

SURGICAL GLOVES AND WOUND INFECTIONS

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UNTIL about 1890 all surgical operations were performed with bare hands. Holmes and Semmelweis were among the first to report that the hands served to carry the organisms of puerperal sepsis, a fact which has been demonstrated over and over again. Since the work of Halsted and others in the 1890 decade, the use of rubber gloves has become an essential part of surgical technique as a means of preventing wound infection. Their use is taken as a matter of routine and, as in all matters which become routine, this step in the performance of a surgical procedure may become subject to a certain amount of unintentional carelessness. It is our purpose in this paper to emphasize that, although we realize that they are only one of several possible sources of infection, perforated gloves are an important source of infection in clean surgical wounds.

HISTORICAL

The infection of clean surgical wounds has been a major problem since the beginning of surgery. At first it was accepted as a normal risk of operation and the resulting suppuration was labeled "laudable pus." With the development of the germ theory of disease the presence of purulent exudate began to take on a new meaning. Surgeons began to realize that while phagocytosis was a normal phase of repair in infected wounds, healing was more rapid and the resulting scar was smaller if bacteria were eliminated from the wound. Since fermentation and putrefaction were brought about by bacteria present in the air, it was reasoned that this was the source of organisms infecting wounds. A wound was considered to be essentially an open culture tube with dead tissue as the substrate upon which bacteria could bring about fermentation and putrefaction. Since the air contained many bacteria capable of producing these changes and since the wound was exposed to the air, infection appeared to be a natural consequence. In order to prevent the development of such a condition, it was considered advisable to sterilize the air by spraying a suitable

disinfectant into it in the vicinity of operation. A solution of phenol was used for this purpose in most operating rooms. However, by about 1895 surgeons were being impressed with the importance of the skin as a possible source of organisms. As early as 1891 Welch demonstrated that staphylococci occurred in stitch abscesses. The importance of the skin as a source of infection was again emphasized when Robb and Ghriskey in 1892 showed that it contained both staphylococci and streptococci as common inhabitants. These findings have been confirmed by many others.

Park recognized the fact that infection could and probably did come from several sources. Among the possibilities he listed as "the principal sources of contact infection: (1) skin and hair, (2) instruments, (3) sponges or their substitutes, (4) suture materials, (5) the hands of the surgeon and his assistants, (6) drainage materials, (7) dressing materials, (8) miscellaneous, e.g., drops of perspiration. . . ." He emphasized that the hands of all those concerned about the field of operation should be carefully disinfected. His concept of the importance of this procedure was vividly portrayed when he said, ". . . cemeteries have been filled in time past by the septic hands of medical students." Robb and Ghriskey isolated staphylococci and streptococci from the stitches and wounds of all the patients so examined. Their insight into the importance of the skin as a source of organisms is portrayed by the statement: "We have no sure and absolute method of rendering the field of operation entirely free from organisms, owing to the impracticability of destroying them in the superficial layers of the skin." No less an authority than McBurney stated in 1898: "My conclusion is that the real source of infection of a wound deliberately made by a careful surgeon who uses perfect materials and handles them perfectly is to be sought either in the skin of the patient or in the hands of those directly concerned in the operation." Also, "The writer does not claim that atmospheric dust is free from harmful germ life, but he does assert that, clinically, no evidence exists that such dust causes wound infection." Bovée commented in 1899 that "the air of the operating room is by no means free of pathogenic organisms, though this

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has probably been slightly exaggerated." He did not consider the introduction of rubber gloves alone sufficient to solve the problem, for he wrote: "We have cleansed our hands just as carefully to use the gloves as was usual without them. This is necessary as gloves may accidentally be perforated during operation." The use of cloth gloves was discredited by Lockett when he said, "The results of the above experiments seem to us to prove the absolute inefficiency of cotton gloves; both in their original state, and when paraffined they fail to prevent infection from the hands." While the use of gloves had already become routine in many places, leading surgeons continued to emphasize their importance after the turn of the century. Burford wrote: "that the operator's hands are the most dangerous sources of infection during operations is the most accepted view, at least in America. It seems conclusive that the operator's hands are more dangerous to the patient than the patient's own skin. . . . (p. 614). One having an infection on the fingers or the hand is not justified in operating while it lasts, even though the hands are covered by gloves, because of the risk of tearing the glove and leakage into the wound." Thomas considered gloves as having an indirect value to the surgeon when he facetiously remarked: "Gloves for unknown assistants are excellent, as the awe of the gloved hands prevents assistants from feeling impelled to feel the patient's pulse or open a door or window during the trying vicissitudes of any long operation." Brewer said that "by far the most important change in our technics which resulted from our bacteriological experiments was the adoption of the rubber gloves."

It was quite natural, therefore, that the interest should change from chemical sterilization of air to preoperative preparation of the hands of the surgeon and the skin of the patient. Many methods of skin sterilization were tried, but mercuric chloride appears to have been a favorite with a great many. The majority of such techniques, however, involved some combination of washing with soap, rinsing with ether or alcohol, washing with bichloride of mercury, and again rinsing with alcohol. Some operators also employed potassium permanganate and oxalic acid (12). In due time it was discovered that the chemical treatments employed were not as practical as had been believed, partly because the solutions were injurious to the hands, partly because they did not sterilize the surfaces in question.

In 1889 Halsted reported on the use of rubber gloves in surgery. Whether this was actually the

first application of such a technique may be debated but a literature search has failed to establish any other priority. Within a few years many types of gloves were being advocated for use in surgery. Some were silk, some were cotton, and others were leather, some were rubber gloves without finger tips and some replaced the heavy finger tips with thin rubber finger cots. Because of the growing belief that passage of bacteria from the surgeon's hands to the wounds might take place through the cloth gloves, attempts were made to impregnate them with paraffin in xylol. Critical bacteriological tests, however, showed this did not make them entirely impervious (9). There was, therefore, a gradual adoption of rubber as the only safe operative glove to prevent wound infection.

By about 1900 rubber gloves were in common use in the better hospitals and private practice. However, there were many claims of greatly reduced incidence of infections by using cloth gloves (cotton or silk). Since Davidsohn (1888) had shown that instruments could be satisfactorily prepared for operative work by boiling, the method was automatically used for preparing the gloves, whether they were of rubber or cloth. Many surgeons, however, preferred chemical sterilization, usually with bichloride of mercury. Curiously enough, in a given operating team it was customary for only part of the individuals to wear gloves. In some cases the surgeons wore the gloves, in others the assistants wore them. Bloodgood in 1896 (3) has been credited with being the first to require all assistants to wear gloves, but the practice was not uniformly adopted until some years later. McBurney claims Halsted required his assistants to use them as early as 1891 but the writings of the latter in 1891-1892 do not mention it. Many objected to gloves as they interfered with the tactile discrimination considered the surgeon's best asset.

The adoption of the rubber glove as a standard part of good surgery was a very slow process. While some were reluctantly accepting them on their merits, others were recognizing certain inherent dangers in their use. As early as 1899 Bovée pointed out that even with the use of sterile rubber gloves it was still necessary to cleanse the hands just as carefully as without them. He said, "This is necessary, as gloves may accidentally be perforated during operation." He also emphasized that "the advantages of rubber gloves in surgery are, first, protection of patient against infection from operator's hands, and second, protection of operator's hands against infection from wounds."

Since the turn of the century, rubber gloves have gradually become an integral part of operative surgery in all reputable hospitals. The preoperative preparation of the hands has also continued as a part of the technique to lessen the hazard of infection from accidentally torn gloves as pointed out by Bovée. There has gradually developed the relatively uniform method of autoclave sterilization of the gloves in cloth packets. They are now usually wrapped individually and arranged for convenient aseptic manipulation by the washed hands of the one to wear them. Previously they were boiled in 5 per cent sodium bicarbonate solution. So long as the gloves remained intact, the chances of infecting a clean surgical wound were minimal. The importance of the glove today is certainly no less than in 1901 when Burford wrote: "Do our wounds heal better and more quickly with gloves than without? I can answer most emphatically that they have done so in my experience. With McBurney, I can say that I believe there is as much difference in the healing of wounds made with and without rubber gloves as there is between healing where the new method (antisepsis and asepsis) is and is not used."

The use of rubber gloves has not completely eliminated worry from infection of clean wounds. While many surgeons deny such developments occur in their practice, Meleney has pointed out that an unbiased critical analysis of the records will usually surprise the surgeon in charge. However, he was of the opinion the infections came directly from the respiratory tracts of the operating personnel. The extensive work of Hart has also emphasized the air as a source of infection in clean operative wounds. On the other hand, Devenish and Mills definitely traced a series of wound infections to one surgeon who was persistently perforating his gloves during operation. Still more recently Hirschfeld has emphasized the hands of the operator as a source of infection.

It thus appears that, as far as wound infection is concerned, scientific thinking has completed a 75 year cycle. During the time of Lister emphasis was placed on air as being a source of infection. Emphasis was then (1890-1910) changed to the skin of the patient and the hands of the surgeon. In 1898 Mikulicz commented, "The rôle of the air in operative infections has been greatly exaggerated since the beginning, especially by Lister." With the more recent work of Meleney and Hart, resulting in the development of ultraviolet irradiation, emphasis has again been placed on the air. During the past few years chemical steriliza-

tion of the air by means of aerosols has been rapidly advancing. It appears now there is a definite need for sterilization of the hands since rubber gloves are easily and unknowingly perforated during operation.

EXPERIMENTAL

During the course of some investigations on the bacterial content of the air in the operating room, recently reported by Rice and associates it was decided to determine the incidence of perforated gloves used in the Central Surgery of the Indiana University Medical Center.

In order to be fair to the surgical staff it should be emphasized that the data recorded herewith were obtained on gloves used by the entire personnel including residents in training, internes, student nurses, and other assistants common to the operating rooms of most university hospitals. It is the opinion of the staff members who have had extensive experience in other hospitals that the frequency of wound infection here is not greater than that found in other teaching hospitals.

The gloves were tested by distending with water and observing for leaks. A more accurate but less convenient method was to distend the fingers with air with the glove immersed in water and observe for bubbles. It is our impression this method is more certain to detect very small holes. However, because of lack of time on the part of the help responsible for examining the gloves, the examinations were made with water. A record was kept of the total number of gloves used during each operation, the number found perforated, the nature of the operation and the name of the surgeon in charge. Data were kept for each operation, irrespective of the type or importance or the number of gloves used.

The significant findings from data collected over approximately 20 months are given in Table I.

TABLE I.

Total number of operations (all kinds)	4,549
Number of operations with perforation of one glove or more	3,409
Per cent of operations with perforation of one glove or more	74.4
Total number of gloves used	35,793
Total number of gloves perforated	8,103
Per cent of gloves perforated	22.6

During the first 2 months the incidence of perforation was 32 per cent. There were two other separate months when the rate was higher than that given for the entire period, but these increases could not be traced to any individual. We

are not certain whether the reduced incidence after the first 2 months' observation is due to increased care on the part of the surgical staff or whether the coincidence is accidental. By the more accurate method of distending the gloves with air and immersing in water, we have examined 200 pairs of new unused gloves and have found none to be perforated.

We desired to obtain statistics on the incidence of wound infection among the patients operated upon in this surgery but consultation with the surgical staff emphasized the theoretical and practical difficulty in doing this. We believe no one factor can be used as a real index of minimal wound infection. Some patients develop a febrile reaction or leucocytosis or both without any grossly demonstrable evidence of wound infection. Others with obvious infection develop only a slight temperature or leucocytic reaction or both. To make cultures of the wounds would be meaningless since the surface of normal skin contains bacteria and the absence of growth on culture might mean either sterility or bacteriostasis due to the chemical used in preoperative preparation of the patient. It becomes a very difficult, if not impossible, task, therefore, to determine a minimal infection. Because of this no record was made concerning the incidence of wound infection during the period in which the gloves were examined.

The work of Price, Hirschfeld, and others have shown that many thousands of bacteria are present on the average hand after the usual routine preoperative preparation. We have confirmed these findings in all essential details (unpublished). Perforation of a glove during operation therefore becomes very important. If one hand contained only 10,000 bacteria uniformly dis-

tributed over the surface, 1 drop of perspiration in the finger tip could introduce a large number of bacteria. Furthermore, this is put directly into the wound when the perforated glove is on the hand of the surgeon. The practical importance of this is borne out by the work of Devenish and Mills.

SUMMARY

Data are presented showing the incidence of perforated gloves in the Central Surgery of the Indiana University Medical Center. The importance of perforated gloves as a possible source of infection of the clean surgical wound is emphasized. We believe some method of complete sterilization of the surface of the hands should be a part of modern surgery.

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