

Staphylococcal infection in subdivided general surgical wards

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SUMMARY

The spread of *Staphylococcus aureus* was studied in three general surgical wards of identical design which consisted of a number of separate rooms, and the results were compared with those in the same unit previously studied, in subdivided wards elsewhere and in large open wards.

The nasal carrier rate of *Staph. aureus* by patients rose during their stay in the ward, but its peak rate was comparable with minimum rates reported in other subdivided wards and was lower than in open wards.

Staphylococcal sepsis rates were lower than in most open wards and were also much lower than those found previously in the same unit when overcrowding was common and each sex had its own ward.

INTRODUCTION

One of the features of recent hospital designs has been the adoption of separate rooms within each ward, mostly containing four patients or less. One reason for this is to reduce the level of cross-infection. This paper investigates the extent to which this has been successful in three general surgical wards in a recently built District General Hospital in Fife.

Architecture and ventilation

All three wards have the lay-out shown in Fig. 1. Wards A and B are on the first and second floors of the south wing and ward C on the second floor of the east wing of the building, which has three floors and a basement. There are one 8-bed, four 4-bed and four 1-bed rooms in each ward. The 8-bed rooms measure 45 ft. by 20 ft., the 4-bed 20 ft. square, and 1-bed 20 ft by 10 ft. Ceiling height is 10 ft. Each room has a door, which is usually left open. Ventilation is natural. Ward doors leading to the central staircase are normally shut, but those leading to the peripheral staircase are usually left open. Also included in the block are a paediatric ward on the ground floor, south wing, the pharmacy on ground floor, east wing and a urology ward and dermatology out-patient unit on the first floor of the east wing.

The west wing, not shown in Fig. 1, comprises the X-Ray department and offices on the ground floor, residency on the first floor and a suite of one small and two main operating theatres on the second floor, which serves the whole block. The theatres are ventilated by positive pressure at between 15 and 20 air changes per hour.

Floors were cleaned daily with a vacuum cleaner, and by mopping and polishing. Bed curtains were hot-laundered about once every 5 weeks and the cotton blankets after discharge of each patient. Otherwise, no special measures against cross-infection were in operation and the hospital did not have an active Control of Infection Committee during the investigation. There was no Control of Infection Officer or Sister.

Air movements were not studied in detail, but the presence of open doorways leading to the peripheral staircase must have led to a considerable exchange of air

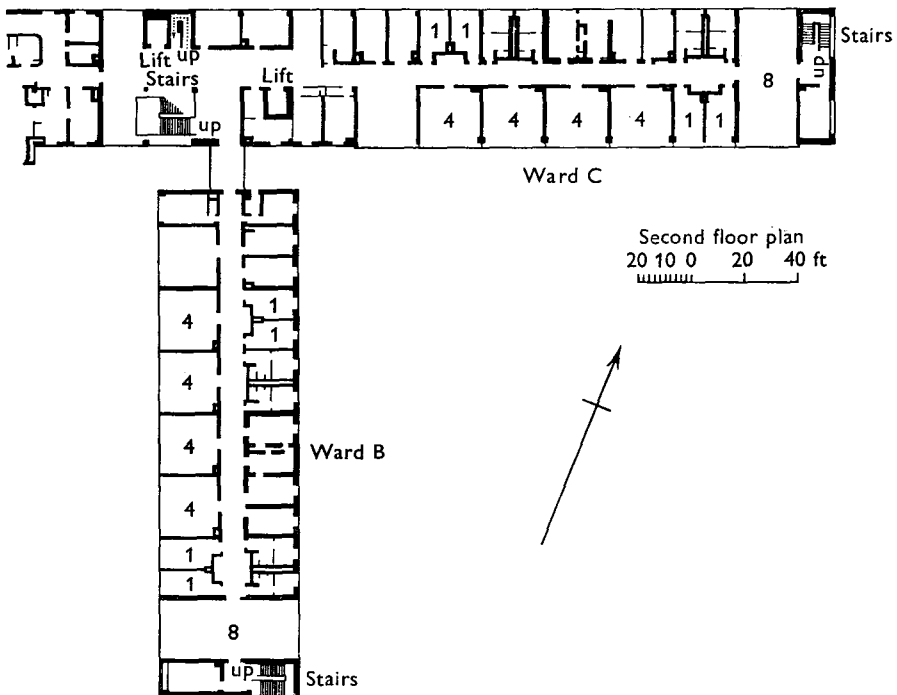


Fig. 1. Plan of wards B and C. Bed-rooms and their bed complements are indicated by the numerals 1, 4 or 8.

between wards A and B. The doors between the paediatric ward and the south and central stair wells were normally kept shut so that air from this ward was unlikely to move in large amounts to wards A and B above it. At the distal end of ward C the staircase led down to an outside door in frequent use by out-patients, so that considerable ventilation by fresh outside air must have occurred through the open doors at this end of the ward.

METHODS

Patients

In all three wards both 1-bed and 4-bed rooms were used for either males or females, but females always occupied the 8-bed rooms. In ward C female patients were sometimes admitted to the 8-bed room prior to undergoing an operation,

followed by transfer to one of the other rooms. In wards A and B most patients admitted to 8-bed rooms remained there throughout their stay. In all three wards there was little movement of patients from 1-bed or 4-bed rooms to other room types.

Wound dressings

In ward A, clean wounds were sprayed with Nobecutane but otherwise left uncovered. In the other two wards dressings were used, which were removed on the 2nd or 3rd day after operation. Stitches were removed on the 8th and 9th days.

Wounds were considered to be septic only when visible pus was present and this was recorded only in major clean or potentially infected operation wounds, e.g. hernia (clean) or uncomplicated appendicectomy (potentially infected). Wounds where gross fouling occurred from a contaminated viscus (e.g. ruptured appendix) or where pus was already present at operation, were excluded from the investigation. 'Staphylococcal other sepsis' was recorded in any clinical infection arising in hospital, other than wound sepsis as defined above, from which *Staph. aureus* was isolated in significant numbers. It thus included respiratory, urinary or cutaneous infections and infections of minor surgical wounds such as drip incisions. It did not include infections already present on admission. Ascertainment of sepsis was made by following up routine bacteriology specimens sent to the laboratory.

Antibiotic treatment

Patients in ward C having operations usually had penicillin and streptomycin both as a local wound application and intramuscularly for several days after operation. There was no routine prophylactic administration of antibiotics in the other two wards. The percentages of patients receiving antibiotics in wards A, B and C were 39.7, 23.2 and 34.1 respectively; and in all wards, 31.7.

Staff

Each ward had one consultant surgeon. In addition, there were 6 beds in ward A looked after by a consultant urologist. The medical staff included one registrar and one house officer in each ward and an additional senior house officer in ward A. There were a sister, two staff nurses, two state-enrolled nurses and eight nursing trainees and auxiliaries in each ward during the day, with two to three nurses at night. Other professional staff included three anaesthetists and one physiotherapist shared between the three wards. There were three domestic staff in each ward.

Bacteriological examinations

Nasal swabs were taken from patients on admission and thereafter weekly on a fixed day, and weekly from surgical, nursing and other staff of the ward. Swabs were cultured on phenolphthalein phosphate serum agar plates which were incubated in air at 37° C. Coagulase-positive staphylococci were phage-typed and tested for resistance to penicillin and tetracycline. Air-sampling was carried out weekly by exposing 13.5 cm. diameter phenolphthalein phosphate serum agar plates for 8 hr. in each room. Up to ten coagulase-positive cultures from each plate

were phage-typed and tested for resistance to penicillin and tetracycline. When more than ten colonies of *Staph. aureus* were present on a plate, strains were assumed to be distributed in the sample in the same ratio as in the ten colonies that had been phage-typed.

Method of analysis

Acquisition of *Staph. aureus* was measured by recording phage-types and antibiotic resistance of strains as they appeared in successive nasal swabs from the same patient. A strain appearing which had not been found in previous swabs or which was different in resistance or phage-type from that found previously was assumed to have been 'acquired'. The conventions adopted for times of acquisition between swabbings were those of Lidwell *et al.* (1966). The survey took place between November 1967 and April 1969.

RESULTS

Incidence of sepsis

Table 1 shows the incidence of post-operative staphylococcal wound sepsis in 11 different operation groups, arranged in increasing order of sepsis rates. There was no sepsis among 24 varicose vein operations; appendicectomy and hernia

Table 1. *Incidence of staphylococcal sepsis in operation wounds*

Operations	Ward A		Ward B		Ward C		All wards	
	No. of operations	% septic	No. of operations	% septic	No. of operations	% septic	No. of operations	% septic
Varicose veins	7	0	3	0	14	0	24	0
Appendicectomy	96	0	134	1.5	123	0	353	0.6
Hernia	24	0	81	1.2	52	0	157	0.6
Biliary tract	56	0	43	2.3	30	3.3	129	1.6
Prostatectomy	5	0	18	5.6	11	0	34	2.9
Thyroid	14	0	15	6.7	4	0	33	3.0
Gastro-duodeno-jejunal	87	2.3	65	6.2	80	1.3	232	3.0
Ilio-colic-rectal	70	2.9	47	6.4	37	0	154	3.3
Miscellaneous clean	90	3.3	92	6.5	84	0	266	3.4
Breast	45	2.2	31	9.7	39	0	115	3.5
Urological	17	11.8	3	0	5	0	25	8.0
Total operations	511	2.0	532	4.1	479	0.4	1522	2.2

operations each gave 0.6% staphylococcal infections and the remaining groups gave rates increasing from 1.6% for biliary to 8.0% for urological operations. The rate for all operations was 2.2%. Ward C had a markedly lower wound sepsis rate than wards A and B (0.4% as against 2.0 and 4.1% respectively). This could not be ascribed to the difference in numbers of the various operations performed on patients in the different wards.

Table 2 shows rates of wound and other staphylococcal infections per 100

admissions in the three wards. The greatest number of admissions was in ward A (1064) and the least in ward C (841). The incidence of post-operative staphylococcal wound sepsis was 0.9% in ward A, 2.3% in ward B and 0.2% in ward C. The corresponding percentages for other staphylococcal sepsis were 1.6, 1.7 and 2.7 and for wound and/or other staphylococcal sepsis 2.4, 3.9, and 2.7. Three per cent of patients in all three wards developed staphylococcal sepsis, 1.2% having wound sepsis and 2.0% other sepsis. Males and females were about equally represented in each of these sepsis classes (this is not shown in the table).

The incidence of staphylococcal other sepsis in patients who had been previously admitted within 6 months was 4.1% while in those without previous admission it was only 1.7%. This disproportion was most marked in the case of sepsis due to tetracycline-resistant (T) strains, the incidence being 2.8% in patients with previous admission and 0.8% in those without.

Table 2. *Staphylococcal infections arising in hospital*

Ward	Admissions	% Patients developing staphylococcal infection		
		Wound sepsis	Other sepsis	Wound or other sepsis or both
A	1064	0.9	1.6	2.4
B	958	2.3	1.7	3.9
C	841	0.2	2.7	2.7
All wards	2863	1.2	2.0	3.0

Nasal carriage of Staphylococcus aureus

The pattern of nasal carriage of *Staph. aureus* by patients in successive weeks of stay was somewhat different from that found by Lidwell *et al.* (1966) in a thoracic ward at St Bartholomew's Hospital of similar lay-out, or by Parker, John, Emond & Machacek (1965) in patients in 1- and 2-bed cubicles at Coppett's Wood Hospital. Figs. 2 and 3 show carriage rates which were considerably lower in patients on admission and in staff (both were 18.3%) than in the other surveys. Thus, Lidwell *et al.* (1966) reported 38% for patients and 39% for staff; and Parker *et al.* (1965), 37% for patients. In addition, the total carriage rate did not fall on successive weeks of stay as in those two surveys, but rose to a peak of 28% in week 6, a level which was however lower than the 6-week minimum of Parker *et al.* and only a little higher than the minimum of about 25% of Lidwell *et al.*

This difference lay chiefly in the very low incidence of penicillin-sensitive (S) strains on admission compared with that reported by the other workers. This fell still further during the patients' stay from 8.0% on admission to 1.5% in week 7. The incidence of tetracycline-resistant (T) strains was 1.7% on admission, a somewhat lower level than in the other surveys, but rose steadily to 10.8% at week 6 and a peak of 17.6% at week 9. These rates were similar to the other surveys shown in Fig. 3 for wards divided into small rooms or cubicles (A-D) but were much lower than in the unmodified open wards shown in E-G.

The incidence of penicillin-resistant (P) strains rose *pari passu* with that for T strains during the first 6 weeks of stay. The rising graph of total carriage rates was therefore determined by a normally rising P and T strain graph modified by an exceptionally low S strain incidence throughout the patients' stay.

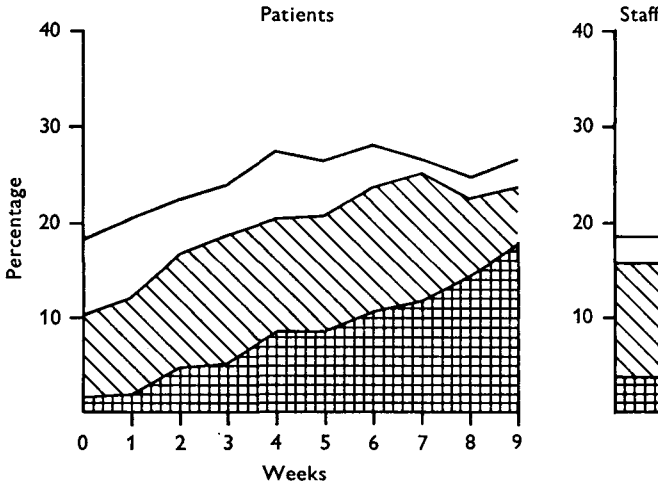


Fig. 2. Nasal carriage of *Staph. aureus* by patients during each week of stay in the three surgical wards. Average rate of nasal carriage by members of the staff. □, Sensitive to penicillin and tetracycline; ▨, resistant to penicillin only; ▩, resistant to tetracycline.

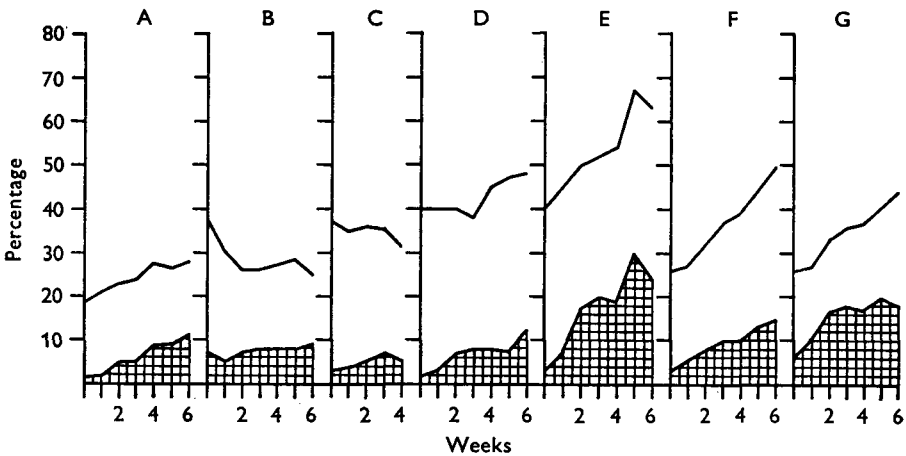


Fig. 3. Nasal carriage of *Staph. aureus* by patients in various hospital wards. Percentage positive in each week of stay in ward. Upper line: all strains of *Staph. aureus*. Lower line: tetracycline-resistant *Staph. aureus* [A, B, C, F and G: all tetracycline-resistant strains; D and E: all strains resistant to penicillin and tetracycline]. A, this investigation in all three wards; B, patients in similar lay-out, 1-bed, 4-bed and 10-bed rooms (Lidwell *et al.* 1966); C, patients in cubicles (Parker *et al.* 1965); D, E, two of three open surgical wards, D with four cubicles, E without (Williams *et al.* 1962). F, medical wards; patients not receiving antibiotics; G, medical wards; patients receiving antibiotics. (F, G, P.H.L.S. Cross-Infection Committee, results as given in Lidwell *et al.* 1966). Histograms B to G reproduced from Lidwell *et al.* (1966) by permission of Dr Lidwell.

The influence of previous admission to hospital on carriage rate was investigated in 440 patients. The incidence of S strains in these patients was 6.6% and in patients not previously admitted, 8.4%; that of P strains was 8.6% in each group but there was a considerably greater incidence of T strains in previously admitted patients (3.4%) than in those not previously admitted (1.3%). This difference persisted for 2 weeks and then disappeared.

Weekly rates of carriage were calculated for the three wards A, B and C separately. Peaks occurred at different weeks in the various wards but the overall trend over 6 weeks was similar and average carriage rates were almost the same for all strains and for S and P strains. There was a somewhat higher average rate of T strains in ward A (5.0%) than in ward B (3.4%) or ward C (3.3%) the excess occurring only in the first 3 weeks. For reasons of space the detailed figures for individual wards are not given here.

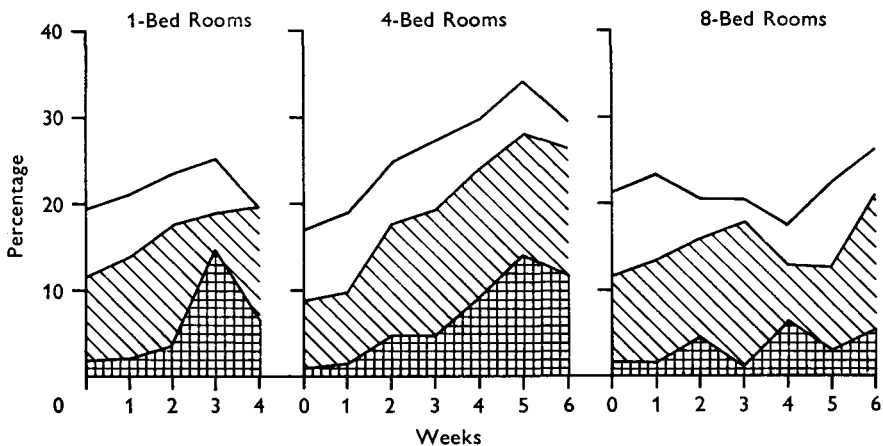


Fig. 4. Nasal carriage of *Staph. aureus* by patients in rooms with one bed, four beds and eight beds. Percentage positive in each week of stay in these rooms. □, ▨, ▩, as in Fig. 2.

Fig. 4 shows corresponding rates in relation to the type of room occupied by the patient throughout his or her stay. It includes only patients who had not been previously admitted to hospital within 6 months. The number of patients in 1-bed rooms became too small after 4 weeks to yield significant results but it is clear that a higher total carriage rate developed in 4-bed rooms than in either 1-bed or 8-bed rooms over the 4–6 weeks after admission. This was mainly due to a sharper rise in P+T strains in the 4-bed rooms than in the others. There was a higher average carriage rate of T strains in the 1-bed than in either 4- or 8-bed rooms during the first 4 weeks of stay, the figures for the three room types being 4.3, 3.0 and 2.7% respectively.

Apparent acquisition of Staphylococcus aureus

Three hundred and seventy-one strains of *Staph. aureus* not found on admission were later isolated from nose swabs of patients. In 4574 patient-weeks exposure (see Table 3) the rate of acquisition was 8.6 per 100 patient-weeks, a figure rather

higher than the 6.4 found in patients in small cubicles by Parker *et al.* (1965), and more than double the figure of 3.4 found in patients in the subdivided thoracic ward of Lidwell *et al.* (1966). However, spurious acquisition of S and P strains due to failure to isolate an organism present on admission must be taken into account. Apparent acquisition of T strains is thought to be more significant than that of P and S strains and the present rate for T strains was 2.1 per 100 patient-weeks as against 1.4 for the cubicle patients and 1.3 for the thoracic subdivided ward patients. According to Parker *et al.* (1965) comparable figures for multiple-resistant organisms in large open wards range from 3.7 to 12 per 100 patient-weeks. Recently, however, the unusually low figure of 3.2 per 100 patient-weeks has been reported by Whyte, Howie & Eakin (1969) for T strains in open general surgical wards.

The effect of antibiotic treatment on acquisition rates is also seen in Table 3. The rate for all strains was highest (11.3 per 100 patient-weeks) in the patients receiving tetracycline only and the rate for T strains was also highest in this group at 4.0 per 100 patient-weeks. Rates for all strains were not much affected by other antibiotics, but T strain rates per 100 patient-weeks were 3.4 for those receiving antibiotics other than penicillin and tetracycline, 3.1 for patients receiving systemic antibiotics of all kinds, 2.7 for those having penicillin and 'other' antibiotics (i.e. not penicillin or tetracycline) 1.3 for penicillin only and 1.1 for those not receiving any antibiotics. Acquisition of S strains naturally tended to be less when antibiotics were given (1.3–2.9) than when no antibiotics were given (3.1). An exception was in the tetracycline only group when a rate of 4.0 per 100 patient-weeks was recorded.

Apparent acquisitions of *Staph. aureus* in relation to presumed sources are given in Table 4. In 233 strains no source was found within 10 days before the acquisition, and 42 were non-typable. Of the remainder, 72 strains were from known single-patient sources, of which 27 were T strains; 20 strains (including 6 T strains) came from a patient or patients in the same room as the recipient, 42 (15 T strains) from patients in other rooms, 27 (12 T strains) from staff and 14 (7 T strains) from patients in other wards.

In comparing rates of acquisition in relation to source with those reported by Lidwell *et al.* (1966), it seems best to pay attention mainly to rates for T strains (Table 4) as these are less likely to be spurious than those of P and S strains. The rates per 100 patient-weeks for patient-sources in the same room as the recipient (0.13), in other rooms (0.33), and from staff (0.26), compared with the corresponding figures derived from the above publication of 0.11, 0.29 and 0.14 respectively. The first two figures were similar in the two surveys, but the third figure, for staff sources, was larger in the present series than in the other.

Nasal acquisition of *Staph. aureus* from the 72 single-patient sources was further analysed according to the mobility and site of the source-patient and the room-type of the recipient in the week before the acquisition. Relatively few acquisitions (4) occurred from ambulant patient sources. The great majority were from patients who were up occasionally (35 total, 12 T strains) and from bed-fast patients (33 total, 13 T strains). On the other hand, 8 out of 12 source-patients who were in

Table 3. *Apparent acquisition of nasal Staphylococcus aureus by patients in relation to antibiotic treatment*

(Rate per 100 patient-weeks exposure. S = sensitive to penicillin and tetracycline, P = resistant only to penicillin. T = resistant to tetracycline.)

Antibiotic treatment and strains	No. of patient-weeks exposure	Rate of acquisition of strains
All patients	4574	—
All strains	—	8.6
S	—	2.5
P	—	3.9
T	—	2.1
No antibiotic	2156	—
All strains	—	8.1
S	—	3.1
P	—	3.9
T	—	1.1
Systemic antibiotic	2393	—
All strains	—	8.9
S	—	2.0
P	—	3.9
T	—	3.1
Penicillin only	77	—
All strains	—	6.5
S	—	1.3
P	—	3.9
T	—	1.3
Tetracycline only	150	—
All strains	—	11.3
S	—	4.0
P	—	3.3
T	—	4.0
Other only*	1365	—
All strains	—	9.0
S	—	1.9
P	—	3.7
T	—	3.4
Penicillin and other*	743	—
All strains	—	9.0
S	—	1.9
P	—	4.4
T	—	2.7
Tetracycline and other*	34	—
All strains	—	8.8
S	—	2.9
P	—	5.9
T	—	0

* Antibiotics other than penicillin or tetracycline.

other wards were either ambulant or up occasionally. Table 5 subdivides these figures. There was a predominance of T strain acquisitions in 1-bed rooms (6 among a total of 12 beds), as compared with 4-bed rooms (13 among 48 beds) or 8-bed rooms (8 among 24 beds). In both 4- and 8-bed rooms, the proportion of acquisitions of all strains from sources in other rooms to those in the same room was about 2:1; the corresponding ratios for T strains were 1.6:1 in 4-bed and 3:1 in 8-bed rooms. There was no greater tendency for patients who were up occasionally to act as other-room sources than patients who were bed-fast.

Table 4. *Apparent acquisition of Staphylococcus aureus in relation to a presumed source*

(Patient-weeks of exposure 4574.)

Source	No. of 'acquired' strains				Rate of acquisition per 100 patient-weeks			
	Antibiotic resistance of strains			All strains	Antibiotic resistance of strains			All strains
	S	P	T		S	P	T	
Known single patient	15	30	27	72	0.33	0.66	0.59	1.57
Patient(s) in same room	10	4	6	20	0.22	0.09	0.13	0.44
Patient(s) in other room	7	20	15	42	0.15	0.44	0.33	0.92
Patient(s) in same/other room	0	1	3	4	0	0.02	0.07	0.09
Patients or staff	1	3	1	5	0.02	0.07	0.02	0.11
Staff	4	11	12	27	0.09	0.24	0.26	0.59
No source within ten days	83	110	40	233	1.82	2.40	0.87	5.09
Non-typable	8	22	12	42	0.18	0.48	0.26	0.92
Patient(s) in other ward	1	6	7	14	0.02	0.13	0.15	0.31

Sources of staphylococcal sepsis

Presumed sources of staphylococcal wound and other sepsis are shown in Table 6. In wound sepsis, the source was unknown in 13 out of 34 strains; of the remainder, the majority could be traced to other patients or staff (12), the rest coming from the patient himself (9). In other staphylococcal sepsis the majority of known-source strains came from the nose of the patient himself (16 out of 29). Eight strains originated from other patients, four from staff and one from patients or staff. About half of all 'other sepsis' strains had no known source (30 out of 59). There was a predominance of T strains in both types of sepsis.

Staphylococcus aureus in the air

Two thousand and thirty-one culture plates were exposed for 8 hr. each in the 27 rooms of the three wards. Two thousand and fifty colonies of *Staph. aureus* grew on these plates. Assuming that the number of bacteria-carrying particles settling on 1 ft.² of culture medium per minute is approximately equal to the number per ft.³ of air (Williams, Blowers, Garrod & Shooter, 1966), this gives an approximate

Table 5. Acquisition of Staphylococcus aureus from single-patient sources

Mobility and site of source patient in week preceding acquisition	Room-type of recipient in week preceding acquisition of <i>Staph. aureus</i>															
	1-bed					4-bed					8-bed					
	Antibiotic resistance of acquired strains			All strains	Antibiotic resistance of acquired strains			All strains	Antibiotic resistance of acquired strains			All strains				
	S	P	T		S	P	T		S	P	T		S	P	T	
Ambulant	—	—	—	—	0	0	0	0	0	0	0	0	0	0	0	0
Up occasionally	0	0	1	1	(1)	1	(1)	3	(2)	0	0	0	0	0	0	0
Bed-fast	—	—	—	—	4	1	4	9		1	2	0	1	2	0	3
	1	2	4	(3)	7	(3)	13	(3)	1	0	2	1	3	3	3	3
	—	—	—	—	3	1	1	5		1	0	2	3	1	0	2
	1	2	1	4	1	6	4	11		1	4	(2)	5	(2)	10	(4)
	—	—	—	—	7	2	5	14		2	2	2	6	2	2	6
	2	4	6	(3)	12	(3)	27	(5)	3	(1)	16	(2)	27	(5)	6	(2)
Total	2	4	6	(3)	12	(3)	41	(5)	10	(1)	18	(2)	41	(5)	3	8

Figures in parentheses are sources in other wards, and are included in 'other room' figures.

average air content of 49.5 *Staph. aureus*-carrying particles per 100 m.³ (14.0 per 1000 ft.³). This is less than half the average figure reported by Lidwell *et al.* (1966) of 124 per 100 m.³ (35 per 1000 ft.³), which was in turn much lower than the values observed earlier in open surgical wards at St Bartholomew's Hospital. Average counts were then between 635 and 776 per 100 m.³ air (180 and 220 per 1000 ft.³ (Noble, 1962).

Table 7 shows the average estimated air contents in the various wards and room types. Wards A and B were roughly equal (62.3 and 60.4 per 100 m.³ respectively), but ward C gave less than half of these (24.1 per 100 m.³). There were fewer *Staph. aureus* particles in the air of the 1-bed rooms than in 4- or 8-bed rooms. Total strains are given in Table 8 for each room type, the average numbers per 100 m.³ air for 1-, 4- and 8-bed rooms being 36.8, 60.2 and 53.8 respectively. Note the

Table 6. *Presumed sources of staphylococcal sepsis*

Type of infection	Presumed source					Total sepsis strains	
	Self	Another patient or		Staff or Not patients known			
		patients	Staff				
Staphylococcal wound sepsis	S	0	0	1	2	4	7
	P	5	2	0	0	4	11
	T	4	6	1	0	5	16
	All strains	9	8	2	2	13	34
Staphylococcal other sepsis	S	1	1	0	0	3	5
	P	6	0	2	1	15	24
	T	9	7	2	0	12	30
	All strains	16	8	4	1	30	59

unexpected finding of the slightly greater number in 4-bed than in 8-bed rooms. There was a lower proportion of T strains to all strains in ward C than in wards A and B (Table 7) and this was true in each of the three room types.

The tendency of 1-bed rooms to yield fewer staphylococci than 4- or 8-bed rooms was reversed for T strains in ward B, there being 28.2, 19.9 and 12.2 colonies per 100 m.³ air in the three respective types of room. This was due to the exceptionally potent source-patient described below, whose room air yielded more than half the total T strains from 1-bed rooms in this ward.

Table 8 shows the distribution of sources of aerial strains. In each room-type the proportion of strains originating from single-patient sources in other rooms to those from the same room was about 1:2. This was the same for all rooms in ward A and B, but in ward C the ratio was 1:3. Other-room sources in this ward were therefore less important in aerial spread than in wards A and B.

The number of strains traced to single members of staff were between 2.7 and 3.8 per 100 m.³ air for the three types of room. The corresponding figures for wards A, B and C were 5.0, 4.1 and 0.7 respectively, the last figure being a particularly low one not only in relation to other wards, but also in relation to patient-sources in the same ward.

Table 7. *Airborne Staphylococcus aureus in relation to antibiotic resistance and ward and room-type where recovery occurred*
 (Average estimated number of colonies per 100 m.³ air over the whole period of survey.)

Room type	Recovery from air in ward									
	A			B			C			
	Antibiotic resistance			Antibiotic resistance			Antibiotic resistance			
	S	P	T	S	P	T	S	P	T	All strains
1-bed	6.5	18.2	14.0	2.6	23.8	28.2	4.5	7.3	3.1	14.9
4-bed	12.7	34.0	33.4	11.8	31.7	19.9	8.2	20.8	6.4	35.5
8-bed	11.6	29.1	32.2	11.8	42.0	12.2	6.2	10.8	2.5	19.5
All rooms	10.0	26.8	25.5	8.1	30.6	21.7	6.4	13.5	3.9	24.1

Table 8. *Airborne Staphylococcus aureus in relation to sources*
(Estimated colonies per 100 m³ air. 1-b, 4-b, 8-b = 1-, 4-, 8-bed rooms.)

Recovery from air	Location of source carriers.						Total
	Single-patient sources		Other ward	Single staff sources	> 1 source	No known source	
Rooms	Same room	Other room					
1-b	11.5	5.4	0.8	3.7	4.2	11.1	36.8
4-b	15.0	6.3	1.4	2.7	3.4	31.4	60.2
8-b	12.6	7.2	0.5	3.8	2.2	27.6	53.8
Wards							
A	10.0	5.0	2.4	5.0	2.3	37.8	62.3
B	19.7	10.1	0.3	4.1	6.3	20.0	60.4
C	9.2	3.0	0.3	0.7	1.8	9.2	24.1
All rooms } All wards }	13.1	6.1	1.0	3.3	3.5	22.6	49.5

Broadcasts of Staphylococcus aureus

The term 'broadcast' here means the isolation of ten or more colonies of *Staph. aureus* of a particular phage type and antibiotic resistance on any one weekly sampling day or 15 or more colonies on two successive sampling days. In ward A there were eight such broadcasts during the survey, yielding 152 colonies; in ward B there were twelve, yielding 454 colonies; and in ward C, four, yielding 80 colonies. Broadcasts were therefore largest and most frequent in ward B and smallest and least frequent in ward C. One of them came from an unusually potent source of staphylococci—a patient in a 1-bed room with tumour obstruction of the larynx and a tracheostomy wound infected with *Staph. aureus*. Over a period of 8 weeks no fewer than 146 colonies from this source were isolated from the routine weekly plates in ward B. There were two phage types involved, the first being a P strain, yielding 20 colonies, the second, a T strain, yielding 126 colonies. The latter strain was found in every room in the ward on one or more occasions and also in three rooms in ward A. Its highest concentration was in the patient's room, when on one occasion 70 colonies were estimated to be present on one 8-hr plate, corresponding to about 3300 staphylococcal particles per 100 m.³ air (970 per 1000 ft.³). During the broadcast, the patient was either bed-fast or up occasionally.

Six of the broadcasts were of T strains, 14 of P strains and four of S strains. Apart from the patient described above, there was no obvious tendency for T strain broadcasts to be larger than those of P strains, but those of S strains were much smaller.

Two broadcasts of P strains were traced to staff, both nurses. One further broadcast came from either a patient or a nurse or both.

Spread of staphylococci between wards

One case of wound sepsis in ward B yielded a staphylococcus indistinguishable from a strain carried by a patient in ward A and by another in ward C, either of whom could have been the source. Nasal acquisitions from single-patient sources in other wards appeared to originate in ward A on two occasions, ward B on six occasions and ward C on four occasions. The direction of spread was from ward A to B once, A to C once, B to A twice, B to C four times and C to A three times.

Staph. aureus from sources in other wards was recovered from the air of bedrooms on a total of seventeen occasions, nine in ward A, four in ward B and four in ward C. Ward B was the source on seven occasions, spread occurring to ward A on six occasions and to ward C on one of these occasions. Ward C was the source on six occasions, spreading on three occasions each to wards A and B. Ward A was only once definitely shown to be a source, spread occurring to ward B.

DISCUSSION

The incidence of post-operative wound sepsis was lower than that found in the same unit in 1962, when 5.6% of clean and potentially infected operation wounds and 8.3% of all admissions to the general surgical wards developed staphylococcal sepsis (figures for unit (A) male and female wards, in Edmunds *et al.* 1965). This was a degree of sepsis commonly found in open wards, e.g. 5.2% of operation wounds derived from the Report (1960) and 5.6% of admissions from Williams *et al.* (1959). The present figures were 2.2% for wounds and 3.0% for admissions, clearly a considerable reduction, which can be attributed to the opening of an extension to the hospital shortly before the start of the survey; this enabled general surgical patients to be accommodated in three wards (A, B and C) with both sexes represented in each ward, instead of the two allocated to the speciality before (A, male, B, female). This prevented the overcrowding which was common before, and was associated with a nearly equal division of sepsis between the sexes, in place of the previous much higher incidence among the males.

The very low rate of staphylococcal wound sepsis in ward C (0.4%) could have been related to the lower turnover of patients and greater stairwell ventilation by fresh air than in the other wards. However, the rate of staphylococcal other sepsis was higher than in other wards and nasal carriage rates were similar, so that one's attention was directed to possible differences in regimen affecting only those patients who had operations. The most likely seemed to be the routine administration of penicillin and streptomycin at and after operation in ward C. If this was a major cause for the low wound sepsis rate it would bear out the experience of Lidwell *et al.* (1966) that extensive use of antibiotics can under certain circumstances be a factor in reducing wound sepsis. The synergistic action of penicillin and streptomycin might well be effective even against penicillinase-producing staphylococci, but many people would not accept the risk of ototoxicity involved in the prophylactic use of streptomycin.

In common with other recent reports on subdivided wards, carriage rates were

considerably lower than those reported from large open wards. The influence of previous admission to hospital was not significant for S and P strains, but the carriage rate of T strains was 2.5 times higher in previously admitted patients than in the others; and this was associated with a higher staphylococcal sepsis rate, particularly due to T strains, in the former group.

An unexpected finding was that carriage rates of P and T strains rose more sharply in patients in 4-bed rooms than in 8-bed rooms. There was also a slightly higher average staphylococcal content of the air in the smaller rooms than in the larger. These facts may be related to the more severe illnesses and more intensive treatment of patients in the smaller rooms, and the exclusive occupancy of 8-bed rooms by females, who are less prolific sources of staphylococci than males (Blowers & McCluskey, 1965). In addition the air space per bed was greater than in other room types. These factors probably also explain the higher acquisition and average carriage rates of T strains in 1-bed rooms than in other rooms.

Nasal acquisition rates, both of antibiotic-sensitive and resistant strains were lower than in open wards, though not so low as those reported by Lidwell *et al.* (1966) in a similar architectural layout. The latter difference may be related to the smaller proportion of patients receiving antibiotics in this unit (37 %) as compared with the other (71 %).

Lidwell *et al.* (1966) found that there was more acquisition of staphylococci from patient-carriers in other rooms than from those in the same room as the recipient. This was confirmed in this investigation, the proportion of other-room to same-room sources of T strains being the same (about 2.5 to 1); however, nearly twice as many such acquisitions occurred from staff in this series as in the other.

It seems unlikely that the degree of ambulation of potential source carriers was of much importance in the spread of infection, as fully ambulant single-patient sources were in a very small minority, the great majority being up occasionally (i.e. for 2 hr. or less per day) or bed-fast. This leaves out of account the majority of acquisitions where patient sources were less well defined and it was therefore not possible to assess their degree of mobility. Nevertheless the ability of bed-fast patients to act as sources of staphylococcal acquisitions was noteworthy.

The low air counts of *Staph. aureus* particles may be explained in part by the long period over which the survey extended. The great majority of colonies were isolated on very few occasions while many weeks exposure yielded no colonies at all. Thus sampling limited to a shorter period might have yielded higher or lower average counts than that reported here, depending on whether or not broadcasts were included. In spite of this, however, the amount of aerial spread of *Staph. aureus* was clearly of a lower order than in open wards.

Ward C, in addition to a lower wound sepsis rate than wards A and B, had a lower average air count of staphylococci and was the site of fewer broadcasts. This was probably due to factors already suggested including a different antibiotic regimen, lower patient turnover and different ventilation, none of which was related to the architecture or design of the ward units themselves. On the other hand, average staphylococcal carriage rates were not significantly different in the three wards, and sepsis other than wound sepsis was more frequent in ward C than

in the other wards. In view of these facts it would seem desirable to study several identical units simultaneously if a proper assessment is to be made of the role of architecture in the spread of infection.

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