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Importance of the carrier state as a source of *Staphylococcus aureus* in wound sepsis*

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Wound sepsis continues to be a significant problem in surgery despite the availability of potent antimicrobial agents. Average rates of wound sepsis are reported to be 5–10% (Williams *et al.* 1959; Jeffrey & Sklaroff, 1958), but vary from 1% to over 50% (Rogers, Duffy & Mou, 1965; Ketcham *et al.* 1962) depending on the population under consideration and the type of surgery performed. Factors known to be important include host resistance (Fekety, 1964), site and duration of operation and need for blood transfusion (Cohen, Fekety & Cluff, 1964), presence of infection elsewhere (Altemeier, Hummel & Hill, 1966), and contact with a carrier or infected person (Browne *et al.* 1959; Burke & Corrigan, 1961).

Regardless of these factors, wound infection or sepsis with *Staphylococcus aureus* cannot occur unless organisms are deposited in the wound. This might take place from several sources and by various mechanisms: blood borne from a remote lesion or the nasopharynx (Walter, 1958); direct implantation from contaminated hands, large droplets, fomites (Colbeck, 1960) or airborne droplet nuclei (Browne *et al.* 1959); or from contaminated skin at the incision site (Cole & Bernard, 1964). Initial contamination might occur in the operating room before wound closure or after the patient has been returned to the ward. The present study was designed to examine one facet of wound sepsis: self-contamination by patients who exhibit nasal and skin carriage of staphylococci preoperatively.

PLAN OF STUDY

Patients admitted to one male and one female general surgical ward were assigned to the study if there was a reasonable assurance of early operation plus easy accessibility of the wound for post-operative bacteriological studies and inspection. Thus, those for whom operation in the near future was not planned and certain orthopaedic and neurosurgical patients were not included in the study

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group. Swabs from the anterior nares, axilla, umbilicus, and groin of the study patients were obtained on admission or soon thereafter and again at frequent intervals—usually every other day. After operation cultures were taken from the wound at the first dressing change and frequently thereafter. Cultures from the anterior nares were obtained weekly from the other patients on the ward. Dry cotton swabs were used for the nares and wounds, and swabs moistened in broth served to culture the other skin sites. The swabs were streaked immediately on mannitol salt agar and the plates were incubated at 37° C. for 48 hr. The amount of growth of *Staph. aureus* was roughly estimated by colony count and by graded evaluations from 1+ to 4+. Two to eight representative colonies were picked from each culture and identified by phage typing, antibiogram and, if necessary, coagulase testing. When the identity of two or more similar strains was in doubt, several more colonies from each culture were retested simultaneously. The phages employed were the conventional set of 22, with the addition of UC 18 and two others developed in this laboratory. Phage was used at 100 times the routine test dilution. With this technique, less than 10% of strains could not be typed.

Skin strips from the incision site secured with a double-blade knife at the beginning of the operation, and wound swabs taken immediately before skin closure, were obtained from many patients. The swabs were inoculated on blood agar, and into trypticase soy broth which was subcultured to a blood agar plate after 24 hr. of incubation. One-half of each skin strip was homogenized by means of a mortar and pestle and the remainder was minced into small pieces with sterile scissors. The minced pieces and the homogenate were cultured separately in trypticase soy broth which was then subcultured onto a blood agar plate after incubation for 24 hr.

A carrier was defined as a patient whose preoperative culture yielded more than one colony of a given phage type, or any number of a single strain on more than one occasion. Roughly half of the subjects had only a single set of cultures before operation.

Wound colonization was defined as the recovery of *Staph. aureus* by culture from the postoperative wound swabs, except that single colonies of a given strain isolated only once were not considered to be significant. Wound sepsis was defined as the presence of purulent drainage from which *Staph. aureus* could be cultured. Minor collections of pus confined to a stitch orifice were not considered to be wound sepsis.

Statistical significance was determined by the χ^2 test, and a P value of less than 0·05 was considered to be significant.

RESULTS

Two hundred and sixty-nine patients were studied over a 2-year period. Ninety-six, or 36%, were carriers of *Staph. aureus* before operation; 82 patients had positive cultures on admission and 14 acquired the organism in the hospital before operation. The relationship of the carrier state to wound colonization and wound sepsis is shown in Table 1. *Staph. aureus* was isolated from the wounds of 63 patients (23%) during the postoperative period. Colonization occurred more than twice as

often in carriers (37 %) as in non-carriers (16 %), and the highest rate (56 %) was found among skin carriers. The difference between 37 % and 16 % is significant, with a P value of $< 0{\cdot}001$.

Table 1. *Relationship of the carrier state to wound colonization and sepsis*

Carriage pre-op.	No. of patients	Wounds colonized		Wounds septic	
		No.	%	No.	%
Non-carriers	173	27	16	16	9
Carriers					
Nose only	51	11	22	6	12
Skin	45*	25†	56	10‡	22
Total	96	36	37	16	17
All patients	269	63	23	32	12

* Ten were carriers on skin only. † Three were carriers on skin only.
‡ One was a carrier on skin only.

Table 2. *Relationship of carrier strain to wound colonization and sepsis*

	Patients with wound colonization	Patients with wound sepsis
Total	63	32
Non-carriers	27	16
Carriers	36	16
With carrier strain only	27	13
With carrier plus exogenous strain	6	3
With exogenous strain only	3	0

The total rate of wound sepsis was 12 %. It was almost twice as great in carriers (17 %) as in non-carriers (9 %), but this difference is not statistically significant. There was a significant difference, however (P value of 0·04), in the wound sepsis rate in skin carriers (22 %) as compared to the non-carriers. Nasal carriage alone, without skin carriage, did not result in a significant increase in wound colonization or wound sepsis in comparison to the non-carrier group. Likewise, carriage on the skin only was not demonstrated to influence rates of wound colonization and sepsis, though the numbers involved were small. Colonization occurred in 3 of the 10 skin-only carriers, and wound sepsis occurred in 1 of 10. This finding suggests that combined nasal and skin carriage might be the important factor, and this in turn might be a reflexion of density of organisms at carrier sites.

The relationship between the strains carried in the nose or on the skin and those which colonized wounds is presented in Table 2. Of the 36 pre-operative carriers whose wounds were colonized, 27 exhibited only the carrier strain and six others yielded both the carrier strain and an exogenous strain from the wound. Therefore,

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it is apparent that when the wounds of preoperative carriers became colonized with *Staph. aureus* it was usually the carrier strain that was recovered. This relationship is even more striking in the case of wound sepsis. Among 16 septic wounds in the carrier group, the carrier strain was recovered in all instances, although in three cases an exogenous strain was also cultured from the wound.

In the total study group, carriers and non-carriers, there were 63 patients whose wounds were colonized, of which 33 yielded the carrier strain; and in 32 whose wounds were septic 16 yielded the carrier organism. Thus, the carrier strain accounted for approximately half of the instances of colonization and sepsis.

The data were analysed to ascertain whether or not there was a difference in wound colonization and sepsis rates between non-carriers versus carriers infected with exogenous strains. Whereas these rates were 16 % for colonization and 9 % for sepsis in non-carriers, the corresponding rates for infection with exogenous strains among carriers were 9 % (9 of 96) and 3 % (3 of 96). These differences in rates for colonization and for sepsis were not statistically significant. It should be remembered, however, that in the latter group 6 of the 9 colonized wounds and all 3 of the septic wounds contained the carrier strain as well as an exogenous strain of *Staph. aureus*. Thus, there was no evidence for either interference as suggested by Shinefield *et al.* (1963) or a predisposition to exogenous staphylococcal infections in carriers.

Table 3. *Wound colonization and sepsis related to carriage on normal* v. *broken skin**

Number of skin carriers		No. of wounds colonized	No. of wounds septic
Total	45	25 (56 %)	10 (22 %)
On normal skin	28	14 (50 %)	5 (18 %)
On broken skin	17	11 (65 %)	5 (29 %)

* For example, vascular leg ulcers, burns, dermatitis, etc.

The association between wound sepsis and infection at a remote site is well known (Altemeier *et al.* 1966). An attempt was made to ascertain whether wound colonization and sepsis occurred more commonly among patients who carried *Staph. aureus* on broken skin as opposed to carriage on normal or intact skin. Examples of broken skin included chronic dermatitis, ulceration of the legs associated with vascular insufficiency, draining sinuses and burns. It should be pointed out that the surgical incisions were not made through these areas. The results presented in Table 3 suggest that carriage on broken skin did not increase wound colonization or sepsis rates compared to carriage on normal skin, but the number of cases was too small for satisfactory statistical analysis.

Using quantitative techniques, White (1961) has documented a greater incidence of skin carriage of *Staph. aureus* among individuals with heavy nasal carriage than among those with light carriage; he also showed a direct relationship between the number of organisms in the nose and dissemination into the air. The data from the present study were analysed in an attempt to relate quantity of nasal carriage to skin contamination, wound colonization and wound sepsis. The results are shown

in Table 4. Although interpretation of these data is difficult because there were ten patients who had infected skin lesions and were not nasal carriers, it was not possible to relate quantity of nasal carriage to positive skin cultures. The only significant difference was in the rate of wound sepsis in that the profuse nasal carriers showed a rate of 31 % as compared with 8 % in those with moderate, light or no nasal carriage ($P = 0{\cdot}01$).

Table 4. *Quantity of preoperative nasal carriage related to skin carriage, wound colonization and sepsis*

Nasal carriage	No. of patients	Skin carriers		Wounds colonized*		Wounds septic*	
		No.	%	No.	%	No.	%
Heavy	36	17 (5)†	47	16	44	11	31
Moderate	31	8 (2)	26	9	29	3	10
Light or none	29	20 (10)	69	8	30	2	7

* With carrier strain.

† Numbers in parentheses represent patients with carriage on broken skin, some of whom carried on intact skin as well.

Table 5. *Results of cultures of operating room specimens obtained from 74 patients*

	No.	Sterile	*Staph. aureus*
Wound swabs	48	13	0
Skin strips	60	14	9*

* Four patients were pre-operative carriers; none had same strain in skin strip. Eight patients had subsequent cultures, and none were colonized later with skin-strip strain.

The results of cultures from the specimens obtained in the operating room are given in Table 5. Only 13 of the 48 wound swabs were sterile but in no instance was *Staph. aureus* recovered. The cultures usually revealed common skin contaminants such as *Staph. albus*, diphtheroids, and α-haemolytic or non-haemolytic streptococci. The majority of the 60 skin-strip specimens yielded similar skin contaminants, but in nine instances *Staph. aureus* was isolated. Four of these patients were pre-operative carriers but none carried in the nose or on the skin the same strain that was found in the skin strip. Eight of the nine were cultured frequently enough postoperatively for adequate follow-up, but subsequent wound colonization with the strain found in the skin strip was not observed. Subsequent observations, involving an additional 97 patients, have revealed a single instance of a carrier strain isolated from an incisional wound swab and later causing wound sepsis.

DISCUSSION

This study was designed to examine the importance of the patient himself as a source of the staphylococci that infect wounds. A divergence of opinion exists in the literature concerning the relationship between carrier strains of *Staph. aureus*

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and those recovered from the wound. A significant correlation has been found by some investigators (Williams *et al.* 1959; Colbeck, 1960; Burke, 1963), but others (Rogers *et al.* 1965; Browne *et al.* 1959; Bullock *et al.* 1964) have not. Williams *et al.* (1959), Weinstein (1959), McNeill, Porter & Green (1961), Williams *et al.* (1962), Ketcham *et al.* (1962), Lindbom, Laurell & Grenvik (1967) and Lindbom & Laurell (1967*a*, *b*) reported a higher incidence of wound sepsis among carriers, but Rogers *et al.* (1965), Bullock *et al.* (1964), Browne *et al.* (1959), Lowden, Vaithilingham & Milne (1962), Bassett *et al.* (1963) and Moore & Gardner (1963) did not find this to be true.

In the present study definite association was found between staphylococcal carriage and subsequent wound colonization. Furthermore, the presence of combined nasal and skin carriage was associated with a higher colonization rate than nasal carriage alone. Although the difference in sepsis rates between non-carriers and the total group of carriers was not statistically significant, there was a significant difference in rates between non-carriers and those who carried the organism on the skin. Since the majority of skin carriers were nasal carriers as well, the important factor was apparently the combination of skin and nasal carriage.

The significance of the carrier state is also emphasized by the finding that the homologous strain appeared in the wounds of 33 of the 36 carriers whose wounds were colonized. Even among the nine carriers whose wounds were colonized with an exogenous strain, in six the carrier strain was also present. More significantly, septic wounds in the 16 carriers yielded the carrier strain in each instance. The carrier strain accounted for roughly half of all instances of wound colonization and sepsis in the entire study group. One can not rule out the possibility that some of the wounds were infected with strains originating from other sources in the ward that happened to be similar to the patient's carrier strain. In most cases, however, the carrier strains were sufficiently distinct from the monitored ward strains to make this possibility very remote.

Infection at a site remote from a surgical incision has been implicated as a causal factor in wound sepsis (Altemeier *et al.* 1966). In the present study, when the skin carriers were separated into those whose organisms were isolated from intact skin and from broken skin, no statistically significant difference in wound colonization or sepsis could be found, but the number of cases involved was too small to justify a definite conclusion.

It has been shown by White (1961) and Ehrenkranz (1964) that skin colonization and airborne dissemination of *Staph. aureus* is a function of the number of organisms present in the nose. The higher incidence of wound colonization and sepsis in skin carriers in this study might be related primarily to heavy nasal carriage. It may be hypothesized that the heavy nasal carriers would not only tend to become skin carriers but would also be most likely to develop colonization and sepsis of the wound. It is not possible from the data accumulated so far to establish a relationship between wound colonization and quantity of nasal carriage. Wound sepsis, however, was found to occur more frequently in profuse nasal carriers.

Browne *et al.* (1959) and Roberts (1965) suggested that isolation of pathogenic organisms from surgical incisions might presage subsequent wound sepsis with that

organism. Howe & Marston (1962), however, were unable to associate wound sepsis with *Staph. aureus* isolated from the incision at the time of closure. Wise, Sweeney, Haupt & Waddell (1959) found that skin strips removed from the incision site some time during surgery were usually not sterile and that 11 % contained *Staph. aureus*, but these organisms did not seem to initiate wound sepsis. The results of the present study were similar to those of the latter two reports. Organisms recovered from skin strips represented bacteria present in or on the skin of the incision site at the beginning of surgery. Wound swab cultures identified those bacteria which contaminated the wound from contiguous skin, airborne particles, operating room personnel, or fomites. Ordinary skin flora was frequently cultured from both types of specimens, but *Staph. aureus* was found in only nine skin strips, and in no instance did these strains cause wound sepsis in the corresponding patient. Later experience revealed a single instance of wound colonization and sepsis with a preoperative carrier strain which had been recovered from an operating room wound swab. These results suggest that, in the patients studied, colonization of the wound usually occurred postoperatively in the recovery room or on the ward rather than in the operating room. A similar conclusion was reported by Rountree *et al.* (1960).

The results of this study also indicate that colonization of the wound in a staphylococcal carrier is usually with the carrier strain. It remains for further investigation to indicate the route by which the carrier strain arrives in the wound and when contamination occurs. Prophylactic antibiotic administration might be helpful if the route is haematogenous, and mechanical exclusion of the wound from external contamination should be effective against organisms transferred by hands, fomites, and air. Rountree *et al.* (1960) were able to reduce wound sepsis significantly by sealing off the incision with an occlusive plastic spray dressing, although there were five instances of autogenous infection of the wound despite an intact seal.

According to the results of the present study, it should be possible to reduce the rate of wound sepsis by approximately one half by preventing or eliminating the carrier state preoperatively or by the use of an occlusive dressing. Many trials of various antibacterial creams, ointments, sprays and soaps for the control of the carrier state have yielded conflicting and equivocal results. In addition to the work of Rountree *et al.* mentioned above, we are investigating the use of an occlusive dressing ('Vidrape') for clean wounds. So far, only one instance of staphylococcal colonization has been observed in the wounds of 32 patients, five of whom were preoperative carriers.

SUMMARY

The relationship of pre-operative nasal and skin carriage of *Staphylococcus aureus* to wound colonization and sepsis was studied in 269 patients. Thirty-seven per cent of 96 carriers developed wound colonization as compared to 16 % among non-carriers (a statistically significant difference). The wound sepsis rates were 17 % and 9 % respectively. The combination of nasal and skin carriage was an important factor, since the sepsis rate among skin carriers (most of whom were

nasal carriers as well) was 22%. Among carriers, the homologous strain was recovered from the majority of wound colonizations and from all instances of wound sepsis. A carrier strain also was recovered from 52% of the wounds colonized and from 50% of septic wounds in the entire study group. Profuse nasal carriage resulted in a significantly greater number of septic wounds (31%) than sparse carriage (9%). Wound cultures before closure, and skin from the initial incision site only once yielded a patient's carrier strain or a strain of *Staph. aureus* that was later recovered from the wound. The results indicate that measures designed to control the carrier state or to isolate the wound from the external environment should reduce wound sepsis by approximately one half.

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