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Bacterial contamination in a modern operating suite, 2. Effect of a zoning system on contamination of floors and other surfaces

By A. HAMBRAEUS, S. BENGTSSON and G. LAURELL
Institute of Clinical Bacteriology, University of Uppsala, Uppsala, Sweden

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SUMMARY

In this investigation the bacterial contamination of surfaces such as walls and floors in a modern operating suite, together with surfaces of lamps in the operating theatres, and the clogs worn by staff, was studied. Counts of colony-forming units were made on impression plates containing blood-agar with Tween 80 for total bacterial counts, Baird Parker medium with egg yolk and tellurite for *Staphylococcus aureus* and trypticase peptone agar with neomycin and polymyxin for *Clostridium* spp.

The areas examined were divided into the patients' route to the operating theatre, the staff's route, and the central area containing the operating rooms, anaesthetic rooms, and exit and scrub-up areas. In the patients' route counts of total organisms ranged from about 10000 to 30000/m^2; for *Staph. aureus* the range was from 70 to 540/m^2. In the staff's route the highest count was about 70000/m^2 in the dressing area, and the numbers of *Staph. aureus* were about the same as along the patients' route. In the inner zone the counts were somewhat lower for both total organisms and *Staph. aureus*. Total counts on the floor from all areas of the inner zone were significantly higher just before the second operation than before the first operation on the same day. The total and *Staph. aureus* counts on walls, floors and lamps were the same after clean operations as after operations classified as 'contaminated' or 'dirty'.

INTRODUCTION

No single factor has had greater influence upon the design and operation of the surgical suite than the problem of wound infection. When planning an operating department great care is therefore taken to prevent transmission of infections by different routes. Most of the matters discussed in connexion with this usually deal with the control of airborne infection.

Dustborne infection has been thought to account for frequent outbreaks of infection but there is no general agreement on this matter. It is, however, well known that floors in hospitals, including those in operating departments, may become contaminated with large numbers of bacteria. Zoning arrangements have been used in order to prevent spread of floor contamination to operating theatres. Great effort has also been made to reduce floor contamination by various methods

of cleaning such as oiling of floors, use of oiled mops and special vacuum cleaners, as well as use of several disinfectants (Van den Ende, Lurk & Edward, 1960; Bate, 1961; Finegold *et al.* 1962; Babb, Lilly & Lowbury, 1963; Versley & Michaelson, 1964).

Few investigations have been made on microbial contamination on hospital room walls. In investigations made (Wypkema & Alder, 1962; Froud, Alder & Gillespie, 1966; Petersen, Marshall & Collins, 1973) the degree of contamination on the walls has been low and on the basis of available data the U.S. Department of Health, Education and Welfare (1970) has recommended that only grossly soiled areas of isolation room walls should be washed with germicidal detergent solution as part of the terminal cleaning.

The contamination of other surfaces in the operating theatre, such as operation lamps, has been very little studied. One investigation by Froud *et al.* (1966) showed high levels of contamination.

This report describes a study of surface contamination in a modern operating suite planned according to the principles laid down by the Operating Theatre Hygiene Subcommittee of the Medical Research Council (Report, 1962). The purpose of the study, which was carried out from June to December 1972, was to find out if the planning, in combination with the cleaning procedures, had any effect on surface contamination and if the environmental conditions in the operating theatre could be considered satisfactory.

MATERIALS AND METHODS

Operating suite

The layout of the operating suite can be seen in Fig. 1. The suite has 12 operating theatres, of which 8 are shown in Fig. 1, situated in rows of four between two corridors. One corridor is used for transporting patients and used material. The other is used by staff and for transport of sterile equipment. The hand-washing facilities (scrub-up) for the operating team are placed in this corridor. Each operating room has its own anaesthetic room but shares the exit area with another operating room.

Staff's route to the operating suite

Staff enter the operating suite via changing rooms in the basement. They enter the changing room from a public corridor and undress in the 'dirty' locker area where they have lockers for their street clothing. Toilets and showers are also situated in this area. In the 'clean' dressing area scrub suits, caps and clogs are stored. Staff members are not supposed to walk from the dirty to the clean area with their ordinary street clothing and shoes on. After dressing they pass directly via a corridor to lifts which take them to the operating suite.

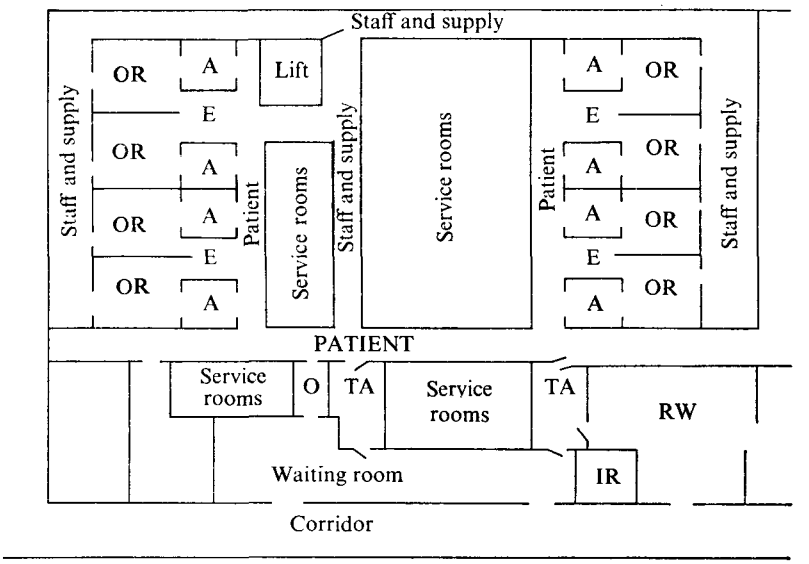

Fig. 1. Layout of the operating suite. A, Anaesthetic room; E, exit area; OR, operating room; TA, transfer area; IR, isolation room; RW, recovery ward; O, office.

Patients' route to the operating suite

The patients are taken, in their beds, from the wards to a waiting room outside the operating suite, where preoperative shaving is carried out. In a transfer room divided into a dirty and a clean area by a line across the middle of the floor the patient is then moved by outside staff from her bed to the top of the operating table. She is then taken to the anaesthetic room by staff from the operating suite.

Cleaning

In the operating suite

The corridors used for patient transport are cleaned with a detergent every night and mopped with a moist mop every morning. The corridors used by staff only are cleaned with a detergent several times a day. After clean operations, floors in the operating theatres are mopped with a detergent. If, according to local rules, the operation is classified as contaminated or dirty the floor is afterwards cleaned with a phenol disinfectant. Every night the floors are washed with a phenol disinfectant. Walls and operation lamps are washed every night and also after a contaminated or dirty operation. No disinfectant is used. The lamps are, however, often polished with ethyl alcohol.

Outside the operating suite

The patient corridor outside the operating suite is cleaned with a detergent once a week and mopped with a moist mop when visibly dirty. The floor in the patients' waiting room is mopped with a moist mop every day and cleaned with a detergent three times a week. The floor of the public corridor leading to the changing rooms is cleaned with a detergent three times a week.

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Cleaning of clogs

The clogs used in the operating suite are cleaned with a disinfectant every night.

Bacteriological methods

In series of parallel samplings from the floor with Rodac impression plates containing blood agar with and without Tween 80 it was found that the blood agar plates with Tween 80 gave a higher yield of bacteria, thus this combination was used for total bacterial counts.

For sampling of *Staph. aureus* several methods were tried, including replica plating from plates with blood agar and Tween 80 to selective media. Since Rodac plates containing Baird Parker Medium (Oxoid), egg yolk and tellurite gave the highest yield, this medium was used throughout the study for sampling of *Staph. aureus*. For sampling of *Clostridium* spp. TSN agar (trypticase peptone agar with neomycin and polymyxin, BBL) was used.

Areas sampled

Total number of bacteria in different zones

Patients' route to the operating suite. On each of 29 days 9 samples were taken from the corridor outside the waiting room, from the 'dirty' and the 'clean' side of the transfer area and from the corridor of the operating suite close to the transfer area. Regardless of activity all samples were taken around noon.

Staff's route to the operating suite. On each of 21 days 6 samples were taken from the locker side and the clean area in two of the changing rooms, from the public corridor and the clean corridor close to these two changing rooms, from the two lifts, and from the staff corridor just outside these.

Operating rooms. From four different operating rooms and their corresponding anaesthetic rooms, exit and scrub-up areas samples were taken before every operation performed during the day on 5–7 days. Twelve samples were taken from the operating room and 6 from each of the other areas. The mean number of operations per day per room was 2·0.

Total number of bacteria on walls and lamps in operating rooms

These experiments comprised 36 operations performed during 12 days. Thirty-six samples were taken on each occasion from the wall of the operating room at three different levels and 12 from the floor just beneath the wall. Five were taken from the lamp.

In another 44 operations performed during 33 days both the total number of bacteria as well as the number of *Staph. aureus* was estimated. Sampling was done as described above except that floor samples were taken from the centre of the room and samples for total number of bacteria on the wall at only one level.

The total number of samples in this part of the investigation was about 7000.

Number of Staph. aureus *in different zones*

On each of 12 days 6 samples were taken to estimate the contamination with *Staph. aureus*. The samples were taken from the same areas as has been described under staff's route, patients' route and operating rooms.

Number of Staph. aureus *on walls and lamps in operating rooms*

On 44 operations 36 samples were taken from three different levels from the walls, 12 from the centre of the floor and 5 from the lamp.

In total about 3700 samples were examined for *Staph. aureus*.

Number of Clostridia on floors in the different zones

Samples for *Clostridium* spp. were taken on 17 days and on 21 days from the same areas along patients' and staff's route as described above. Four impression plates were taken from areas along the patients' and three from areas along the staff's route. Altogether some 1200 samples were examined.

Samples from clogs

During 27 days samples were taken with impression plates from 20 pairs of clogs in the morning and 20 pairs in the afternoon. Two plates were used for each pair of clogs and both total number of bacteria and *Staph. aureus* were estimated.

Calculation

For each series of investigation the differences between the areas have been calculated for the days in question. Statistical analysis of variation has been made after logarithmic transformation.

RESULTS

The total number of bacteria and *Staph. aureus* in different areas can be seen in Fig. 2. Both are shown as mean number per impression plate and per m^2. In the patients' route the lowest value is that found in the corridor outside the waiting room where the count was 10000/m^2 which is significantly lower ($P < 0{\cdot}001$) than elsewhere in this series. There is no difference between the waiting room and the dirty and clean side of the transfer area which all have about 30000/m^2. In the patient corridor the count was 22000/m^2 which is significantly lower than in the dirty side of the transfer area, 31000/m^2 ($P < 0{\cdot}05$).

As expected the number of *Staph. aureus* found is much lower than the total number of bacteria. They do not always correspond and the results are sometimes surprising. So, the number of *Staph. aureus* is 70/m^2 on the dirty side of the transfer area but 541/m^2 on the clean side. The number of samples taken is, however, limited and the difference not statistically significant.

The right part of the figures shows the number of bacteria along the staff's route. The highest value is found in the dressing area, the mean number of bacteria being about 70000/m^2. This is significantly higher ($P < 0{\cdot}001$) than the values found in the other areas.

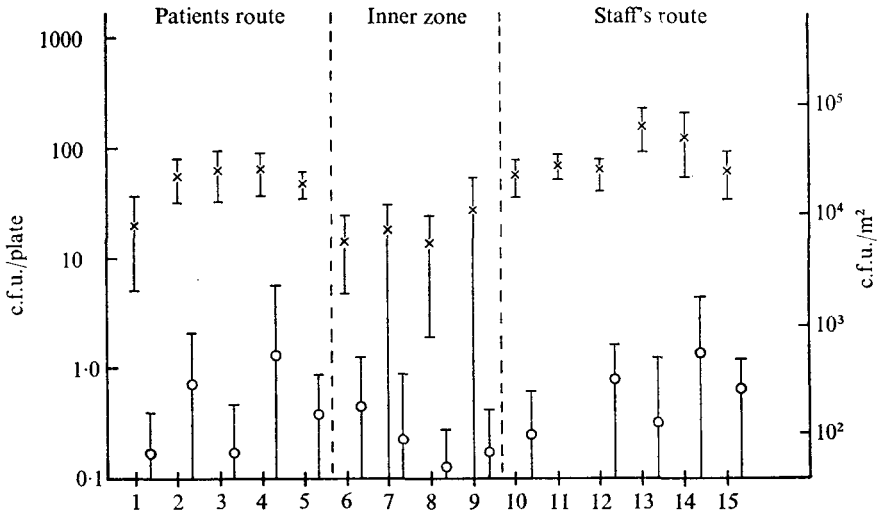

Fig. 2. Total number of bacteria and number of *Staph. aureus* in different areas in the operating suite. 1, Corridor outside waiting room; 2, waiting room; 3, transfer room 'dirty' side; 4, transfer room 'clean' side; 5, patient corridor; 6, anaesthetic room; 7, operating theatre; 8, exit area; 9, staff corridor; 10, upper corridor, operating suite; 11, lifts (total no. bacteria only); 12, inner basement corridor; 13, 'dirty' locker area; 14, clean dressing area; 15, public corridor. ×, Mean number total bacteria; ○, mean number *Staph. aureus*; ——, ± one standard deviation.

The number of *Staph. aureus* per m^2 was about the same as in the areas along the patients' route.

The results from the inner zone are of special interest since this area includes the operating theatre with its anaesthetic room and exit area where the highest hygienic standard should be maintained. The values are mean values from 22 observations before the first operation, 17 before the second, and 3 before the third operation of the day. When comparing different areas it can be seen that the number of bacteria per m^2 is slightly higher in the theatre, 7200/m^2, than in the anaesthetic room and exit area, 5400/m^2. The highest values are found in the staff corridor. The differences are not significant.

Comparisons were also made between the floor contamination before the first and the second operation. The results can be seen in Fig. 3. In all areas there is a significantly higher number of bacteria on the floor before the second than before the first operation. The number of third operations were too few to be included. The number of *Staph. aureus* found in different areas were about the same as in other areas.

This study was also extended to include contamination of walls and lamps in the operating room. The results with regard to the total number of bacteria can be seen in Fig. 4. As can be seen from this figure there was no statistically significant difference between the contamination on the lamps compared with that on the floors.

The environmental contamination in operations classified as contaminated or

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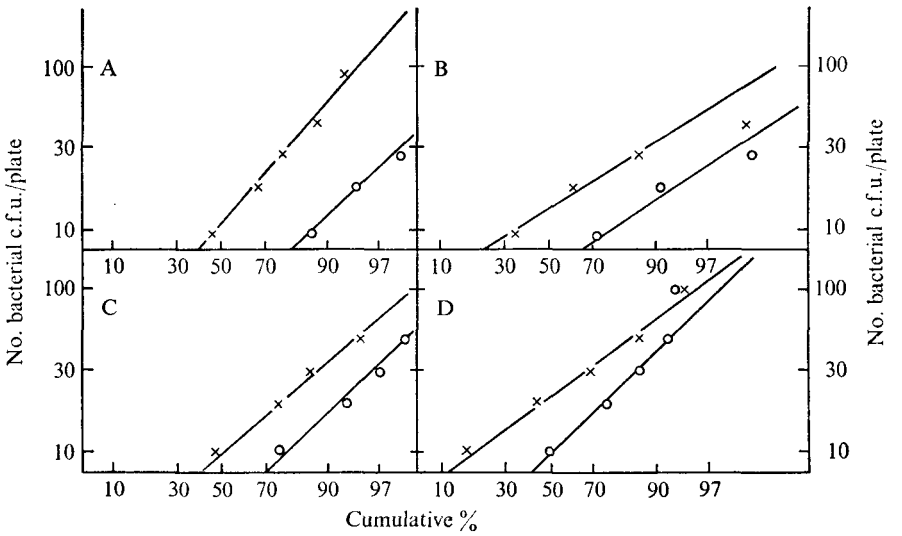

Fig. 3. Distribution of total number of bacteria on the floor before the first and second operation. ○, First operation; ×, second operation. A, operating theatre; B, anaesthetic room; C, extubation room; D, staff corridor.

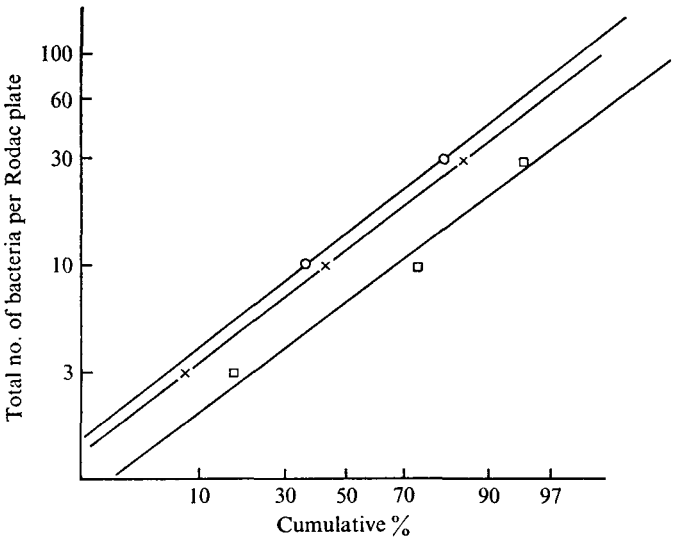

Fig. 4. Distribution of the total number of bacteria on floor, wall, and lamp. ○, Floor; ×, lamp; □, wall.

dirty cases was also studied. Among the 44 operations 19 were classified as contaminated or dirty according to local rules. Eight were operations on the gastro-intestinal tract, 6 were amputations, and the remainder were other infected cases. The result can be seen in Table 1, which shows that there was no significant difference between the total number of bacteria after clean and infected operations.

Staph. aureus were found on the walls in only 4 operations, on the floors in 15 and on the lamps in 8. The mean value of c.f.u. of *Staph. aureus*/m² after clean

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Table 1. *Bacteria found on walls, floors and lamps, after 25 clean and 19 contaminated or dirty operations*

	Type of operation	
Walls	Clean	Contaminated or dirty
Total bacteria*	3700	1000
*Staph. aureus**	3·2	2·2
No. of operations with *Staph. aureus*	2	2
Floors		
Total bacteria	11000	8700
Staph. aureus	48	33
No. of operations with *Staph. aureus*	7	8
Lamps		
Total bacteria	8600	6900
Staph. aureus	11	35
No. of operations with *Staph. aureus*	2	6

* All counts expressed as the mean number of c.f.u. per m^2 per operation.

and infected operations was 3·2 and 2·2 for walls, 48 and 33 for floors and 11 and 35 for lamps.

Clostridia were found along the patients' route in 15 out of 340 impression plates. Six of these were from the same day. All areas were represented except the corridor outside the waiting room.

In 751 samples taken along the staff's route *Clostridia* were found in 21. Of these 13 were from the public corridor and the dirty locker side of the changing room. The remaining 8 were evenly distributed in cleaner areas.

The clogs were heavily contaminated during the day. Assuming a sole area of about 1/80 m^2 the mean total number of bacteria per clog was 109, i.e. $8{\cdot}7 \times 10^3/m^2$, before use, and 1580, i.e. $1{\cdot}3 \times 10^5/m^2$, after use. The corresponding values for *Staph. aureus* was 0·03/clog, i.e. $2{\cdot}5/m^2$, before use, and 12·2/clog, i.e. $980/m^2$, after use.

DISCUSSION

This paper presents the effect of a zoning system in reducing bacterial surface contamination on floors in an operating suite planned according to modern principles (Report, 1962).

In transport areas for patients the total number of bacteria was more or less the same in different zones. The contamination of clean and dirty zones in the transfer area was the same. The corridor outside the operating suite was the least contaminated area.

The contamination in the transport area for staff was about the same as that for the patients. The most contaminated of all areas studied was the changing room and there was no difference between the dirty locker and the clean dressing area. The lowest values were found in the public corridor outside the changing room.

Both the public corridor and the corridor outside the patients' waiting room are seldom cleaned. The reason that they do not show more contamination may be that the population density in these corridors is low. The changing rooms are small and they are almost always occupied by people, which can explain the high degree of contamination. The results obtained disagree with the theory that a division of transfer areas into 'clean' and 'dirty' sides results in a reduction of the bacterial contamination on the clean side. This has already been pointed out by Ayliffe, Babb, Collins & Lowbury (1969).

The contamination in the inner zone consisting of operating theatre, anaesthetic room and exit area is lower than in most other zones. This can at least partly be due to a zoning effect since the traffic in the operating theatre with adjacent rooms is probably lower than in the changing rooms and corridors. The floors in this inner zone are, however, also cleaned with a disinfectant in the afternoon which might contribute to low values in samples taken early next day. Irrespective of cleaning procedures the values found before the second operation were significantly higher in all rooms in the inner zone. This agrees with the results of Ayliffe, Collins & Lowbury (1966), who showed that the cleaning of floors with a disinfectant was more efficient than the cleaning with a detergent and that, irrespective of cleaning method used, the rate of recontamination was rapid.

Sampling of pathogens may give a clearer answer as to whether the zoning system is effective. The recovery of *Staph. aureus* from different areas did not, however, differ much between the zones. In general the contamination seems low, *Staph. aureus* being about 1 % of the total number of bacteria. The contamination of the inner zone is lower than for other areas but again this can partly be the result of more effective cleaning. It is probably not meaningful to try to show small differences between different zones within the operating suite. It might be of greater interest to compare the contamination in intensive care units and surgical wards with that of operating suites to see whether there are any general differences.

The investigation of other surfaces showed the same total number of bacteria on the operation lamp as on the floor as already found (Froud *et al.* 1966). This seems to indicate that sedimentation of bacteria is a more important cause of contamination of the theatre floor than the transport of bacteria by shoes and wheels. As lamps are situated above the patient and bacteria-carrying particles may be redistributed into the air when the lamp is moved around, cleaning of lamps after each operation should be important (Williams, Blowers, Garrod & Shooter, 1966). The contamination of the wall was about half that of the floor and the lamp.

The total recovery of *Staph. aureus* from the Rodac plates was 5·9 % from floors, 4·4 from lamps and only 0·7 % from walls. The mean contamination on the walls was around 3 c.f.u./m^2, which is only one tenth of that found on the floors. This contamination might seem unexpectedly high considering the better ventilation in the operating theatres. These values from walls are higher than those of Peterson *et al.* (1973) who isolated *Staph. aureus* in 0·3 % of samples from walls in isolation rooms. It is, however, lower than the values found in this hospital in isolation rooms in a burn unit, where *Staph. aureus* were found in 27·7 %, and in

isolation rooms in a department of infectious diseases where 1·8 % of the samples were positive for *Staph. aureus*. One explanation can be that air is evacuated through ventilator grilles at the bottom of the wall and that this might increase the risk for airborne contamination. One contributory factor could be that the staff in the busiest part of the theatre contaminate the walls with bacteria from their clothes.

On both walls, floors, and lamps the total number of bacteria and the number of *Staph. aureus* were the same after clean operations and such classified as contaminated or dirty.

Clostridium sp. were found on only 3·3% of all Rodac plates, which is much lower than has been shown in some investigations from older English hospitals (Sewitt, 1953; Lowbury & Lilly, 1958; Ayliffe & Lowbury, 1969). The investigations of the clogs used in the suite showed that they were contaminated during the day but were effectively cleaned every night. As they were more heavily contaminated than the floor they may have contributed to the contamination of the floors in the cleaner areas.

To sum up, it seems likely that the layout of this operating suite with different clean zones contributed to the fairly low degree of bacterial contamination of the floor and other surfaces in the operating theatre. As floor contamination in areas frequently cleaned is mainly due to sedimentation the reason for this is probably the reduction in staff traffic into the cleaner zones. The study showed that the contamination in the operating theatres is the same after contaminated or dirty and clean operations and there seems to be no need for more extensive cleaning procedures with the use of disinfectants after these operations as compared with clean operations.

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