STAPHYLOCOCCAL INFECTIONS IN SURGICAL UNITS:  
THE NEED FOR COMPREHENSIVE CONTROL*

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The invasion of hospitals by strains of staphylococci resistant to antibiotic treatment has reawakened interest in preventive measures based on sound principles of hygiene, for which prophylactic medication is no substitute. The cost, in both health and money, of infections contracted in hospital is difficult to assess but is certainly very great.

The staphylococcal lesions liable to occur in a surgical unit include wound sepsis, boils and carbuncles, pneumonia, and enteritis. The diversity of these diseases and careful examination of the timing of individual cases, quite apart from other observations, indicate that there are many routes of infection and that any attempt to control these conditions which does not take into consideration all routes of infection is doomed to failure. The chart (Fig. 1) shows the methods by which infection may be spread in a hospital.

There is now a large bibliography dealing with nosocomial staphylococcal infections, but these, with few exceptions\(^1\)\(^2\), overemphasize or are concerned primarily with one mode of spread or another, e.g., carriers, infection from blankets, or contaminated dust. While in no way wishing to minimize the importance of the various valuable contributions, we consider that it is necessary to stress the need for a comprehensive system of control in hospitals. The busy surgeon or administrator who has neither the time nor the training to study the large volume of literature and to assess it correctly, is liable to seize on one or another aspect of the problem and to disregard others. In a brief article such as this it is impossible to do justice to the accumulated knowledge on the subject, to describe adequately the measures considered necessary in control, or to give adequate documentation supporting our own opinions.

There are two primary sources of staphylococci, the carrier and the infected case.

In the consideration of carriers, the limitations of bacteriological knowledge must be appreciated. The coagulase-positive staphylococci reported as *Staph. aureus*, *Staph. pyogenes* or *Micrococcus pyogenes* var. *aureus* coagulase positive form a large group of organisms, the strains of which vary very greatly in pathogenicity.

The laboratory has no method of recognizing the strains of high pathogenicity. A negative coagulase test indicates that an organism is of very low pathogenicity, but a positive result does not necessarily indicate pathogenicity. Resistance to antibiotics is not related to pathogenicity. If in a particular hospital most of the infections are caused by a particular bacteriophage type, it is reasonable to consider as pathogenic organisms of the same type isolated from carriers or fomites. However, it is not justifiable to regard as non-pathogenic all strains not belonging to the prevalent types. Moreover, bacteriophage typing is laborious and difficult and is essentially a research technique. These facts contribute greatly to the difficulty in understanding the epidemiology of staphylococcal infections and in their control.

Coagulase-positive staphylococci may be isolated from nose, tonsils, saliva, skin, and faeces of healthy persons and such persons qualify as carriers.

**Nasal Carriers**

In carriers the nose is the chief breeding ground of *Staph. pyogenes*. The nasal carrier rates of various types of communities have been investigated very extensively; those reported vary with the type

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Fig. 1
of community and the methods used. They have been summarized by Gould and McKillop.\(^3\)

In general it may be said that nasal carrier rates as high as 50% discovered at a single efficient swabbing are not unusual. However, if a group of people is repeatedly swabbed much higher rates will be observed over a period of time. Of a group of medical students swabbed weekly for 30 weeks, 83% showed coagulase-positive staphylococci on at least one occasion,\(^3\) and Lepper, Jackson, and Dowling\(^4\) found that 76% of a group of hospital workers showed positive cultures at least once during approximately one year.

These results illustrate the futility of searching for carriers of \textit{Staph. pyogenes} in general in a hospital community.

\textbf{SKIN CARRIERS}

We have already suggested that the reported incidence of nasal carriers is affected by technique, but this applies even more to skin carriers, where the results are very greatly affected by the method and site of swabbing. This is well shown by Williams's report on 50 medical students, 40% of whom had staphylococci on the back of the wrist, 20% on the volar surface of the forearm, and only 8% in the axilla;\(^5\) the examination of 11 skin sites showed that 70% of the students were carriers on at least one site.

It appears that in most cases the skin is repeatedly reinfected from the carrier's nose and that the healthy skin is not readily colonized by coagulase-positive staphylococci.

It is, therefore, very important to know the means by which staphylococci are spread from the nose of carriers: so long as they remain in the nose they are of no significance in the spread of disease. It has been shown that very few staphylococci are expelled from the nasopharynx during respiration,\(^6\) yet the hands and clothing of nasal carriers are frequently very heavily infected. Many more organisms are released into the air as the result of the movement of infected clothing than by a sneeze. Hare and Thomas\(^8\) consider that fingerling the anterior nares and nose blowing are the first stage in the spread of infection to the surroundings of the staphylococcal carrier.

The results of our investigations, which have proceeded along similar lines, are in agreement with theirs on most points. We swabbed the nose and upper lip of carriers both before and after nose blowing, using paper handkerchiefs in most cases. Of 27 nasal carriers 22 showed positive lip cultures either before or after nose blowing, while 55 non-carriers were all negative; similarly, the fingertips of 59 non-carriers showed only one positive culture, whereas those of 37 nasal carriers were all positive.

![Fig. 2.—Spread of fluorescent powder from the nose. Note contamination of pocket lining. (Photograph by ultraviolet lighting.)](image)

The number of organisms produced by one nose blow is often very great, and counts totalled more than a million in some cases. Since such a load may be discharged on to a handkerchief many times in a day, and the handkerchief retained in the pocket, the heavy infection of clothing is not surprising. We have used Zn-8-hydroxyquinoline which fluoresces brilliantly under ultraviolet light, to demonstrate the spread. The photograph (Fig. 2) was taken six hours after sniffing up the fluorescent powder, and shows the spread to the hands, face, and clothing.
Thus, it appears that the most useful procedure in limiting carriers is the control of nasal secretions. Paper handkerchiefs only should be used and the hands washed afterwards. Staff should be warned against fingering and fidgeting with the nose. Isolation of all staphylococcal carriers is impracticable since they are so numerous and treatment is difficult and unreliable. It must be emphasized that carriers may be as frequent among patients as among staff, so that preventive methods should cover all.

**Spread from Infected Cases**

We have carried out a number of experiments in which single- or double-bedded rooms, often with their adjacent toilet facilities, were thoroughly disinfected. Patients suffering from various open staphylococcal infections were then admitted and the articles repeatedly tested. Those investigated and frequently found to be infected included blankets, mattresses, bed tables, water closet seats, baths, and toilet basins. The probable importance of mattresses and washing facilities has been reported. Fig. 3 shows the result of the direct plating of a swab taken from a water closet seat used for three days by a patient with boils on his arms.

Bacteriophage typing showed that in most instances the organisms infecting the environment were the same as those causing disease in the patient. Thus it has been shown that there is more or less heavy infection of the environment of the suppurating case by organisms which the patient has proved to be pathogenic.

Objection may be made to the significance of these findings with the often repeated statement that staphylococci are ubiquitous. It is true that our early random swabbing of the various articles in hospital often showed heavy and widespread infection by coagulase-positive staphylococci, but there is no justification for accepting this as inevitable and allowing its continuation.

Rooms were disinfected as described and no patients admitted. In one experiment carried on for nine days, no staphylococci were isolated except for two colonies from a total of 40 cubic feet of air. Furthermore, the later admission of patients who were not nasal or skin carriers resulted in only minimal infection, although six members of the staff of the six-bed unit were carriers: during a six day observation period a total of only six colonies of staphylococci were isolated from the various articles listed above and none by means of a slit air sampler.

In many instances the spread of infection from the suppurating lesions can be greatly reduced by the use of better designed and antiseptic dressings and by careful dressing techniques, but reduction of spread from patients with widespread lesions such as burns or with pneumonia is virtually impossible.

It is important to recognize that owing to the long survival of staphylococci in dust, etc., the contamination of certain articles, such as mattresses, is cumulative. Repeated and thorough disinfection of all possible reservoirs is therefore necessary and equipment should be designed to facilitate cleaning and disinfection. Upholstered furniture, curtains, and blinds which cannot readily be disinfected should be rigorously avoided. Spring mattresses, which may be a serious source of infection, constitute a considerable problem requiring special methods of control.

Because it is impossible in many cases to prevent the spread of infection to the patient’s environment, and because of the extra care required in infectious diseases,
we consider that cases of open infection should be treated at least by room isolation and preferably in a separate unit. On discharge or transfer of an infected patient, thorough disinfection of his bedding, etc., is essential. Members of the staff with open lesions should be suspended from duty.

**Infections in the Operating Room**

Infection in the operating room may be acquired from members of the staff, from other patients, or from the patient himself. We shall not attempt to cover all aspects of theatre technique but to discuss some factors in need of clarification or emphasis.

**Skin Preparation.**—It has been shown that many accidental wounds become infected by staphylococci present on the patient’s skin at the time of injury, and doubtless this may occur during surgery. The high skin carrier rate and the liability of a nasal carrier to infect his skin has already been stressed.

Medrek and Litsky and Zintel have recently reviewed the many different techniques for preoperative preparation of the skin of both patient and surgeon. It is agreed that it is virtually impossible to render skin germ-free except for very short periods. However, it appears that *Staph. aureus* can in most instances be removed from healthy skin by adequate preparation.

At the Shaughnessy Hospital we have swabbed the area of intended surgical incision, prior to preoperative preparation, with liquid hexachlorophene soap and tincture of proflavine, and found coagulase-positive staphylococci in 12%. Skin biopsies were taken at the beginning and end of surgical procedures on 215 patients: no coagulase-positive staphylococci were detected, although 75% of cultures of the biopsies taken at the end of operation grew the usual skin saprophytes.

**Surgeon’s Gowns.**—The inadequacy of the surgical gown in preventing aerial spread from clothing has been demonstrated bacteriologically by Duguid and Wallace, and the passage of fine dust through a gown during an operation has been traced by means of a fluorescent powder. Moreover in long operations the surgeon’s gown and underclothes are often stained with blood, so that the passage of bacteria from his skin or clothing are liable to occur. For this reason we have used a sterile apron of light plastic material under the ordinary surgical gown.

**Drapes.**—The same arguments apply to surgical drapes: when wet with blood or saline they form no barrier to the passage of bacteria, and thus infection from unprepared areas of the patient’s skin or from non-sterile clothing may pass to the wound. For this reason we also use drapes of light plastic beneath the usual towelling for major procedures.

**Aerial Infection in the Operating Room.**—Opinions about the importance of aerial infection in the operating room have varied greatly during the past century. Lister’s era of the carbolic spray, in which aerial infection was over-emphasized, was followed by a period in which aerial infection was disregarded. Now it is possibly over-emphasized. It appears that aerial infection is more easily controlled than are some of the other methods of infection in the operating room.

Contrary to the common belief, the chief source of infection of the air is not directly from the noses of the staff but from fine dust derived from dressings, bedding, or clothing of patients or staff. It is now accepted that blankets should not be allowed in the operating room; and no one should enter in ordinary clothes even when wearing a gown, since a gown only moderately reduces the aerial infection. The heavy and persistent infection of the air after removal of infected dressings has been shown by Bourdillon and Colebrook, and the importance of segregating such cases from the clean areas is obvious.

An adequate ventilation system of the plenum type is highly desirable; it should be checked periodically to ensure that the flow of air through doors, etc., is from the clean areas.

**Anesthetic Equipment.**—The danger of infection from anesthetic equipment and in particular endotracheal tubes has not received adequate attention. Frequently face masks and tubes are only rinsed in water or washed with soap between cases when the survival of pathogenic cocci and tubercle bacilli and viruses is to be expected.
Before the introduction of improved methods in theShaughnessy hospital, bacteriological examination of endotracheal tubes ready for use showed coagulase-positive staphylococci and/or β-haemolytic streptococci in a number of instances. Chemical disinfection of such equipment has been recommended, but this should be avoided if possible because of its unreliability. The standard practice in this hospital is to boil the tubes for three minutes after washing and then to wrap them in a sterile towel. The anaesthetists state that this treatment is less harmful to the red rubber tubes than is prolonged soaking in antiseptics.

Infections in the Postoperative Period.—A soaked dressing is no barrier to infection. This was fully recognized by Lord Lister and has been confirmed by modern methods.

It is commonly believed that there is no danger of infection of surgical wounds after the first 24 hours, but there appears to be little evidence for this and some experimental evidence to the contrary. The dry sterile scab advocated by Lister is doubtless an efficient barrier if complete, but often there is a slight discharge; if bacteria gain access to such places and are allowed to grow, deep infection is likely to develop. Such infections are particularly common when drains are used. This route of infection may be blocked by the use of antiseptics or by mechanical barriers.

An antiseptic which is only bacteriostatic in the conditions may be of value, since the spread is largely the result of bacterial growth rather than of mechanical flow and the initial inoculum is small. Most mechanical barriers have the disadvantage of preventing evaporation and result in maceration of the skin, but certain microporous or semipermeable membranes do not have this disadvantage and have been reported upon favourably.18-20 We have used a nylon derivative ("Avlonyl" I.C.I.) on a large series of cases with very satisfactory results.

Wounds may be infected during dressing, particularly during the changing of drains or packs or during irrigation. Dressings should be performed with a care similar to that used in the operating room. By the use of a meticulous technique McKissock et al.29 reduced the rate of infection of head injuries by β-haemolytic streptococci from 15.4% to 1.1%, while Williams et al., using the same technique reduced the added staphylococcal infection of septic hands from 100% to 17.8%.29

FURUNCULOSIS, ETC.

As already stated, furuncles and carbuncles may constitute a serious problem on both medical and surgical wards. Some may arise from staphylococci present in the patient's nose or on his skin on admission to hospital, but the high rate of antibiotic-resistant strains and of particular bacteriophage types indicate that these, like pyoderma in neonatal units, are often the result of infection in hospital, from other patients, staff, or articles in general use. During one period only 7.7% of boils contracted in this hospital were sensitive to penicillin, whereas 64% of boils among R.C.A.F. personnel were sensitive when the same technique was used.

The hands of members of the staff treating infected cases may transmit bacteria, as suggested by Lowbury and Fox31 in the case of Pseudomonas pyocyanea. Decubitus and stasis ulcers frequently contain staphylococci and infection may be transmitted during back rubs. Thus, hands should be washed with hexachlorophene after treatment of each patient, and wash basins should be disinfected each time after use.

DISCUSSION

In this short article it has been possible to deal only briefly with a few aspects of the problem. Our views may be summarized as follows.

In the control of staphylococcal infection, it is first essential to persuade the staff that diseases such as boils, staphylococcal pneumonia, and wound sepsis are infectious. The staff must also understand that nasal carriers are numerous and everyone regarded as a possible carrier even if previous swabs have been negative for pathogenic organisms. Techniques must be devised and constantly enforced to prevent or mitigate the spread of infection by
all routes. Proper control requires education and co-operation in all departments and at all levels, including hospital design and administration: the most junior cleaner and the most senior clinician are equally important in such a program.

Summary
1. The many methods of spread of staphylococcal infections in hospital have been stressed.

2. Some aspects of control which we consider to be relatively neglected have been emphasized.

References


plaie est baignée au savon liquide à l'Hexachlorophène, puis à la teinture de Proflavine. On n'a trouvé par suite aucun staphylocoque positif à la coagulase. La blouse du chirurgien n'est pas suffisante, surtout si elle est humide, pour empêcher le passage des bactéries; on a employé en dessous un tablier de plastique léger stérilisé. De même sous les champs opératoires on a utilisé des champs de matériel plastique. La contamination de l'air de la salle d'opération se fait surtout par les poussières fines venant des pansements, litière, vêtements du patient ou de personnel. Aucune couverture n'est aménée de l'extérieur et personne ne doit entrer dans la salle vêtu de ses vêtements ordinaires même s'il porte une blouse, vu qu'elle n'est qu'une barrière bien imparfaite. Une ventilation adéquate est désirable et doit se faire de l'intérieur propre vers l'extérieur. Le danger d'infection à partir du matériel de l'anesthésiste n'a pas reçu suffisamment d'attention; le lavage à l'eau et au savon, la désinfection chimique simple ne sont pas suffisants. Dans notre hôpital les tubes intra-trachéaux sont bouillis pendant 3 minutes, puis enveloppés dans des serviettes stérilisées.

Durant la période post-opératoire, la route peut être barrée à l'infection par l'usage d'antiseptiques ou par des barrières mécaniques, telles les nouvelles membranes semi-perméables. Les auteurs ont employé un matériau de nylon semi-poreux (Avlonyl) avec succès. Les pansements, changements de tubes, drains, doivent être faits avec les mêmes soins qu'à la salle d'opération. Les infections cutanées — pustules et furonculoses — peuvent provenir d'un patient déjà porteur de germes, mais le plus souvent elles résultent d'une contamination hospitalière. Les basins, bassins, toilettes, literie doivent être désinfectés soigneusement. Les mains des garde-malades qui soignent des cas infectés doivent subir un lavage avec l'Hexachlorophène entre deux patients, et le bassin de lavage lui-même doit être désinfecté après usage.

Cet article rappelle que pour contrôler les infections staphylocoques, il est d'abord essentiel de persuader le personnel que les folliculites, la pneumonie et l'infection de la plaie opératoire sont hautement infectieuses. Il faut aussi comprendre l'importance des porteurs de germes surtout dans le nez, de même que la voie de propagation des infections. Il faut constamment reviser et mettre en force des techniques destinées à enrayer la propagation. La coopération doit se faire à tous les niveaux; à ce sujet, le moindre balayeur peut-être aussi important que le chirurgien en chef.

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**MECKEL'S DIVERTICULUM**

**A 42-YEAR REVIEW OF 273 CASES AT THE HOSPITAL FOR SICK CHILDREN, TORONTO**

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This survey was undertaken because there is still a significant mortality associated with complications of Meckel's diverticulum. The diagnosis is infrequently made preoperatively and remains a challenge to the clinician's diagnostic ability. It was felt that a review of the cases occurring at the Hospital for Sick Children would outline the problems more clearly and clarify certain principles of diagnosis and management. The records of all cases of Meckel's diverticulum including both the clinical cases and the autopsy cases were examined.

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**EMBRYOLOGY**

Meckel's diverticulum is an abnormality of embryological development which appears as a result of incomplete obliteration of the vitelline duct. This duct in the fetus passes from the yolk sac to the mid-gut. In viviparous mammals the yolk sac is of little significance save possibly in the very early days of embryo life when it is believed to provide a means of transfer of nutritive fluids to the embryo. The mid-gut develops from the roof of the yolk sac and assumes the characteristics of a tubular structure about the fifth week. The yolk sac recedes from the gut, maintaining connection with it by means of the vitelline duct. With the growth of the fetus, the duct elongates in the umbilical cord while the shrinking yolk sac lies functionless between the amnion and the chorion. About the sixth week, the mid-gut herniates into the umbilical cord as a loop of gut at the apex of which is the vitelline duct. The cephalic arm of the loop becomes small bowel and grows quite rapidly, whereas the caudal arm developing slowly becomes ileum and a portion of the large bowel.