

WOUND INFECTIONS, SURGICAL GLOVES AND HANDS OF OPERATING PERSONNEL*

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INVESTIGATION of the causes of wound infection in aseptic surgery has been going on for over 13 years at this hospital. In this study, only aseptic wounds for the repair of hernias and associated conditions have been considered primarily, as no other type of surgery was performed at this institution. Ideal conditions therefore existed for such investigations.

Early ambulation after hernia operations has been the practice, as described by one of us.¹ All patients left hospital two to three days after operation and before there would be evidence of wound infection. If wound infection occurred, it greatly hindered and interfered with the rapid recovery of patients in this type of surgery. Altogether, infection of aseptic wounds was of greater importance under these circumstances than in general hospitals where patients usually remain long enough for signs or symptoms of infection to appear.

That patients left the hospital before evidence of wound infection appeared may conceivably have caused us to miss a very occasional case. However, all patients are instructed and urged to contact the hospital, return for examination, write or telephone if too distant, and report on their postoperative condition.

During this experiment 330 herniorrhaphies were performed; 292 or 88% were examined two weeks or later after discharge from hospital, a sufficient length of time for infection to have developed; 38 or 12% have not been examined or heard from since discharge from hospital but it can be taken for granted that we would have heard from them if infection had developed.

As early as 1904, Harrington² stated that "The danger of infection through the escape of droplets of sweat of a carefully prepared hand through an accidental puncture of a rubber glove is accorded

undue weight." He "took sweat from sterilized forearms and hands and in not a single instance was bacterial growth obtained".

Several approaches to the study of this subject have taken place. In 1945, observations of torn gloves during operations were made and noted. There was no evidence of a relationship between glove tears and wound infection.

Experience with operating personnel who developed eczema of the hands, in our opinion due to overscrubbing and not to an allergic condition as stated by Stokes,³ indicated to us that a more realistic approach to the preparation of hands for operations should be developed. Such personnel were instructed to reduce scrubbing time to two minutes with: (1) a soft brush while using surgical liquid green soap and water which was followed by a rinse with pure isopropyl alcohol, or (2) pHisohex (a hexachlorophene and detergent emulsion) and water only. Great care was taken when putting on the gloves. They were allowed to continue to operate and assist at operations until their hands healed up and there was no evidence of any increase in the infection rate during this time. It has been a routine for a number of years in this hospital for operating personnel to scrub hands gently and no longer than two minutes. There has been no evidence of eczematous conditions of the hands of operating personnel since this routine was established and no evidence of an increased infection rate.

In 1954, a short study of the hands and gloves of operating personnel was carried on at our new (second) hospital.¹² At this time we had a higher rate of wound infection in this new division than at the old hospital. This brief study of 16 swabs of the gloves, hands and sweat inside the gloves, when operations were completed, did not show pathogenic bacteria (*Staphylococcus aureus*, coagulase-positive), which was rather surprising. Further study of punctured gloves in wound infections was carried on in February 1958.

METHOD AND RESULTS OF BACTERIOLOGICAL STUDY

The plating of the swabs on culture plates was made the responsibility of one person (C.M.), so as to obtain the most accurate results. This study

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TABLE I.—RESULTS OF SWABBING

| Surgeon or assistant surgeon | 2-minute scrub | | *Pre-operation swabs 3½ hours after scrubbing: total of 80 | Post-operation swabs during glove removal: total of 80 | | Outside of gloves near completion of operation: total of 67 | | |
|---------------------------------|---|-------------------------------------|---|---|--------------|--|--------------|------------------------------|
| | Green soap followed by alcohol rinse | pHisohex, no alcohol rinse | No growth | Growth: non- pathogens | No growth | Growth: non- pathogens | No growth | Growth: non- pathogens |
| Dr. A..... | " | | 17 | 0 | 15 | 1-3C 1-8C | 12 | 1-4C 1-2C |
| Dr. B..... | " | | 10 | 1-1C 1-2C 1-14C | 9 | 1-2C 1-1C 1-L.G. 1-2C | 11 | 0 |
| Dr. G..... | " | | 4 | 0 | 3 | 1-H.G. | 3 | 0 |
| Dr. M..... | | " | 13 | 0 | 13 | 0 | 11 | 1-1C |
| Dr. O..... | | " | 16 | 1-3C | 15 | 1-1C 1-1C | 14 | 1-2C |
| Dr. S..... | " | | 0 | 1-3C | 0 | 1-1C | 0 | 0 |
| Dr. W..... | | " | 14 | 1-2C | 13 | 1-3C 1-H.G. | 9 | 1-3C 1-2C 1-3C |
| | | | 74 | 6 | 68 | 12 | 60 | 7 |

*Pre-operation scrubbing was done for first operation only and about 7.30 a.m. Swabbing of hands was done after two or three operations without scrubbing between operations or the use of pHisohex but all hands were rinsed with isopropyl alcohol and dried with a sterile towel and then swabbed.

C. = Colonies.
M.G. = Moderate growth.
L.G. = Light growth.
H.G. = Heavy growth.
V.H.G. = Very heavy growth.

included a search for pathogenic bacteria (especially *Staphylococcus aureus*, coagulase-positive) on areas of the hands of operating personnel, surgeons, assistant surgeons and nurses.

BACTERIOLOGICAL METHODS*

All swabs were plated on 5% sheep-blood agar. The plates were incubated at 37° C. for 48 hours and then examined for the presence of *Staphylococcus aureus*. Coagulase-negative staphylococci, Micrococcus species and aerobic spore-bearing bacteria were reported as non-pathogens.

The following criterion was used in estimating the number of colonies present: 1-10 colonies—actual number of colonies reported; 10-20 colonies—light growth; 20-35 colonies—moderate growth; more than 35 colonies—heavy growth.

Scrubbing and Swabbing Methods

All operating personnel scrubbed for a two-minute period for their initial scrub using green soap followed by an alcohol rinse or pHisohex only and no alcohol rinse, during this experiment.

(A) Surgeons and assistant surgeons carried out the initial scrub daily but in between operations they removed their gloves carefully so as not to contaminate their hands, and everyone rinsed his hands well with undiluted isopropyl alcohol only and dried hands with a sterile towel before re-gloving. They usually performed an average of four operations every morning without re-scrubbing their hands. This procedure is much the same as that described by Price.¹

1. A swab was taken of the hands along the thumbs, index fingers and between the fingers and around the nails as well as the dorsum and palmar surface of the hands after alcohol rinse and just before re-gloving for the last operation (fourth case) and immediately plated on blood agar.

2. A swab was used on the inside surface of the gloves (hands, thumbs and index fingers), also the skin of the hands, thumbs and index fingers while gloves were being removed at the end of the fourth operation. Great care was taken in removing the gloves so as not to contaminate the inside of the gloves or the hands when a swab was being taken.

3. A swab was taken of various puncture areas on the outside of gloved hands, including thumbs and index fingers, just before the final operation was completed (suturing of Scarpa's fascia). Results are summarized in Table I, which shows that:

a. One assistant surgeon, Dr. M., had no growth on pre-operation swabbing or post-operation swabbing of hands and sweat.

b. Surgeon's and assistant surgeon's pre-operation swabs and post-operation swabs were mostly negative and the rare growth was non-pathogenic. There was a slight increase of non-pathogens in post-operation swabs as compared to pre-operation swabs but no increase in bacteria considered to be pathogenic. Of the 80 pre-operation and 80 post-operation swabs (total 160), 142 swabs showed no growth, one was unchanged as regards the number of colonies, five showed a decrease in growth and eight showed a slight increase in growth. This is difficult to show clearly in a table because of the variation in the number of colonies

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TABLE II.—SURGEONS ASSOCIATED WITH WOUND INFECTION

| Surgeon | Number of operations | Number of infections | % infected wounds |
|------------|----------------------|----------------------|-------------------|
| Dr. B..... | 80 | 4 | 5.0 |
| Dr. G..... | 109 | 2 | 1.8 |
| Dr. O..... | 57 | 0 | 0.0 |
| Dr. W..... | 84 | 0 | 0.0 |
| Total..... | 330 | 6 | 1.8 |

Note: Surgeon B. was associated with a very high percentage of infected wounds. Assistant surgeons, nurses, operations, etc., were equal for all surgeons. Surgeon G. had an average record whereas Surgeons O. and W. had a perfect record.

from 1 to 35 or more. The comparatively light growth of bacteria from the hands and gloves of surgeons and assistant surgeons is evidence that these are seldom, if ever, a source of wound infection at this institution.

3. There were no colonies of pathogenic *Staphylococcus aureus*, coagulase-positive, in all this swabbing of the hands before and after operation or in the sweat in gloves of surgeons and assistant surgeons.

Of the six cases of infection (mostly mild) that occurred during the experiment, three wounds showed cultures of *Staphylococcus albus*, which is unusual. These infections with *Staphylococcus albus* were the most superficial and could be from the patient's skin, but Table II indicates that something associated with the surgeon was more likely. All our study of wound infection points to the surgeon's nose as the source of most if not all wound infection in this surgery.

No glove punctures were found in any of the three operations which resulted in wounds showing *Staphylococcus albus*.

(B) Nurses carried out an initial scrub daily and removed their gloves when the first operation was completed. Before one operation was completed another nurse was setting-up for another operation in the same operating room. Each nurse prepared for two operations every morning, although four operations were performed in each operating room (three operating rooms in all). In between operations the nurses washed instruments, folded operating linen, etc. These duties easily tore the gloves, so the latter were removed immediately when each operation was completed. Therefore each nurse had to re-scrub in between the two operations at which she assisted.

1. One swab was taken of the hands along the thumbs, index fingers and in between the fingers after alcohol rinse or pHisohex just before gloving for their last operation.

2. One swab was taken of the inside of the gloves (hand, thumb and index fingers) and the skin of the hands, thumbs and index fingers. Great care was taken in removing the gloves so as not to contaminate the inside of the gloves or the hands, when the swab was being taken.

3. Swabs were taken of the outside of gloved hands, thumbs and index fingers before the operation was completed (suturing of Scarpa's fascia). Results are summarized in Table III, which shows that:

1. Post-operation swabs from all nurses except Mrs. O. showed less growth of non-pathogens than

TABLE III.

| Nurses | 2-minute scrub | | Total of 71 pre-operation swabs immediately after scrubbing | | Total of 71 post-operation swabs during glove removal | | Total of 61 swabs from outside of gloves near completion of operation | |
|-------------|--------------------------------------|----------------------------|---|--|---|-----------------------|---|-----------------------|
| | Green soap followed by alcohol rinse | pHisohez, no alcohol rinse | No growth | Growth: non-pathogens | No growth | Growth: non-pathogens | No growth | Growth: non-pathogens |
| Mrs. B..... | | " | 2 | 2-8-9C 1-L.G. | 2 | 2-1C 1-5C | 4 | 0 |
| Mrs. H..... | | " | 10 | 2-1-2C 2-L.G. | 12 | 1-1C 1-2C | 12 | 0 |
| Miss K..... | | " | 2 | 6-1-4C 2-L.G. | 10 | 1-10C | 9 | 0 |
| Mrs. L..... | " | " | 1 | 1-H.G. | 2 | 0 | 2 | 0 |
| Mrs. O..... | | " | — | 1-1C | — | 1-H.G. | — | — |
| Miss O..... | | " | — | 1-16C | — | 1-2C | — | — |
| Mrs. S..... | | " | 7 | 4-1-4C 2-L.G. | 11 | 1-L.G. 1-H.G. | 12 | 0 |
| Mr. S..... | | " | 4 | 5-1-5C 1-L.G. | 8 | 1-1C 1-L.G. | 5 | 4 |
| Mrs. W..... | | " | 5 | 3-1-6C 4-L.G. 1-H.G. 1-V.H.G. | 13 | 1-1C | 13 | 0 |
| | | | 31 | 40 | 58 | 13 | 57 | 4 |

—Swab not taken
C = Colonies.
M.G. = Moderate growth.

L.G. = Light growth.
H.G. = Heavy growth.
V.H.G. = Very heavy growth.

did their pre-operation swabs (eight out of nine nurses). Of the 71 pre-operation and 71 post-operation swabs (total 142), 89 showed no growth. Of the 71 post-operation swabs, 29 showed no growth, two were unchanged as regards number of colonies, six showed a slight increase in growth but 34 showed a marked decrease, and of these 29 grew nothing. It is of great interest that certain nurses, Mrs. B., Miss K., Mrs. H. and Mrs. W., showed this marked decrease in growth in their post-operation swabs. It is difficult to illustrate this individual decrease clearly in Table III on account of the various amounts of growth, ranging from heavy growth through moderate and light growth to an actual small number of colonies. The overall fall in growth of bacteria from 40 on the pre-gloved hands to 13 after an average of 1½ hours confined within rubber gloves was most unexpected. One would expect to find the opposite, that is, an increased growth of non-pathogens at the end of the operations. This would indicate that on the hands of personnel who scrubbed with pHisoHex for each operation the pHisoHex and/or their sweat had some effect in devitalizing bacteria. We suspect that sweat contained within the gloves had some bacteriostatic or bactericidal effect, such as undecylenic acid has in inhibiting growth of fungi.⁵

2. There was no growth of pathogenic coagulase-positive *Staphylococcus aureus* in all this swabbing of the hands and gloves of nurses.

It is interesting to note the difference between doctors and nurses as regards growth of bacteria. In doctors who scrubbed only once at the beginning of the morning's operations there was slight change in the overall picture. In the case of the nurses who scrubbed twice, once for each of two operations, there was a marked reduction in the growth of bacteria after wearing gloves for one operation. This may be significant but in no way changes the overall picture as regards the relation of glove puncture to wound infection.

GLOVE PUNCTURES

During this study we also tested for punctured gloves by filling gloves with air and testing under water. The rate of glove puncture was high, probably because of the use of fine stainless steel wire for ligatures and sutures. Many of these punctures were so fine that to detect them the gloves had to be filled with air and submerged under water. Results of this study are summarized in Tables IV and V.

Weed and Groves⁶ reported that 22.6% of the gloves were punctured and that 74.4% of operations were associated with glove perforations, but no record of the incidence of wound infection was reported by them during their experiment. Hirschfeld⁷ reported that the glove puncture incidence was 18% in 429 gloves. Devenish and Mills⁸ did other experiments on surgeons' gloves. Some of these surgeons were non-carriers, nasal carriers,

TABLE IV.—ALL GLOVES
SURGEONS, ASSISTANT SURGEONS AND SCRUB NURSES

| Total number of gloves tested after operations | Total gloves punctured | % gloves punctured |
|--|------------------------|--------------------|
| 2061 | 330 | 16% |

skin carriers and so-called "double-carriers". One surgeon who was a so-called "double-carrier" performed 45 clean operations without suppuration. This observation confirms the conclusion reached by their tests that "the leakage-infective dose of cocci from a skin carrier is determined by more

TABLE V.—OPERATIONS AND PUNCTURED GLOVES
SURGEONS, ASSISTANTS AND SCRUB NURSES

| Total operations | Operations with punctured gloves | % operations with punctured gloves |
|------------------|----------------------------------|------------------------------------|
| 330 | 203 | 61% |

than mere punctures of the gloves". They carried out effective precautionary measures such as "the avoidance so far as possible of direct handling of the tissues". Such effective precautionary measures—especially avoidance of blunt dissection and perfect hæmostasis—are keenly practised by our surgeons.

Infected Wounds Related to Punctured Gloves

During the time of this study there was one patient in the hospital with bilateral moderate wound infections. Swabs of these infected incisions grew cultures of *Staphylococcus albus*. This patient was very aged and debilitated. At his operation no glove punctures were demonstrated (two infections and no glove punctures). Three other non-hospital patients reported a mild wound infection after herniorrhaphy. One of these patients had bilateral inguinal herniorrhaphies and an umbilical hernia repair. The umbilical hernia repair and one inguinal hernia repair became infected and at both these operations glove punctures were noted. The second patient also had bilateral hernia repairs; at the operation in which the wound did not become infected a glove puncture was demonstrated, whereas at the hernia operation with subsequent infection no puncture was demonstrated. A swab of this infected wound grew *Staphylococcus albus*. The third patient had a very mild infection after one herniorrhaphy and at this operation a glove puncture was demonstrated. That makes a total of six infections. Three of these infections were associated with punctured gloves and three were not, out of a total of 330 herniorrhaphies. Nearly twice as many cases were infected when gloves were not punctured as where punctures were found, i.e. 2.4% to 1.4%. This is further evidence that, in this institution at least, wound infection does not come from damage or puncture of gloves during operations. This is shown in Table VI.

TABLE VI.—OPERATIONS, PUNCTURED GLOVES AND WOUND INFECTIONS

| | Number of operations | % of cases | Number of infections | % infections |
|-------------------------------------|----------------------|------------|----------------------|--------------|
| Operations with punctured gloves | 203 | 61 | 3 | 1.4% |
| Operations without punctured gloves | 127 | 39 | 3 | 2.4% |
| Total | 330 | 100 | 6 | 1.8% |

That two patients developed four infected wounds out of five operations (two herniorrhaphies in one case and three herniorrhaphies in the other) strongly suggests that low resistance and debility was a much greater factor in causing infection of these wounds than the development of infection from punctured gloves. None of these cases received prophylactic antibiotics. It has always been our practice to have a two-day interval between operations on the same patient.

CONTROL OF HOSPITAL CASES OF WOUND INFECTION

Infected cases in hospital are semi-isolated, and ultraviolet lights are kept on constantly in their rooms. In this way we believe that many pathogenic bacteria are destroyed, as does Hart.⁹

Operating personnel rarely come into direct contact with a hospital case of wound infection. If so they are required to wear a mask and carry out isolation technique. Price⁴ recommended a simple dependable method for disinfection of contaminated hands by using a brush and soap for one minute and drying the hands with an individual towel, followed by wetting the hands with 70% alcohol.

WOUND INFECTIONS AND ANTIBIOTICS

As mentioned previously during this study, patients with infected wounds after herniorrhaphy had not received prophylactic antibiotics. It is only in cases such as incisional hernia, very difficult recurrent hernia, large difficult hernia, or previous wound infection that prophylactic antibiotics are given and the rate is rather low. Summarized results of the use of prophylactic antibiotics and the rate of wound infection for the period of this study and for the full year 1957 are shown in Table VII.

The infection rate in this institution is low, 1.2% as compared with the 4.9% reported by Beekman¹⁰

TABLE VII.—COMPARATIVE FIGURES FOR PERIOD OF STUDY AND THE FULL YEAR 1957 OF INFECTED RATES AND ANTI-BIOTIC RATES

| | Number of operations | Number of infections | Rate of infections | Rate of prophylactic use of antibiotics |
|-----------------|----------------------|----------------------|--------------------|---|
| Period of study | 330 | 6 | 1.8% | 4% |
| Year 1957 | 3303 | 42 | 1.2% | 5% |

in 2000 cases of inguinal hernia. Hirschfeld,⁷ Meloney¹¹ and other more recent authors have reported higher rates of wound infection but in connection with general hospitals and general surgery.

SUMMARY AND CONCLUSIONS

During this study of 430 swabs of the hands and gloves of operating personnel, no swab grew pathogenic coagulase-positive *Staphylococcus aureus*. We conclude, therefore, that the hands of the operating personnel, their sweat in the gloves or the method of scrubbing has not been a cause of wound infection.

It must be emphasized that this bacteriological work was carried out on the hands of operating personnel who did not ordinarily come in direct contact with any coagulase-positive *Staphylococcus aureus* found in discharging wounds or on infected dressings because such cases are isolated in our hospital.

Operating personnel prepared their hands daily with only a two-minute-scrub period, and not for ten minutes as is recommended elsewhere.

Of the operations performed during this study, 61% were associated with glove punctures whereas the overall infection rate was 1.8% and the prophylactic antibiotic rate was 4%. Infected cases that occurred during this period did not receive prophylactic antibiotics. In this study the incidence of infected wounds was actually greater in cases in which no glove perforations could be demonstrated than in those in which punctures were proven.

In 1957, there were 3303 herniorrhaphies performed in the Shouldice Surgery with an infection rate of 1.2%. The prophylactic antibiotic rate was 5%.

We wish to express our appreciation of the bacteriological work carried out for us by the Ontario Provincial Laboratory and of the great co-operation of that institution.

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RÉSUMÉ

L'auteur fait part d'une enquête menée à sa clinique chirurgicale et portant sur l'infection des plaies dans ses rapports avec les mains du personnel et les gants caoutchoutés portés à la salle d'opération. En 1957 on y pratiqua 3303 interventions pour hernies, avec un taux d'infection de 1.2%. Les antibiotiques furent administrés à titre préventif dans 5% des cas. Une série de 430 prélèvements bactériologiques des mains et des gants n'a jamais révélé la présence de staphylocoque doré positif à la coagulase. Le personnel examiné n'entre pas en contact avec les cas infectés qui dans l'institution en question sont isolés des autres. Le personnel de la salle d'opération n'est tenu de se brosser les mains que pendant deux minutes. On trouva des gants troués dans 61% des cas rapportés dans cette série, accompagnés d'une fréquence d'infection de 1.8%. (Par un curieux hasard, la fréquence d'infection accompagnant les interventions où les gants furent trouvés intacts, fut légèrement plus élevée.)