

Transfer areas and clean zones in operating suites

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(Received 11 November 1968)

It is generally assumed that floors in the aseptic zone of operating suites should be protected against contamination with bacteria brought in from other parts of the hospital. The use of plastic overshoes and theatre boots are convenient measures against contamination from the soles of shoes, but it is harder to devise practical methods of preventing contamination from the wheels and other surfaces of trolleys. The use of tacky mats or disinfectant dips for this purpose is of rather doubtful value (Ayliffe *et al.* 1967; Medical Research Council, 1968).

A design of operating suites has been recommended in which the aseptic ('sterile') zone, including the operating and sterilizing rooms, is approached through a clean zone, where theatre clothes are worn; the clean zone is approached through a protective zone, where the staff changes into theatre clothes, footwear, etc. (Medical Research Council, 1962). Between the protective and clean zones in some operating suites a transfer area is provided, where patients are transferred from the hospital trolleys, on which they are brought from the wards, to clean theatre trolleys; this arrangement is thought to have some value in protecting the aseptic zone against contamination from trolleys (Weeks, 1964; Barron, 1964).

The presence of such an area with clean trolleys requires a considerable addition to the floor space allocated for the operating suite; transfer to fresh trolleys involves additional handling of sick patients, and also some congestion and delay in conveying patients to the operating room. The inclusion of transfer areas in plans of new hospitals can be justified only if it is shown to reduce the hazards of infection by reducing the levels of bacterial contamination in the aseptic zone.

In the study reported here we attempted to answer three questions: (1) does the presence of a transfer area reduce the amount of contamination introduced into the clean and aseptic zones of operating suites? (2) are the clean and aseptic zones of operating suites provided with transfer areas cleaner than those without transfer areas? (3) is the presence of a clean zone associated with less contamination in the aseptic zone than that which is found in theatre suites with no clean zone? The role of the environment as a source of infection with *Clostridium welchii* is also discussed.

METHODS

Theatres

Studies were made in the operating suites of two hospitals, including one suite with a transfer area and one with neither clean zone nor transfer area. Nine other operating theatres, including suites in eight other hospitals, were also studied in less detail.

The operating suite in Hospital 1 is of recent design; it is ventilated with a plenum system and consists of well-defined protective, clean and aseptic zones. The protective zone is separated from a clean zone by a trolley transfer area and changing rooms. The patient is transferred from a hospital trolley to a theatre trolley in this area. Ward staff accompany the patient to the transfer area and theatre staff accompany the patient to the anaesthetic room and the operating theatre. Ward staff do not enter the clean or aseptic zone without changing into theatre clothing and theatre staff should not leave the clean zone in theatre clothing or footwear. Theatre trolleys are used in the clean and aseptic zones only and are cleaned weekly or on special occasions if necessary. Hospital trolleys are also cleaned weekly and never pass beyond the transfer area into the clean zone. Occasionally, a patient is taken from the theatre to the ward on a theatre trolley (if too ill to be transferred to another trolley). The trolley is then cleaned before being returned to the clean zone. If the patient's bed is required in the theatre, the bed is cleaned before being taken into the clean zone. Floors of protective and clean zones are mopped daily and more thoroughly washed and polished weekly. Theatre floors are cleaned after each operating session with a detergent and water.

Two operating suites were investigated in Hospital 2. Suite A is of recent design, plenum ventilated and with protective, clean and aseptic zones, but no transfer area. Staff entering the clean zone change to theatre footwear or put on plastic overshoes. Suite B has no mechanical ventilation system or clean zone, and personnel in outdoor clothes and shoes may walk up to the doors of the operating theatre. In both of these operating suites patients are brought into the theatre without changing trolleys and returned from the theatre to the ward on the same trolley. The floors of the suites are washed with a disinfectant at least once a day, and trolleys are washed at irregular intervals.

None of the nine other operating suites that were studied in less detail had a transfer area, and the presence of a plenum ventilation system or well-defined clean zone was variable. In all the theatres studied, bedding from the ward was removed before the patient was taken into the clean zone, or into the theatre if there was no clean zone.

Bacteriological methods

Alne disposable surface contact plates were used for sampling floors, trolley wheels and footwear. These plates are 6.25 cm. in diameter and are marked with a grid of 21 1 cm. squares; they are a modification of sampling plates described by Hall & Hartnett (1964). The plates are filled with an agar medium (approximately 18 ml.) to provide a surface raised slightly above the rim of the plate. After drying, the plate is pressed firmly on the surface to be sampled. Nutrient agar, containing

phenolphthalein diphosphate (P.P.D. medium, Barber & Kuper, 1951), was used for total counts and counts of presumptive *Staphylococcus aureus*, and Neomycin-Nagler agar (N.N.A. medium, Lowbury & Lilly, 1955), was used for counts of *Cl. welchii*. Swabs moistened with peptone water were used for sampling trolley wheels and the framework of trolleys; they were rubbed over half of the surface of a P.P.D. plate, and this primary inoculum was spread with a loop over the other half of the plate. Counts of colonies on all plates were made after 18 hr. incubation at 37°C. Five colonies or 10% of the colonies of presumptive *Staph. aureus* (whichever was the higher) were examined for coagulase production by the slide method and a selection of colonies from N.N.A. plates was examined for inhibition of lecithinase by *Cl. welchii* antiserum. All presumptive *Staph. aureus* and *Cl. welchii* were confirmed in this sample of strains.

Trolleys

Details of sampling

Wheels. Two samples were taken from the outer surface of the tyre of each wheel with a contact plate containing N.N.A. medium. A swab, moistened with Ringer's solution, was rubbed over a further 6.0 cm. of the tyre of each wheel. Twenty-four wheels from six theatre trolleys and 24 wheels from six hospital trolleys were examined in Hospital 1. Samples were taken 6 days after the trolleys were cleaned. Twenty trolley wheels from five trolleys in Hospital 2 were similarly sampled. Trolleys used in clean and aseptic zones only are referred to as 'Theatre trolleys', trolleys used in the hospital but not in the theatres are referred to as 'Hospital trolleys', and trolleys used both in the hospital and in the theatres are referred to as 'Hospital and Theatre trolleys'.

Handles, bars and tops. A moistened swab was run along the whole length of the trolley handle on the upper and lower surface. Moistened swabs were also rubbed over the surface of approximately 6 cm. of an upper bar near the top of the trolley and of a lower bar. Samples were also taken from the top of the trolley with contact plates.

Floors

Samples were taken from hospital corridors adjacent to the theatre suites and from protective zones and theatres in the three theatre suites in Hospitals 1 and 2 and also from the clean zones in Hospital 1 and in theatre A of Hospital 2. The transfer area in Hospital 1 was also sampled. Two visits for sampling were made to each theatre suite. From ten to 28 samples were taken in each area.

Floor and air samples were also taken in 11 theatres during single operating sessions. In each theatre 250–750 ft³ of air was sampled with a slit-sampler on an N.N.A. plate, and in five of the theatres ten contact plates containing N.N.A. were taken at random sites from the floors.

Theatre footwear and outdoor shoes

Theatre shoes or boots and outdoor shoes from three hospitals were sampled. The outdoor shoes were sampled in theatre changing rooms. A sample was taken from

the heel and sole of each pair of boots or shoes with a contact plate. The heel of one shoe and the sole of the other shoe in each pair was sampled with a plate containing N.N.A. and the opposing heel and sole with a plate containing P.P.D. agar. Theatre footwear was washed weekly, or more often if contaminated, in the theatres studied.

RESULTS

Trolleys

Bacterial counts from trolley wheels are shown in Table 1. The mean counts of *Cl. welchii* from theatre trolley wheels were significantly lower than those from the wheels of hospital trolleys in the same hospital ($t = 26.63$, $P < 0.001$); there was a similar difference between the counts of *Cl. welchii* on these theatre trolley wheels and hospital trolley wheels in the other hospital (2).

Table 1. *Bacterial contamination of trolley wheels*

Hospital	Number of samples	Mean total organisms per plate	Mean <i>Staph. aureus</i> per plate	% of plates showing <i>Staph. aureus</i>	Mean <i>Cl. welchii</i> per plate
1 Theatre trolleys	24	550	18.6	12.5	3.13 ± 0.47
1 Hospital trolleys	24	834.5	18.6	41.7	67.90 ± 7.68
2 Hospital and theatre trolleys	20	287.6	6.0	35	45.10 ± 3.90

Table 2. *Bacterial contamination of trolleys*

Hospital	Site of sampling	Number of samples	Mean total organisms per plate	Mean <i>Staph. aureus</i> per plate	Mean <i>Cl. welchii</i> per plate
1 Theatre trolleys	Top	12	48.2	0.42	0.75
	Bars	12	89.3	2	—
	Handles	6	12.3	0	—
1 Hospital trolleys	Top	12	36.8	5.6	0.92
	Bars	12	88.7	0.17	—
	Handles	6	12.6	0	—
2 Hospital and theatre trolleys	Top	10	35.2	0.33	0.5
	Bars	10	9	0.1	—
	Handles	5	11.4	0	—

Mean counts of total organisms were lower from wheels of theatre trolleys than from the hospital trolleys in the same hospital, but both were higher than from the wheels of the hospital-and-theatre trolleys of Hospital 2. The mean count of *Staph. aureus* was high from the theatre trolley wheels; this was due mainly to one heavily contaminated wheel, and in the theatre trolleys the percentage of wheels contaminated with *Staph. aureus* was lower than it was in the hospital trolleys or in the trolleys from the other hospital. Table 2 shows the bacterial contamination of the trolley top and framework. Mean total counts were low from all areas,

particularly the bars of trolleys from Hospital 2. Mean counts of *Staph. aureus* were also low; the higher mean count from the tops of hospital trolleys in Hospital 1 was due mainly to one plate showing 50 colonies.

Floors

Table 3 shows the mean bacterial counts from the operating suite of Hospital 1, and Table 4 from operating suite A of Hospital 2.

In both suites a significantly lower mean count of *Cl. welchii* was found in the clean zone than in the hospital corridor (Hospital 1: $t = 10.04$, $P < 0.001$;

Table 3. *Bacterial counts of floors*

(Hospital 1 with transfer area and clean zone.)

Site of sampling	Total organisms and <i>Staph. aureus</i>			<i>Cl. welchii</i>	
	Number of plates	Mean total organisms per 100 cm ² .	Mean <i>Staph. aureus</i> per 100 cm ² .	Number of plates	Mean per 100 cm ² .
Hospital corridor	15	483.3	1	15	36.67 ± 13.37
Protective zone	20	469	8.33	20	41.17 ± 10.57
Transfer area	15	379.3	1.67	15	65.77 ± 15.13
Clean zone	25	295.7	1.33	25	2.80 ± 2.07
Theatre	20	111	0	20	0.83

Table 4. *Bacterial counts of floors*

(Hospital No. 2, Theatre A, no transfer area.)

Site of sampling	Total organisms and <i>Staph. aureus</i>			<i>Cl. welchii</i>	
	Number of plates	Mean total organisms per 100 cm ² .	Mean <i>Staph. aureus</i> per 100 cm ² .	Number of plates	Mean per 100 cm ² .
Hospital corridor	15	1052.3	8.7	20	50.50 ± 5.83
Protective zone	18	336.0	2.0	20	11.50 ± 1.87
Clean zone	28	206.0	1.7	20	1.33 ± 1.40
Theatre	18	283.3	1.0	20	0.5

Hospital 2, theatre A: $t = 10.34$, $P < 0.001$). The protective zone in theatre A of Hospital 2 shows much lower counts of *Cl. welchii* than those found in the protective zone of Hospital 1; the transfer area in Hospital 1 shows higher counts of these organisms than were found in the hospital corridor or protective zone. However, the low counts from clean zones and theatres in both suites suggest that transferring patients to clean trolleys has little effect on floor contamination in these zones. Mean total counts and counts of *Staph. aureus* also showed reductions

between contaminated, clean and aseptic areas, but no marked difference between the two theatre suites.

Table 5 shows the results from theatre B in Hospital 2. This theatre has no transfer area or defined clean zone. Mean counts of *Cl. welchii* per plate show a reduction between the hospital corridor and protective zone similar to that found in theatre A, but there was a higher mean count of *Cl. welchii* on the floor of the aseptic zone (theatre) in this suite (20.5) than in the two other suites (0.83 and 0.5). This was due mainly to two plates with counts of 71 and 24 colonies respectively. The plates with high counts were taken from near the theatre doorway. The mean count from the theatre floor was significantly lower than the count from the corridor ($t = 3.70$, $P < 0.001$).

Table 6 shows counts of *Cl. welchii* in the air from studies of eleven theatres, including two of those already described, and from the floors of five theatres. The counts of *Cl. welchii* in the air and on the floor were generally low, although the counts in the air were higher in theatres without plenum ventilation.

Table 5. *Bacterial counts of floors*

(Hospital No. 2, Theatre B, no transfer area or clean zone.)

Site of sampling	Total organisms and <i>Staph. aureus</i>			<i>Cl. welchii</i>	
	Number of plates	Mean total organisms per 100 cm ² .	Mean <i>Staph. aureus</i> per 100 cm. ²	Number of plates	Mean per 100 cm ² .
Hospital corridor and doorway	15	560	2.33	15	102 ± 19.4
Protective zone	15	346.67	0.33	15	15.1 ± 3.6
Theatre	10	286.67	0.33	20	20.5 ± 12.33

Table 6. *Cl. welchii* in the air (slit-sampling) and on the floor of operating theatres

Hospital	Plenum ventilation	Clean zone	Transfer area	<i>Cl. welchii</i> per 100 ft ³ of air	Mean <i>Cl. welchii</i> per 100 cm. ² (10 plates)
1	Yes	Yes	Yes	0.7	2.67
2A	Yes	Yes	No	0.4	2.33
C	No	No	No	3.6	2.33
3	Yes	Yes	No	0	0.67
4	Yes	No	No	0.3	1.67
5	No	No	No	1.3	—
6	No	No	No	3.4	—
7	Yes	Yes	No	0.5	—
8	Yes	Yes	No	0.8	—
9	No	No	No	1.4	—
10	No	Yes	No	0	—

— Not tested

Footwear

Bacterial counts from theatre shoes or boots and outdoor shoes from the theatre suites of three hospitals are shown in Table 7. Mean total counts and counts of *Staph. aureus* were much lower in samples taken from theatre footwear than from outdoor shoes. The mean count of *Cl. welchii* was significantly lower from theatre shoes than from outdoor shoes ($t = 28.9$, $P < 0.001$).

Table 7. *Bacterial contamination of theatre footwear and outdoor shoes from three hospitals*

Type of footwear	Total organisms and <i>Staph. aureus</i>			<i>Cl. welchii</i>	
	Number of samples	Mean total organisms per plate	Mean <i>Staph. aureus</i> per plate	Number of samples	Mean per plate
Theatre	40	360	1.1	44	10.45 ± 0.98
Outdoor	36	> 1,000	10.6	40	74.05 ± 10.52

DISCUSSION

From earlier studies on the bacteriology of air in a hospital (Lowbury & Lilly, 1958) it was concluded that *Cl. welchii*, unlike *Staph. aureus*, is introduced into buildings from the exterior; there is little evidence that it is dispersed by human carriers inside the building. These conclusions are also supported by results described here. *Cl. welchii* therefore appears to provide a good index of contamination introduced into the operating suite from outside. But the wheels of trolleys that are pushed through hospital corridors must also carry other bacteria, including staphylococci, into the operating suite. Viable counts of total organisms and of *Staph. aureus*, as well as *Cl. welchii*, are therefore relevant measurements in the assessment of contamination, though diluted by the effects of dispersal of these organisms from human sources in the operating suite.

These studies were made in ten hospitals and include comparisons of operating suites with and without clean zones and transfer areas. They showed that the wheels of trolleys used only in the operating suites ('theatre trolleys') usually had much lower levels of contamination with *Cl. welchii* than the wheels of trolleys used to convey patients from their wards to the operating suite ('hospital trolleys' and 'hospital-and-theatre trolleys'). It can therefore be assumed that fewer contaminants are introduced into the clean and probably also into the aseptic zone when there is a transfer area. However, in operating suites both with and without transfer areas the mean counts of *Cl. welchii* from samples taken in the clean zone and the theatre were significantly lower than those taken in the corridor. Counts of *Cl. welchii* from theatre floors in the suites with clean zones, with or without a transfer area, were very low, and there was no appreciable difference between suites with and without transfer areas judged by counts of *Staph. aureus* and of total organisms on theatre floors. Counts of airborne *Cl. welchii* fell within the same

range under both of these conditions, but were lower in theatres with a plenum ventilation system.

A theatre which had neither a transfer area nor a clean zone showed more *Cl. welchii* on the floor than theatres with a clean zone, whether a transfer area was present in the latter or not. It appeared that the clean zone might be an important factor in protecting the aseptic zone against contamination of floors with *Cl. welchii*. This protection in suites with clean zones may have been due to the exclusion of bacteria deposited from shoes when overshoes or theatre boots were worn by all of those who entered the theatre; it may also have been due, in part, to the presence of a longer stretch of floor between the hospital corridor and the aseptic zone, on which the more readily detachable bacteria could be deposited before the trolleys entered the theatre. The frequent washing of theatre floors is another factor which would tend to reduce the need for a transfer area; but in the progress from corridor to theatre the principal reduction in counts of *Cl. welchii* had occurred already in the clean zone, which is not washed as frequently as the theatre floor.

The bacteriological evidence suggests that, while it may be advantageous to have a clean zone, it is hard to justify the inclusion of a transfer area for trolleys in the theatre suite. This view is reinforced by the results of other studies in this laboratory which showed virtually no redispersal into the air of bacteria from floors on which they had recently settled, provided that brooms were not used for sweeping (Ayliffe *et al.* 1967). It may be thought desirable to exclude potentially contaminated trolleys from the theatre for operations on high risk cases. Transfer to the theatre table in the anaesthetic room could be arranged without a special transfer area.

Though *Cl. welchii* is a useful indicator of contamination from outside the operating suite, there is little evidence to suggest that gas gangrene occurs in operation wounds through contamination from the environment. Studies reported elsewhere on the isolation of *Cl. welchii* from the skin and on cases of post-operative gas gangrene show that self-infection is a much likelier mechanism of contamination in these cases (Ayliffe & Lowbury, 1969).

SUMMARY

The value of clean zones and of transfer areas in operating suites was assessed by comparisons of the amounts of contamination on floors, trolleys and footwear in suites with and without a clean zone and a transfer area; counts of *Clostridium welchii* were used as an index of bacterial contamination introduced into the aseptic zone from outside.

The mean counts of *Cl. welchii* on contact plates from the wheels of trolleys used to convey patients from wards to the operating suite (67.9 ± 7.68 per plate) were significantly higher than those from theatre trolleys (i.e. those used only inside a theatre suite provided with a transfer area) (3.13 ± 0.47 per plate); mean counts of total bacteria were only slightly lower on the wheels of theatre trolleys than on those of hospital trolleys. Other surfaces of hospital trolleys showed counts similar to those found on theatre trolleys.

Contact plates from floors showed significantly lower counts of *Cl. welchii* in the aseptic zone and the clean zone than in the hospital corridor, the protective zone and (when present) the transfer area.

The mean counts per 100 cm² of *Cl. welchii* were approximately the same on the floor of a theatre with a clean zone and a transfer area (0.83) as in one with a clean zone but no transfer area (0.5). Counts of total bacteria were higher in the latter. A suite with no clean zone or transfer area showed a higher mean count of *Cl. welchii* on contact plates from the aseptic zone (operating theatre) (20.5 ± 12.33 per 100 cm²). These higher levels of contamination were due to sporadic high counts of *Cl. welchii* found near the door of the theatre with no clean zone; in another theatre with no clean zone the level of *Cl. welchii* on the floor was not higher than that in the theatres with clean zones.

Theatres with plenum ventilation had lower mean counts of airborne *Cl. welchii* than those ventilated by windows: there was no significant difference in the levels of *Cl. welchii* on the floors of theatres with the two forms of ventilation.

On sampling with contact plates, theatre footwear yielded fewer total organisms, *Staphylococcus aureus* and *Cl. welchii* than outdoor shoes removed before entering the clean zone.

The hygienic value of transfer areas and clean zones is discussed. Bacteriological support could not be obtained for the former, but the latter appeared to contribute something to the cleanliness of the theatre by preventing heavy sporadic contamination.

We wish to thank Mr M. Wilkins for valuable assistance, the staff of the operating theatres for their co-operation and Alne Engineering Limited, 57 High Street, Henley-in-Arden, Solihull, for supplying disposable contact plates.

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