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# Studies on transmission of *Staphylococcus aureus* in an isolation ward for burned patients

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SUMMARY

A one-year epidemiological investigation was made in an isolation ward for burned patients. The transmission of *Staphylococcus aureus* was mainly studied. In spite of the design of the ward the cross-infection rate was high. In all, 49 of 69 patients were infected 114 times. Twenty-six of the strains causing infection were found in a patient only, 10 in a member of the staff only and 23 in both patients and staff the week before they caused a new infection. There were three epidemic outbreaks caused by three strains of *Staph. aureus* all belonging to phage group III; one was resistant to methicillin. Environmental studies with settle plates showed that the number of staphylococci dispersed by a burned patient was often very high. In 8 % of the observations in occupied bedrooms the air count of *Staph. aureus* was more than 1800 col./m.$^2$ hr. However, the counts of *Staph. aureus* in the corridor and service areas were low. This seems to indicate a rather good protection against airborne transfer of bacteria. Other routes of infection were probably of greater importance.

## INTRODUCTION

Modern medicine has made it possible to treat extensive burns with good results. Infections are, however, still very common and the dominant bacteria are staphylococci, beta haemolytic streptococci and gram-negative bacteria such as *Pseudomonas aeruginosa* and coliforms.

Several methods of preventing infections have been tried. Amongst these are a number of different kinds of local treatment which have had varying success (Cason, Jackson, Lowbury & Ricketts, 1966; Weyer, Krauss & Sussell, 1968; Matter, Barclay & Koničková, 1970). Isolation is generally regarded as an important measure for the protection of those patients highly susceptible to infection and the usual method of providing this is in single-bedded rooms, preferably with positive-pressure mechanical ventilation. The main object of this system is to reduce the risk of airborne transfer of infection from one room to another, but doubtless the risk of transfer through fomites and contact is also reduced.

In October 1968 an isolation ward for burned patients was opened at the University Hospital in Uppsala. The effectiveness of the isolation provided in this ward has been studied from different aspects and the results will be presented in a series of papers. These studies have mainly been concerned with the behaviour

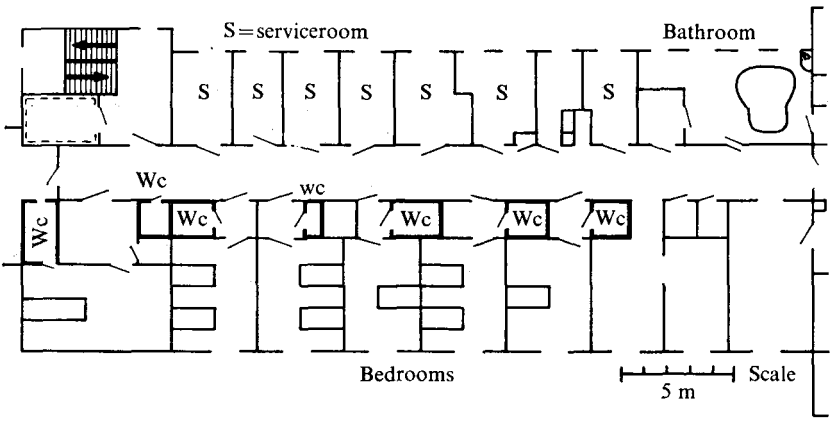


Fig. 1. Plan of the burns ward.

of *Staph. aureus* as it is evident that these bacteria are conveyed between patients by air as well as by contact (Lowbury, Babb & Ford, 1971).

In this paper the epidemiological events during the first year the ward has been in use will be reported. The results of investigations into the transmission of *Staph. aureus* by airborne routes and by means of nurses' gowns and protective clothing will be published separately.

## MATERIALS AND METHODS

### *Isolation ward*

Figure 1 shows the plan of the isolation ward. It is entered via an airlock with double doors, and a corridor runs down the middle of the ward. There are five bedrooms of similar dimensions and a sixth larger room containing an airbed. All of these have individual airlocks and are situated along one side of the corridor. On the opposite side of the corridor are service rooms and a bathroom. The bathroom has three doorways: one of these opens directly to the corridor for bed transport and the other two open via airlocks, one into the ward entrance airlock and the other into the corridor. The ventilation rate is approximately 4 air changes per hour in the patient rooms (Hambraeus & Sanderson, 1972).

### *Clinical material*

The primary investigation period lasted from October 1968 to October 1969 and covered 52 weeks. During this time 80 patients were treated in the unit. Of these, 49 patients had small burns, 22 medium sized, and 9 extensive burns. The extent of burns and age of the patients is shown in Table 1.

Length of stay in the ward for about half the patients was less than 3 weeks, one third stayed between 4 to 7 weeks, and ten patients stayed for more than 8 weeks. Seven patients, all with extensive burns, died.

The method of treatment was exposure and bathing. After 2 to 3 weeks exposure the patients were bathed 2–3 times per week and necrotic tissue was excised at the same time.

Table 1. *Distribution of the material according to age of patient and size of burn*

| Age in years | Small burns < 15 % totally < 5 % III°* | Medium-sized burns 15–30 % totally 5–15 % III° * | Extensive burns > 30 % totally > 15 % III° * | Total |
|---|---|---|---|---|
| 0–5 | 14 | 6 | — | 20 |
| 6–20 | 2 | 4 | — | 6 |
| 21–50 | 17 | 7 | 7 | 31 |
| > 50 | 16 | 5 | 2 | 23 |
| Total | 49 | 22 | 9 | 80 |

* III° = third degree.

From each patient specimens were taken from nose, throat, wound and perineum on admission and thereafter once a week or if necessary more often. The total numbers of specimens were 354 from wounds, 349 from nose and throat, 331 from skin and 330 from perineum.

*Staff*

About 200 persons worked in the ward during the investigation period. Of these 36 belonged to the more permanent staff and 11 were doctors and research staff. Specimens from nose and throat were taken from the staff twice before the ward was opened and thereafter once a week. The number of nose and throat specimens was 974.

*Antibiotic policy*

Prophylactic antibiotic therapy with penicillin was used for moderate and severe wounds. In cases of clinical infections antibiotic therapy was directed by sensitivity determinations of isolated bacteria.

*Routine*

Protective gowns and masks were used when treating the patients in their rooms. The gowns were kept in the airlock and changed once a day. For newly admitted uninfected patients sterile gowns, gloves, caps and masks were used. The bathtub was cleaned with a phenolic compound (0·5 % Gevisol).

*Bacteriological technique*

Swabs from nose, throat, skin and perineum were plated on blood and phenol-mannitol-agar. For specimens from clinical infections blood-agar with gentian violet, haematin and anaerobic blood-agar were also used. After incubation at 37° C. for 24 and 48 hr. the plates were read and colonies picked for identification and typing. Presumptive *Staphylococcus aureus* colonies were tested for deoxyribonuclease production. Positive strains were phage typed with the international set of phages (Blair & Williams, 1961). All strains from wound specimens and to some extent from other specimens were tested for antibiotic resistance according to Ericsson's disk diffusion method (Ericsson, Högman & Wickman, 1954). Although the main purpose of the investigation was to study the epidemiology of

Table 2. *Analysis of bacteriological findings from* 354 *wound cultures in* 76 *patients*

| Organism isolated | Relative frequency in culture (%) | | | Relative frequency in patients (%) | | |
|---|---|---|---|---|---|---|
| | Pure | Mixed | Total | Sole organism isolated | Mixed infection | Total |
| *Staph. aureus* | 37·6 | 29·1 | 66·7 | 12 | 66 | 78 |
| *Staph. albus* | 7·1 | 10·5 | 17·6 | 4 | 47 | 51 |
| Coliforms | 0·3 | 20·1 | 20·4 | — | 40 | 40 |
| *Pseudomonas* spp. | 0·6 | 5·4 | 6·0 | 1 | 12 | 13 |
| *Proteus* spp. | — | 5·1 | 5·1 | — | 7 | 7 |
| Enterococci | 0·3 | 8·2 | 8·5 | — | 24 | 24 |
| β-streptococcus (group A) | 1·7 | 0·6 | 2·3 | — | 7 | 7 |
| β-streptococcus (other than group A) | — | 2·3 | 2·3 | — | 9 | 9 |

*Staph. aureus*, isolation and typing of haemolytic streptococci and *Ps. aeruginosa* was also carried out. In specimens from clinical infections all potentially pathogenic organisms were isolated and identified according to current methods.

*Environmental studies*

For this purpose settle plates were used and they contained 2 μg. nalidixic acid per ml. to prevent swarming of proteus. They were placed at 8 fixed places in the corridor, service rooms and bathroom and after the 19th week of the investigation also in the bedrooms. They were exposed for 4 hours 3–5 days a week and then examined for presence of *Staph. aureus* as described above. All *Staph. aureus* colonies found on settle plates in the corridor and service rooms, together with 25 % of colonies (up to a maximum of 8 per plate) from settle plates in the bedrooms, were phage typed. In all, 1163 settle plates were examined from corridor and service rooms, 165 from the bathroom and 456 from bedrooms. Swabbings from three different sites in the bathtub have been made 90 times in all, i.e. about twice a week.

*Bacteriological findings*

*Patients.* Wound specimens from 76 of the 80 patients admitted to the ward, 354 in all, were examined. *Staph. aureus* was the most common organism found. The occurrence of different pathogens in the wound specimens is shown in Table 2. In 59 patients *Staph. aureus* was isolated, and in 9 of these patients it was the only pathogenic organism isolated from the wound during the stay in the ward. As the main purpose of this investigation was to study the epidemiology of *Staph. aureus* these are the only organisms to be reported in detail.

## RESULTS

Specimens from wound, upper respiratory tract, skin and perineum were taken from 76 patients on the day of admission. In 35 of these patients no *Staph. aureus* could be isolated. In 18 patients *Staph. aureus* was isolated from the wound and

other sites, in 5 patients from the wound only, and in 18 patients only from sites other than the wound, usually the upper respiratory tract. In all, 69 patients were examined on two or more occasions and 49 of these were shown to have acquired hospital strains of *Staph. aureus*. In 5 of these cases *Staph. aureus* could never be isolated from the wound but only from the upper respiratory tract, skin or perineum.

Thirty-six patients acquired a new strain of *Staph. aureus* during the first week of their stay in the ward, 9 during the second or third week and 4 patients between the third and fourth week. No less than 26 patients became infected before the isolation had been broken and the patients had been taken out of their rooms for bathing or operation.

Of the 20 patients who did not become infected during their stay, 8 already had *Staph. aureus* in their wounds on admission and the others were treated for less than three weeks.

It was not uncommon for patients to become infected with *Staph. aureus* of more than one phage type. Fourteen patients were infected with two strains, and 8 with three strains, 7 with four strains and 3 with five. As could be expected the risk of acquiring new strains increased with length of stay in the ward. Of the 10 patients infected with 4 or more types only 2 stayed for less than 6 weeks and they both had extensive burns.

*Staff*

An analysis of the carrier situation was made in 39 people who worked in the ward for more than six weeks. *Staph. aureus* was found in 80% or more of consecutive cultures from the upper respiratory tract in 18 persons, in 45 to 80% in 14, and in less than 45% in 7. The number of strains acquired per person varied from 1 to 8, the mean value being 2. Two members of the staff had wounds infected with hospital strains.

*Phage typing*

A total of 1827 *Staph. aureus* isolates were phage typed, and amongst these 155 patterns could be recognized. Table 3 shows the distribution of phage groups among patients and staff, the lytic pattern of 11 strains isolated from more than 2 patients is also presented. Group III strains were the most common among patients and staff, the dominating phage types being type 84, 53/77/84 and 88 typable at 1000 RTD only, which were isolated from 54% of the patients and 20% of the staff. As might be expected types belonging to 52/52A/80/81 complex were fairly common too, these were isolated from about 30% of both patients and staff.

*Environmental studies*

Table 4 shows the results of the environmental studies with settle plates. The number of *Staph. aureus* colonies isolated on plates exposed in occupied bedrooms varied considerably: 27% of the exposed plates yielded no colonies, 31% had 1–5 colonies, 8% had more than 100 (i.e. about 1800 col./m.$^2$ hr.) the highest

Table 3. *Occurrence of various phage-types/groups in specimens from patients and staff*

| Phage-type/group | No. of patients | No. of staff |
|---|---|---|
| 52/52A/80/81 complex | 23 | 57 |
| Rest of group I | 5 | 12 |
| Total of group I | 28 | 69 |
| 55/71 | 3 | 2 |
| 3A/55 × 1000 RTD | 3 | 3 |
| Rest of group II | 7 | 24 |
| Total of group II | 13 | 29 |
| 84 | 24 | 34 |
| 53/77/84 | 10 | 7 |
| 88 × 1000 RTD | 7 | 8 |
| 6/47/54/85 | 4 | 3 |
| 54 × 1000 RTD | 4 | 3 |
| Rest of group III | 24 | 58 |
| Total of group III | 73 | 113 |
| Total of group IV | 1 | 1 |
| 187 | 3 | 1 |
| 52A/55/6/53/54 × 1000 RTD | 4 | 2 |
| 52/52A/42E/54 × 1000 RTD | 3 | 5 |
| Rest of mixed group | 11 | 21 |
| Total of mixed group | 18 | 28 |
| N.T. | 27 | 44 |

N.T. = Not typed.

Table 4. *Distribution of colony-forming units of* Staph. aureus *on settle plates in corridor, service rooms, bedrooms and bathroom*

| C.f.u. *Staph. aureus* settle plate | Number of settle plates: Bedrooms | Corridor and service rooms | Bathroom |
|---|---|---|---|
| 0 | 122 (26·8 %) | 705 (60·6 %) | 75 (45·6 %) |
| 1–5 | 141 (30·9 %) | 420 (36·1 %) | 38 (23·0 %) |
| 6–10 | 52 (11·4 %) | 28 (2·4 %) | 21 (12·7 %) |
| 11–20 | 35 (7·7 %) | 9 (0·8 %) | 11 (6·7 %) |
| 21–50 | 45 (9·9 %) | 1 (0·1 %) | 11 (6·7 %) |
| 51–100 | 23 (5·0 %) | — | 7 (4·2 %) |
| 101–200 | 19 (4·2 %) | — | 2 (1·2 %) |
| 201–400 | 10 (2·2 %) | — | — |
| > 400 | 9 (2·0 %) | — | — |
| Total | 456 | 1163 | 165 |

count being about 800. In the corridor and service areas the variation was less and the counts lower than in the bedrooms: 61 % yielded no colonies of *Staph. aureus*, 0·9 % had more than 10 colonies and no plate yielded more than 30 colonies (i.e. 540 col./m.$^2$ hr.). The number of staphylococci found in the bathroom was often rather high; 12 % of the plates had more than 20 col.

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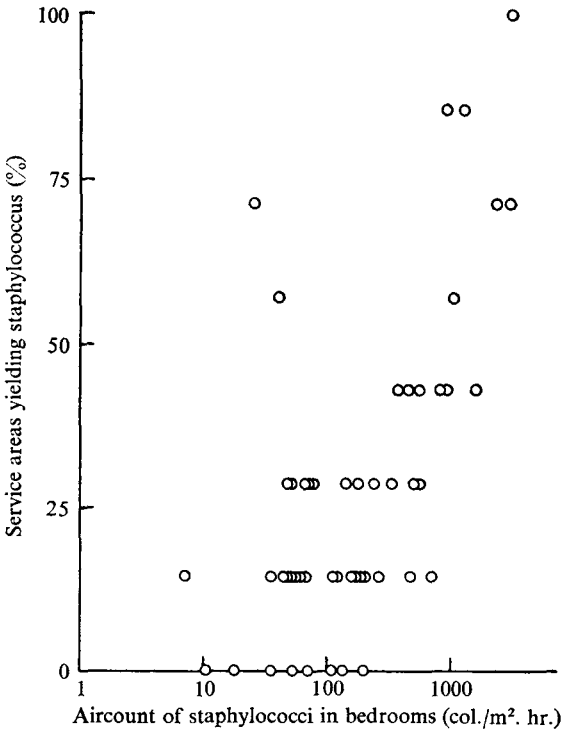


Fig. 2. Spread of staphylococci from bedrooms to service areas.

In Fig. 2 the mean number of *Staph. aureus* found/m.² hr. in the bedrooms is plotted against percentage of service areas yielding staphylococcus. The presence of staphylococci is given without regard to differences in phage types. As transport of patients in the passage and the presence of a disperser in the bathroom causes a break in the isolation system those occasions when staphylococci were found in the bathroom have been excluded.

It is seen in Fig. 2 that on only 8 occasions (16% of the total) were staphylococci found on more than half the plates exposed in the passage and service areas. When, however, the mean count in the bedrooms exceeded 1000 colonies/m.² hr., then staphylococci were recovered from more than half the plates from passage and service areas on 75% of occasions (6/8).

Sixteen of the 90 specimens from the bathtub yielded small amounts of staphylococci, they were usually found on the immersion lift used to lower the patient into the water.

*Epidemiological results*

The epidemiological situation in the ward was complicated. In all, 114 strains colonized 49 patients. Twenty-six of these strains were found in a patient, 10 in a member of the staff and 23 in both patients and staff the week before it caused a new infection. Sixteen of the strains were isolated from several persons in the ward in the same week thus making it impossible to deduce who infected whom. In 39 cases no source of infection was found in the ward.



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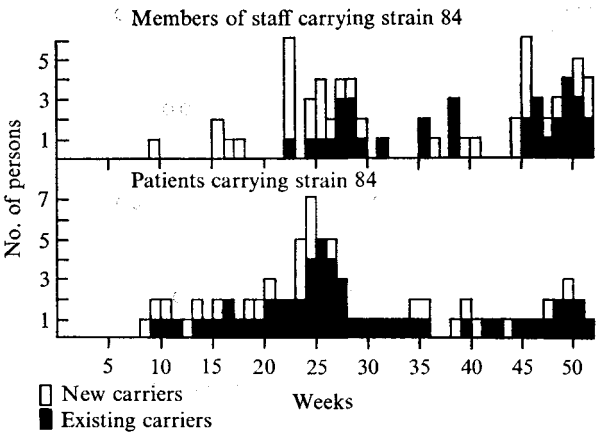


Fig. 3. Course of the epidemic due to *Staph. aureus* phage type 84 III.

As seen in table 3 11 phage types were isolated from more than 2 patients. Although types belonging to the 52/52A/80/81 complex were isolated from 23 of the patients and 57 members of the staff, it was only possible to show epidemiological relationship with any certainty in 8 of these persons, 3 patients and 5 members of the staff. Thus there remain only 3 types of *Staph. aureus* that caused epidemic outbreaks. Some aspects of these epidemics are now described.

*Strain phage type* 84

Strains of this phage type were easily identified. They were interesting in that they were multiresistant even to methicillin and produced enterotoxin B. The strain was first isolated from a settle plate in week 8; its origin could not be found. The week after, *Staph. aureus* phage type 84 was isolated from a patient with a small burn wound. He was admitted from another ward of the hospital and the first strain isolated from his wound had another phage pattern.

The course of the epidemic can be seen in Fig. 3. Up to week 21 there were only sporadic cases, 8 altogether. Four of these 8 patients were probably infected because they shared rooms with carriers. During weeks 22 and 23 no new case occurred. During weeks 24 to 27 there was an epidemic outbreak with 7 new cases. In fact all patients treated in the ward during weeks 24 and 25 were infected with the strain. The last 8 cases occurred sporadically during the following 26 weeks. In all, the strain was isolated from 24 patients, and in 20 of them from the burn as well as from the upper respiratory tract, skin or perineum. In 4 cases the strain could not be isolated from the burn but only from other sites. In 16 cases the infection occurred after the isolation had been broken and the patients were brought out of their rooms for bathing or operation. The operating room was not a very likely source of infection since it was also used for other surgical specialities where no infection occurred with this strain. The bathtub in the bathroom was a more likely source. In 9 of the 16 cases where *Staph. aureus* was isolated from the bathtub the isolated strain was of phage type 84. It is, however, difficult to determine the possible mode of acquisition in any one case; of the 3 patients infected during

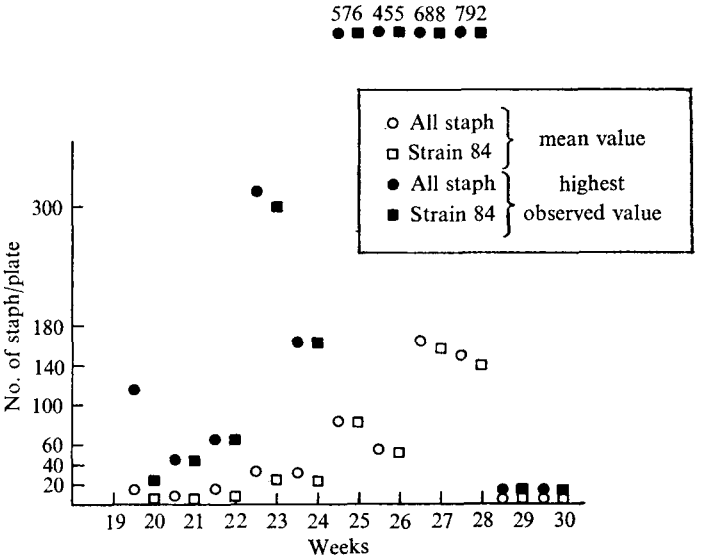


Fig. 4. Weekly settle plate counts of *Staph. aureus* phage type 84 III.

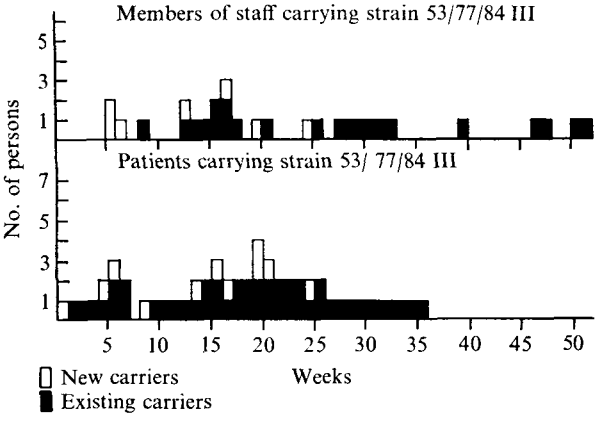


Fig. 5. Course of the epidemic due to *Staph. aureus* phage type 53/77/84 III.

week 24 2 had been operated upon and 1 had been bathed; of the 3 patients infected during week 25, two shared a bedroom, and neither had been bathed or operated upon.

With regard to the possibility of airborne infection it can be seen from Fig. 4 that the week before the epidemic outbreak among the patients there was an increase in the number of colonies with phage type 84 found on settle plates in the bedrooms. This was due to one of the patients becoming a heavy disperser. The same patient caused the high values found during weeks 23 to 25; thereafter two other extensively burned patients began to disperse bacteria. During these weeks there was probably transfer of *Staph. aureus* through the airlock out into the passage, and an increase of staphylococcus found on settle plates in the corridor was noticed.



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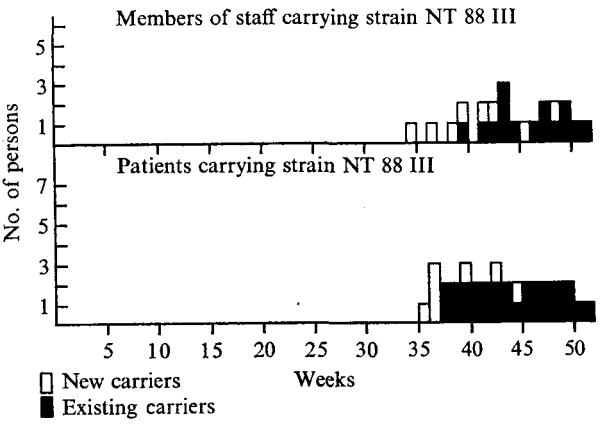


Fig. 6. Course of the epidemic due to *Staph. aureus* phage type 88 III.

Figure 3 shows that phage type 84 was first isolated from the staff after it had been found among the patients. Of interest, however, is the large number of carriers observed during week 23, when the strain was isolated from 6 members of the staff. This high carrier-rate preceded the outbreak among the patients, and after this cumulation which continued up to week 30 the number of carriers decreased again. From week 44 and thereafter was a new increase of carriers and the strain was found among 11 members of the staff, one of whom had a clinical hand infection. This new increase of carriers, however, was not followed by any new outbreak of infections among the patients.

*Strain phage type* 53/77/84

This was also a multiresistant hospital strain producing enterotoxin B. It was, however, sensitive to chloramphenicol and methicillin. It was brought into the ward during the first week by a patient who was admitted to the ward from another hospital. The course of this smaller epidemic in which ten patients became infected can be seen in Fig. 5. The first infection in the ward occurred during week 5 in a patient who shared a room with the one who introduced the strain into the ward. The remaining 9 cases occurred sporadically during the first 25 weeks the unit was in use and there was no accumulation at any specific period.

In all cases this strain could be isolated from the burn as well as from the upper respiratory tract, skin or perineum. Of epidemiological interest is that before the infection occurred, isolation had been broken for 4 patients because of operation and bathing, and for another 2 for operation.

The strain was isolated from 2 members of staff during the 6th week and thereafter from another 5 between weeks 7 and 25. After that 1 member of the staff was a carrier of the strain for the rest of the year, and there was 1 case of wound infection among the staff.

It is difficult to draw any definite conclusions from environmental studies since settle plates were not used in the bedrooms until after week 19. *Staph. aureus* of type 53/77/84 were, however, only sporadically found on the settle plates in the

corridor and service rooms during these first 19 weeks so that it is not very likely that there were any heavy dispersers among patients treated in the ward unit during this period. After week 19 strains of this type were found on settle plates in the bedrooms but usually only in small numbers.

*Strain phage type* 88

This strain was resistant to penicillin but sensitive to tetracycline, chloramphenicol and methicillin. It was typable only at 1000 RTD and was first isolated from the upper respiratory tract of a nurse during week 35. The course of the epidemic in which 7 patients became infected can be seen in Fig. 6. The first case occurred during week 36, one week after it was first found among the staff. The week after there was a small accumulation with 3 new cases and during the following 8 weeks there were another 3 isolated cases. All these patients had been treated in different rooms, but in all cases the isolation had been broken before the infection occurred for operation or bathing in 6 cases and for dialysis in one. In 5 cases this strain was isolated from the burn as well as from other sites, in 1 from the upper respiratory tract only, and in 1 from skin only.

Eight members of the staff became infected. The bacteria were, however, only isolated from the upper respiratory tract and there was no clinical infection.

Strains of this phage type were found occasionally on settle plates in the bedrooms, only 1 patient was for a short time dispersing any considerable amount of the bacteria (max. 100 col./plate) and it was found only sporadically on settle plates in the passage. The short episode of dispersal did not coincide with the accumulation of new cases.

## DISCUSSION

The main purpose of this investigation was to estimate the risk of cross-infection in an isolation ward for burned patients. During the first year the unit was in use 44 of 69, i.e. 64% of the burns became infected with *Staph. aureus*. In another 5 patients acquisition of staphylococci could be demonstrated only in specimens from the upper respiratory tract, skin or perineum. As could be expected the infection risk increased when the patients were treated for any length of time in the unit and if the patient stayed more than 5 weeks he was usually infected with 3 or 4 different types of *Staph. aureus*. The infection rate is in agreement with that found by other authors from the same time period (Thomsen, 1970; Wickman, 1970) or maybe slightly less. Of greater interest is to compare our findings with the infection rate found by Körlof in his investigation on burns treated in the plastic surgery unit in Uppsala 1951–5 (Körlof, 1956). The patients were treated in rooms with 1 to 4 beds and no airlocks. He found a *Staph. aureus* infection rate of 83%. The main principle of treatment was exposure, and the acquisition of *Staph. aureus* occurred within a few days. Thus even if techniques other than isolation have changed since then it seems as though the present ward offers an increased protection against cross-infection. However, it is obvious that cross-infection could not be prevented.

The epidemic situation in the ward was complicated. There were at least three epidemic outbreaks caused by different strains of *Staph. aureus*. In particular one strain, phage type 84, caused a rather extensive epidemic outbreak with no less than 20 infections in burns. Thirty-four members of the staff also became carriers of this strain.

Airborne infection is often considered to be of importance. In this ward high numbers of *Staph. aureus* were often found on settle plates in the bedrooms. In 8% of the observations there was a dispersal of more than 1800 col./m.$^2$ hr. and the maximum value was 14,300 col./m.$^2$ hr. Corresponding values in an investigation from an isolation unit for open septic lesions (Williams & Harding, 1969) are more than 283 col./m.$^2$ hr. in 8% of the observations and a maximum value of 2,260 col./m.$^2$ hr. It is obvious that patients with infected burns are often heavy dispersers.

A high number of staphylococci in the bedrooms caused an increase in staphylococci in the passage and service rooms. It is, however, difficult to estimate the actual airborne transport of staphylococci from one room to another in this investigation as, especially during an epidemic outbreak, several persons, patients as well as staff, carried *Staph. aureus* of the same phage type and thus possible sources would be found in several rooms in the ward at the same time. In a study of airborne transmission within the ward using tracer particles (Hambraeus & Sanderson, 1972) the transport of particles from one room to another under normal conditions was less than 1 in $4 \times 10^4$. According to this investigation it seems likely that other routes of infection have been of greater importance. The significance of this experimentally obtained figure is of course uncertain, and calculation of the airborne transport of staphylococci by studying the ward during selected non-epidemic periods is the object of an investigation now going on.

In the epidemic with type 84 III, the presence of a disperser among the patients did afford a risk, but certainly the risk of transport of bacteria by other routes, such as by nurses' clothes, for example, also increases when the environment is heavily contaminated.

In the 114 bacteriological infections with *Staph. aureus*, 26 of the strains were found in a patient only, 10 in a member of the staff only and 23 in both patients and staff the week before it caused a new infection. Only in a few cases was a patient infected because he shared a room with an infected patient, which seems to indicate the presence of a passive transport of staphylococci from patient to patient.

Carriers among the staff were probably of importance. During two of the epidemics there was a high carrier rate in the staff of the epidemic strain. In the epidemic caused by type 84 a high carrier rate among the staff preceded the epidemic outbreak. During the last part of this epidemic a new increase of carriers among the staff did not result in any new cases among the patients.

It is interesting that many infections occurred after the isolation had been broken for bathing or operation. The bathtub might have been of some importance; *Staph. aureus* of the same type as that causing infections could be isolated from it now and then. The operating ward was regarded as a less important source as

strains common in this ward were hardly ever noticed in other wards served by the same operation unit and team.

It is obvious that with present knowledge no route of infection can be altogether excluded.

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