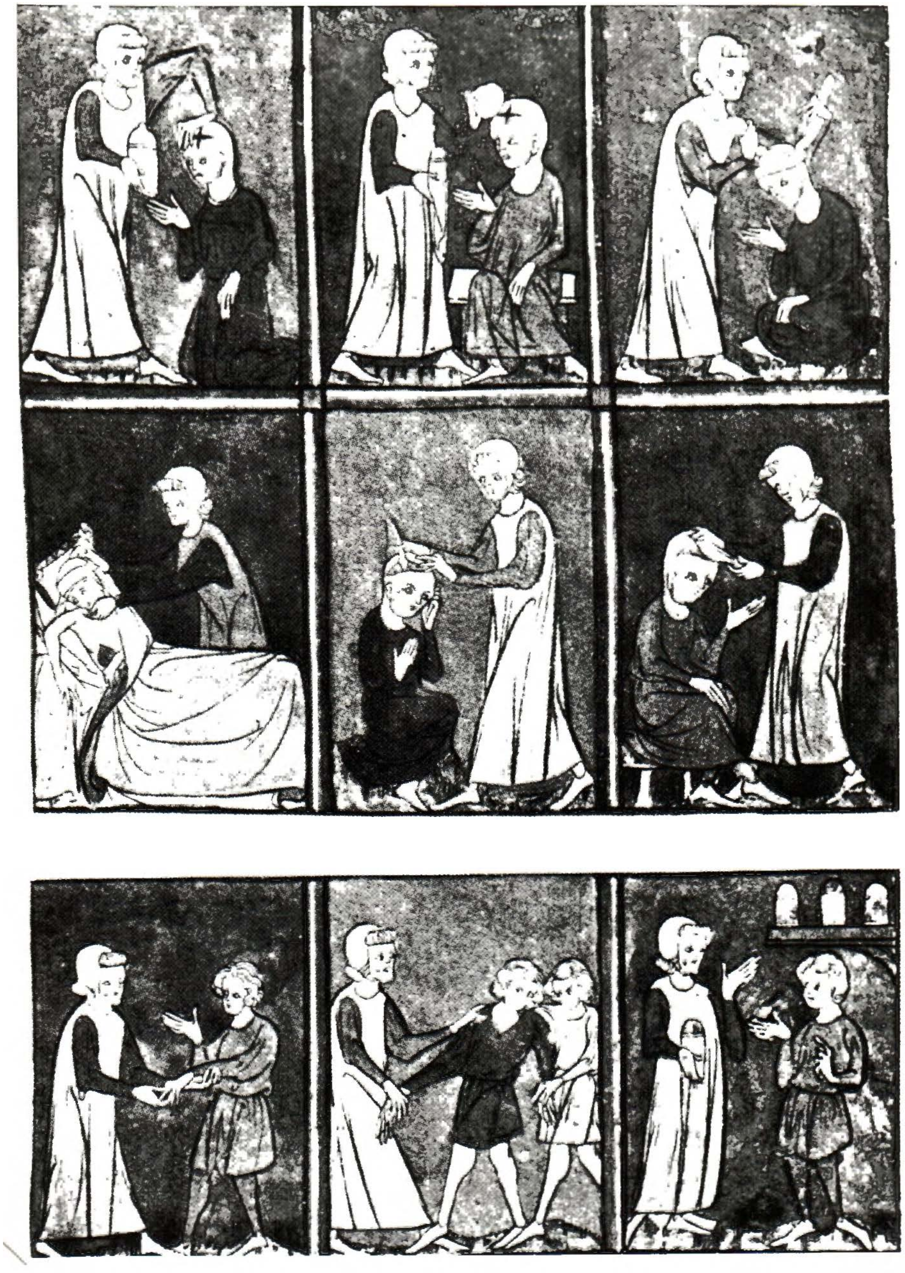

Fig. 1. Pictures of operations as performed at Salernum in the thirteenth century. (British Museum) From Dana, C.L., Peaks of Medical History, Paul B. Hueber Inc. N.Y., 1926.

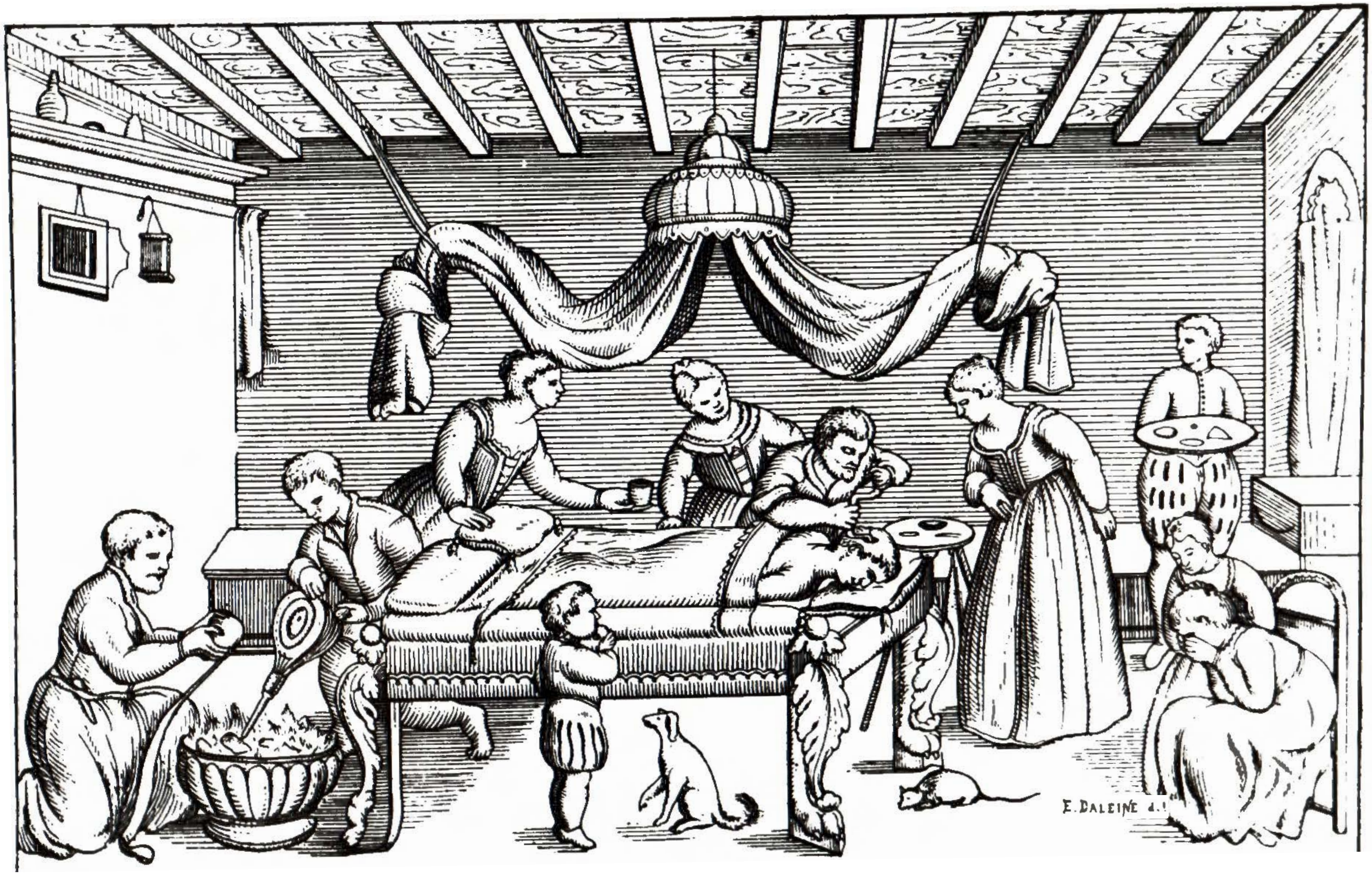

Fig. 2. Early Examples of Trephining (An artist's conception, of course, but note the rats and dog.) From: Peaks of Medical History, Paul B. Hueber, N.Y., 1926.

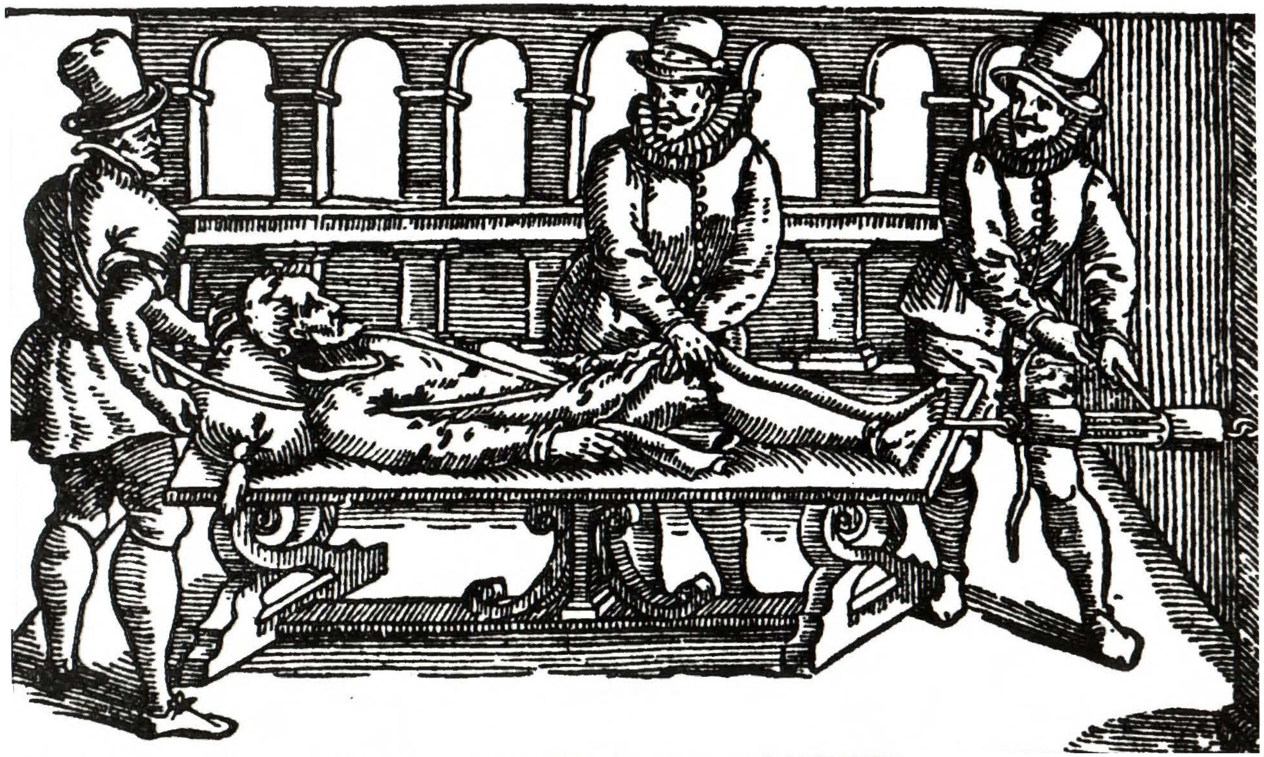

Fig. 3. Surgical Practice in the seventeenth century. From a work entitled "Thesaurus Chirurgical", published in 1610. Taken from C. L. Dana's book, The Peaks of Medical History, Paul B. Hueber Inc., N.Y., 1926.

Fig. 4. The pre-antiseptic era. Amputation of an arm under strict "septic" conditions. (From Laurenz Heister's Chirurgie, Dritte Auflage, Nurnberg, 1731.)

Fig. 5. Scene in the operating amphitheater of Massachusetts General Hospital, 1888. Ether is being administered to the patient by placing a sponge soaked with the drug over the nostrils. Note that all of the operating room personnel have either beards or mustachios, but masks, caps or gloves were unknown at this time. (Taken from reprint in the Am. J. Surg. 82:25, July, 1951).

Fig. 6. About May of 1889 or slightly earlier. Dr. Agnew is shown leaning on the railing, having finished an excision of the breast for cancer. Note the white gowns; these were very new and represent an innovation, due to antiseptic technic. (Reprinted from Am. J. Surg. 82:110, July, 1951)

Fig. 7. Operating room about 1898. Note the absence of operating gowns which had been introduced about ten years earlier (see Fig. 6.) This serves to illustrate the slowness with which new ideas and attire were accepted. (Reprinted from Am. J. Surg. 82:118, July, 1951.)

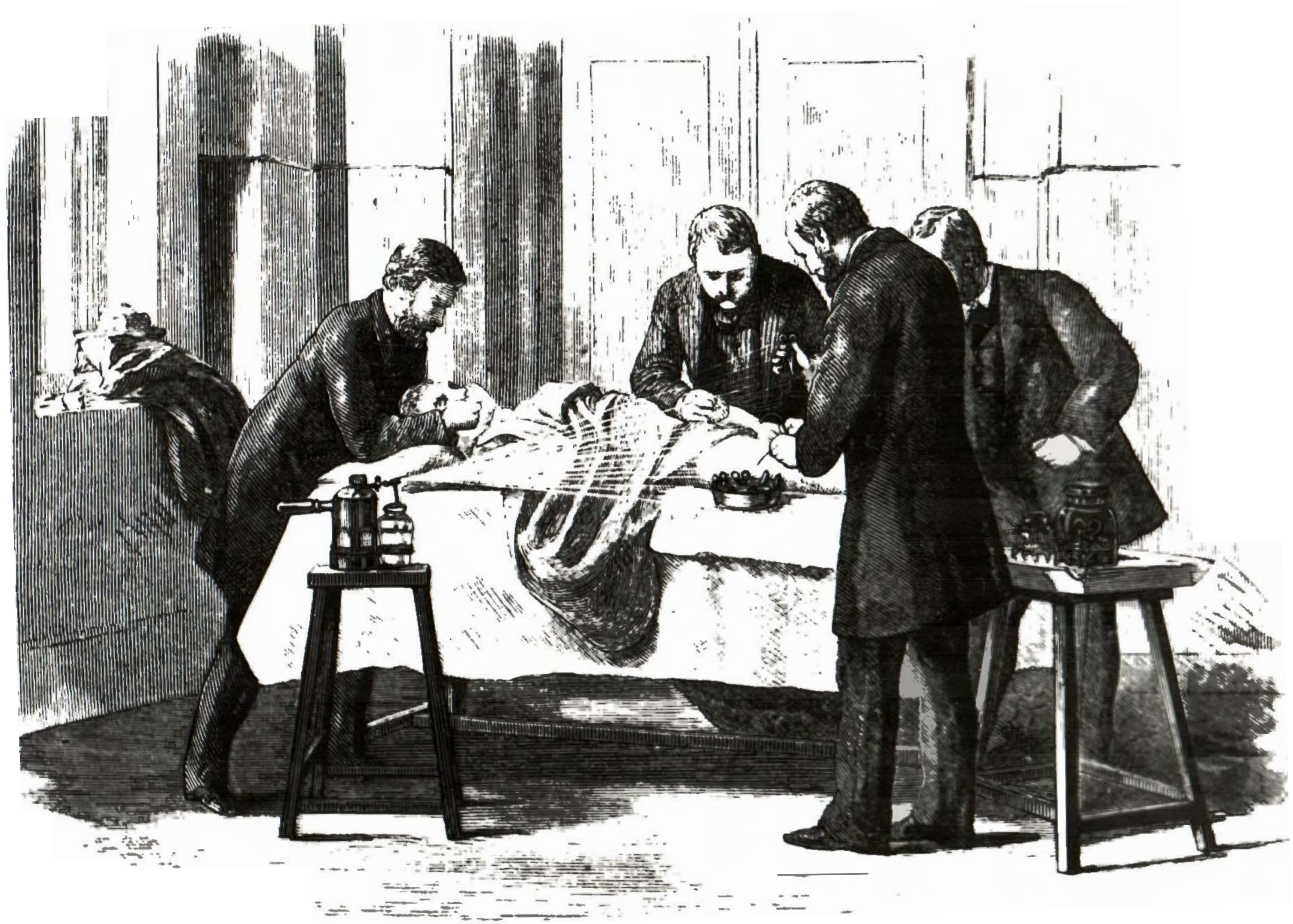

Fig. 8. The Antiseptic Method. 1882. A drawing showing strict observance of the method developed by Lister. He first used this technic about 1866 or slightly later. (Reprinted from the textbook of W. Watson Cheyne, Antiseptic Surgery, It's Principles, Practice and Results, London, 1882.)

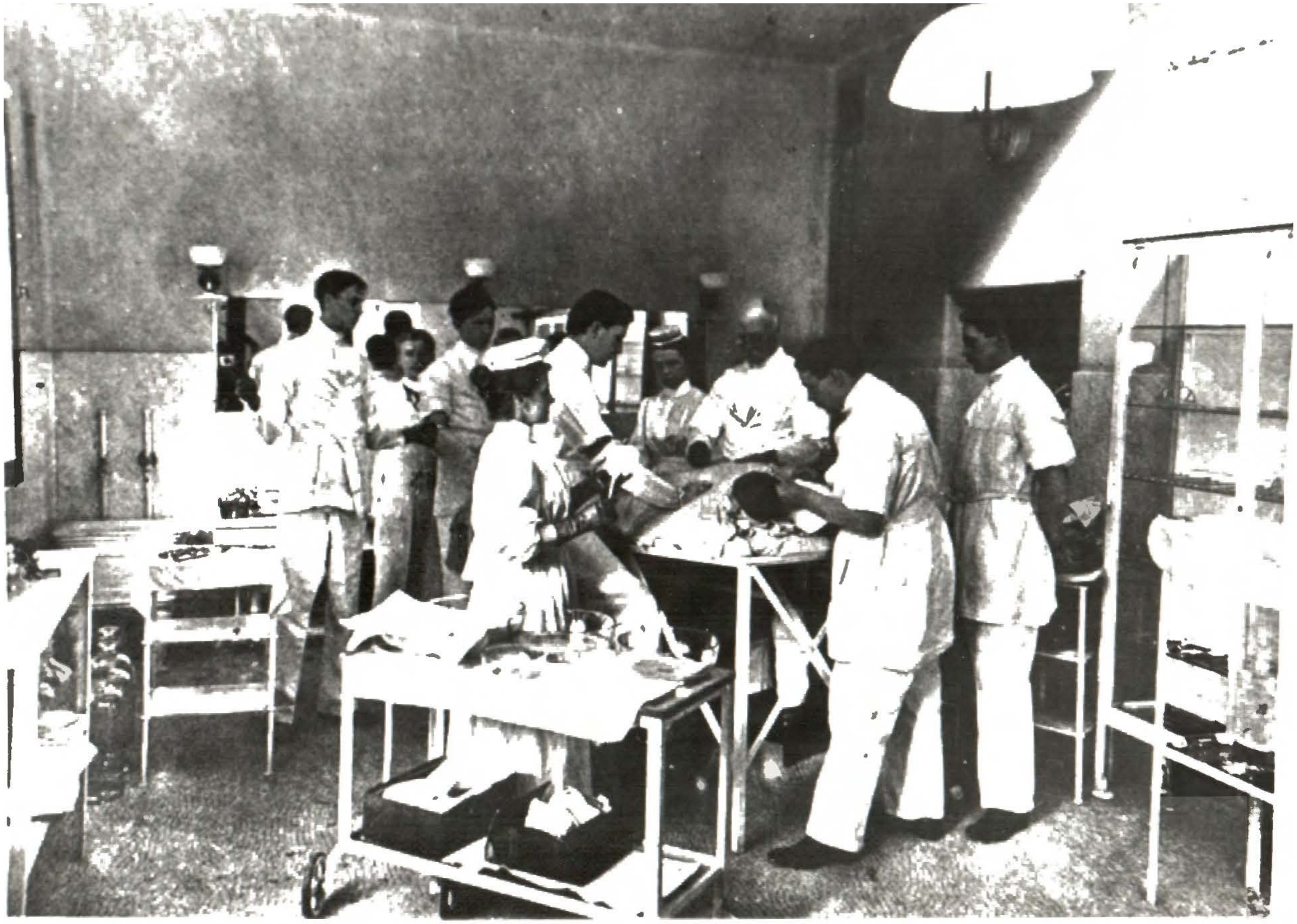

Fig. 9. Typical operating room at the beginning of the century. Professor McBurney, famous for the McBurney point, is seen performing an operation. Note the absence of masks and caps which had been introduced about 1897 by Mikulicz. Also note the short sleeves and apparent absence of sterile gowns which had been recommended and used by von Bergmann about 1888 or 1889. (Reprinted from Am. J. Surg. 82:181, July, 1951.)

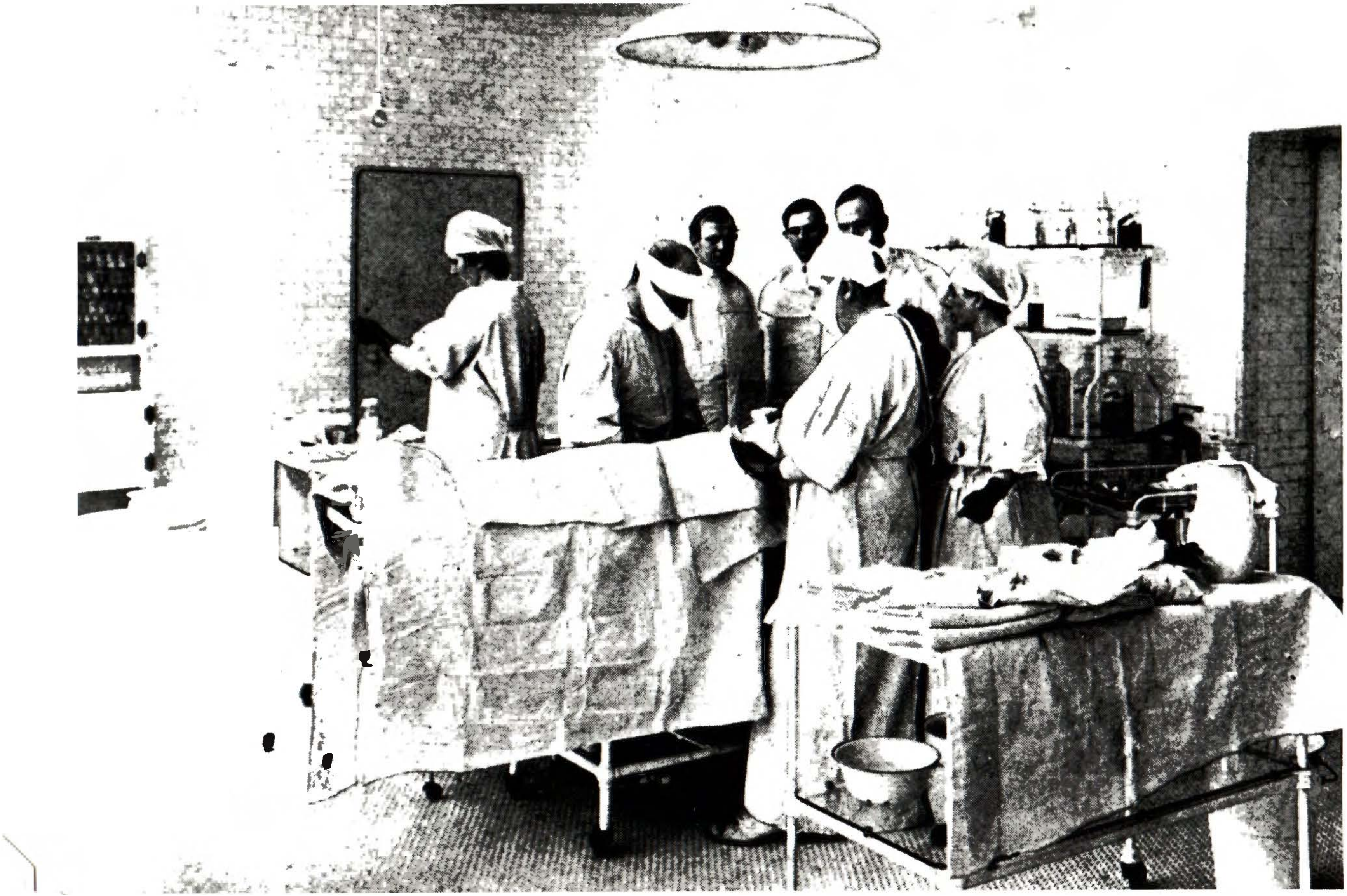

Fig. 10. Present day operating room. (About 1909) Note the short sleeves on gowns but here the gowns are long and have probably been autoclaved or steamed. Also note the presence of masks, but only on some of the persons. (Reprinted from the Textbook of Keen and DaCosta, Surgery, It's Principles and Practice, W. B. Saunders Co. Philadelphia & London, 1909.)

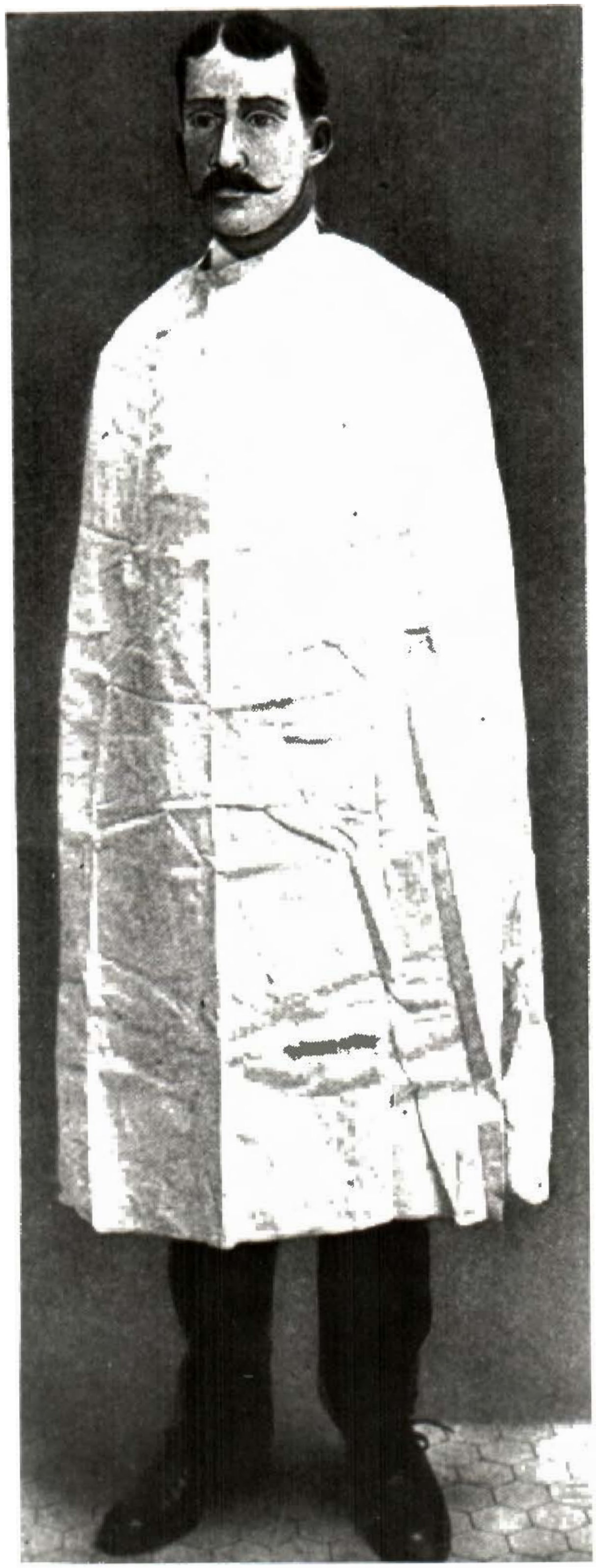

Fig. 11. Spectator's Gown, about 1909 or earlier. (Also from Keen's Surgery Text, 1909)

 

217.—Surgeon's Operating Garb. Fig. 218.—Operating Garb for N

of more durable material and fewer buttons is preferable

Fig. 12. Surgeon's Operating Garb and Operating Garb of Nurse. Also from Keen's Surgery Text about 1909 or earlier. Note the short sleeves for the nurse's gown, also absence of her mask.

Fig. 13. Use of Rubber Gloves. A photograph of Halsted's first operation in the new surgical amphitheater at Johns Hopkins in 1904. Face masks were not used in 1904 although introduced earlier. This is one of the earliest photographs showing an entire operating team wearing rubber gloves. Compare this with Fig. 9 and 10 which were taken later.

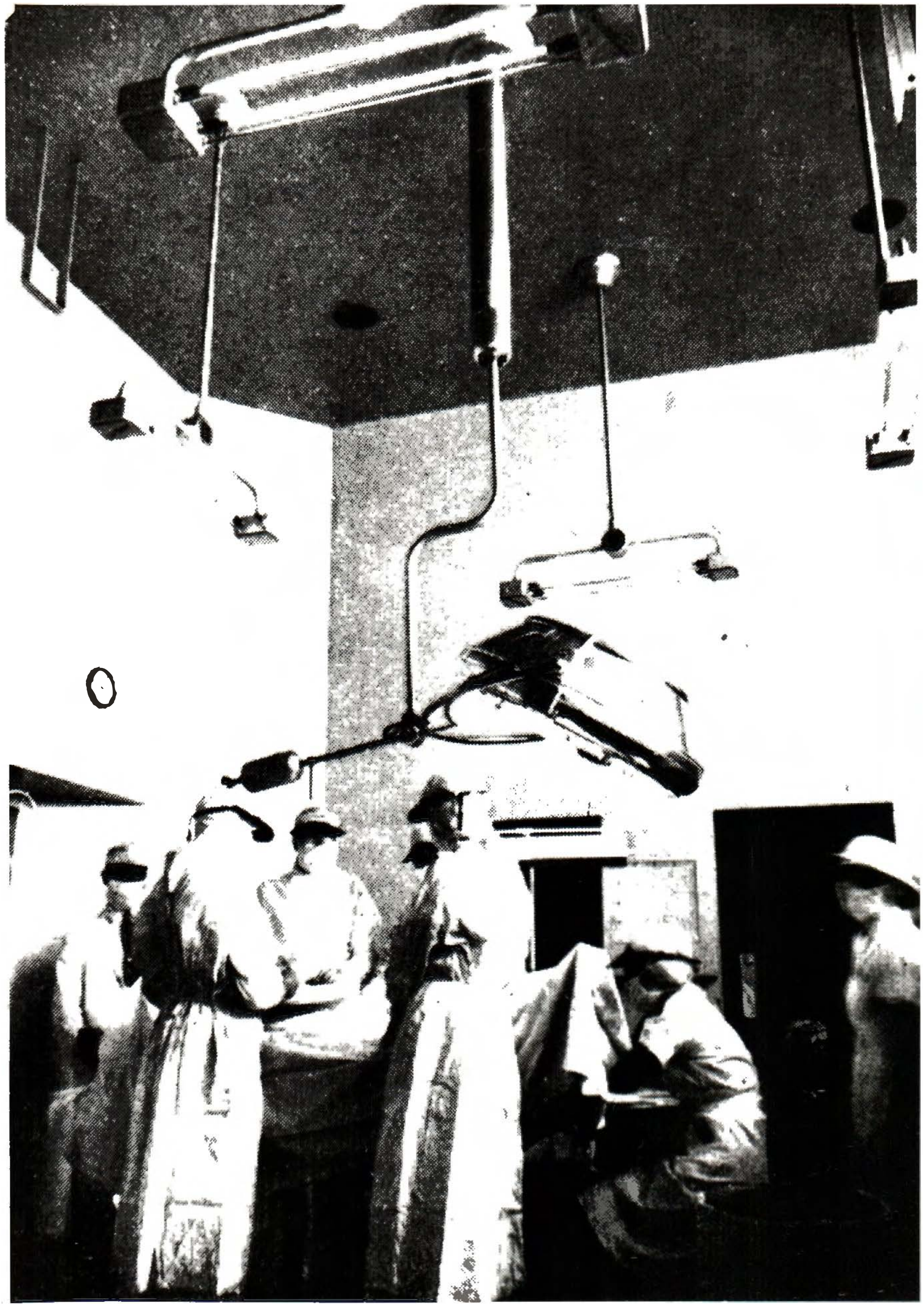

Fig. 14. Modern Asepsis (About 1936). An operation performed under bactericidal ultra-violet light. Taken at the Duke Hospital, Durham, North Carolina. Note the covering of all exposed skin surfaces for protection from burns. Also note the male observer to the far left in street clothes with only a white coat pulled over them.