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Airborne contamination in an operating suite: report of a five-year survey

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SUMMARY

Airborne contamination in an operating suite was studied with a slit sampler, settle plates and a light-scattering particle counter. In conventional operating rooms there was a significant difference between the empty rooms and rooms in use; the mean total bacterial count by a slit sampler changed from 1·1 in empty to 42·5 c.f.u./m^3 in use (39 times increase), the settle plates count changed from 1·5 to 17·4 c.f.u./m^2/min (12 times increase), and the mean total particle count changed from 56·9 to 546·7/l (10 times increase) respectively. The increase was caused mainly by persons present in the room.

Another difference was found between zones in the operating suite; the bacterial count in the clean area doubled in the semi-clean area and further doubled in the dirty area in slit sampler count as well as settle plates count, and particle count in the clean area increased by 14 times in the semi-clean and dirty areas. This difference resulted from the different quality of the ventilating system.

Air cleanliness of operating rooms in use by persons present in the room dropped to a level between the clean and the semi-clean area in spite of the high quality of the ventilating system.

Bacterial species identified were mostly coagulase negative staphylococci and micrococci.

Our study indicates that reduction of airborne contamination in an operating suite is accomplished by the combination of an efficient ventilating system and the restriction of the number of persons present in the room.

INTRODUCTION

The importance of airborne bacteria as a cause of post-operative wound infection in operating rooms has been the subject of animated controversy. Recently, in a multicenter study of sepsis after joint replacement, a good correlation (correlation coefficient 0·90, $P < 0·02$) between the airborne bacterial contamination and the incidence of joint sepsis was demonstrated (Lidwell *et al.* 1982; Lidwell *et al.* 1983). The reduction of airborne bacteria is therefore of prime importance in the operating room.

With the installation of a new ventilation system in 1978, airborne contamination in our operating suite has been followed over a period of five years. This paper reports the results of periodic examination of airborne bacteria and airborne particles in the operating suite of the Nagoya University Hospital in evaluating the relationship between efficiency of the ventilating system and the cleanliness of the operating room environment.

MATERIALS AND METHODS

The operating suite of the Nagoya University Hospital is divided into three zones by two doors located in the middle corridor. The left zone, which includes 13 operating rooms, is a clean area, the area between the two doors is semi-clean, containing doctors and nurses lounges, while the right zone is the dirty area, which includes dressing rooms and the patient's entrance. The rooms of the suite are arranged so that cleanliness increased through zones from right to left. The suite is equipped with a positive-pressure, fresh-air ventilation system. The quality of supplied air differs among the different zones. The operating rooms are supplied air through a medium-efficiency bag filter (97 % by colorimetry) and a high-efficiency particulate air (HEPA) filter (99·97 % by DOP test). The clean area, excluding operating rooms, is supplied air through a medium-efficiency bag filter, and the semi-clean area is supplied air via a medium-efficiency roll filter (90 % by colorimetry); the dirty area air is passed over an electrostatic cleaner. A horizontal-flow bioclean operating room (BCOR) is located at the left end of the corridor, which has partial air recirculation. The air exchange rate is 180/h in BCOR, 20/h in operating rooms and in the other areas ranges from 6 to 15/h.

Airborne bacteria

Airborne bacteria were sampled both by a large-volume Mattson-Garvin 200J slit sampler (Mattson Garvin Co., Florida, U.S.A.) and settle plates at 4- to 6-month intervals. Nutrient agar was used for both the slit sampler plates (150 mm in diameter) and settle plates (90 mm in diameter). The slit sampler collected air at the rate of 28·3 litre per minute for 60 min in one revolution (1·7 m^3) and was secured 50 cm above the floor. During surgery the sampler was placed within approximately 1 m of the operating table. Settle plates were exposed for 30 min at a level lower than 120 cm above the floor. There were 30 sampling sites in the operating suite, and at each examination the same sampling site was used. However, sampling in dressing rooms was not carried out by slit sampler. All plates were incubated aerobically for 48 h at 37 °C, after which the colonies were counted.

Airborne particles

Volumetric particulate sampling was accomplished using a light-scattering particle counter Rion Kc-01 (Rion Co., Tokyo, Japan). Measured particle size was 0·5 μm and/or larger. Particulate sampling in operating rooms and BCOR was performed at the HEPA filter face, at 50 cm above the operating table and at the air discharge vent near the floor. The samplings in other areas were performed at the same site as with the slit sampler.

In 1976, however, two years before the installation of the new ventilation system, airborne particles had been measured in operating rooms in which air was supplied solely through an electrostatic cleaner.

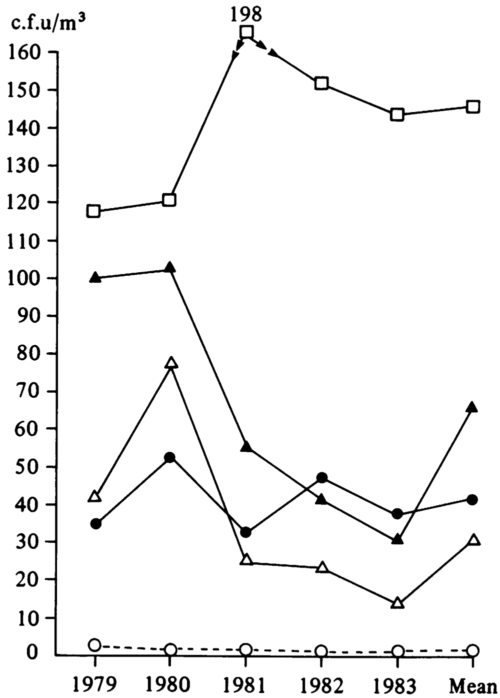

Fig. 1. Change of airborne bacterial counts by slit sampler in various areas of the operating suite during five-year period. ○---○, Empty operating rooms; ●——●, operating rooms in use; △——△, clean area; ▲——▲, semi-clean area; □——□, dirty area.

RESULTS

Airborne bacterial counts by the slit sampler

Since June 1979, 115 samplings have been carried out. Fig. 1 illustrates changes of mean colony count in the past five years. The counts in the empty operating rooms were invariably the lowest and stable throughout the test periods. The values in operating rooms in use varied between 32 and 53 c.f.u./m³. However, the counts in the other areas varied markedly from year to year, and both the counts and variation were greatest in the dirty area.

The mean total count of all samplings is shown in Table 1. In operating rooms, a significant difference ($P < 0{\cdot}005$) exists between the empty rooms and rooms in use; in BCOR the count was 0·1 in empty rooms and increased by 26 times while in use (2·6 c.f.u./m³) when the average number of staff present in the room was eight. In conventional operating rooms, the count of 1·1 in empty rooms increased by 39 times and resulted in 42·5 c.f.u./m³, and the staff number in the rooms varied between 4 and 16; averaging 7 or 8. The cleanliness of operating rooms in use dropped to a level between the clean and the semi-clean area. An excellent correlation exists between the quality of ventilating system and the colony count. The count in the clean area doubled in the semi-clean area, and further doubled in the dirty area. The difference was significant ($P < 0{\cdot}01$ or $0{\cdot}05$) between these three areas.

Table 1. *Mean total count of airborne bacteria collected by a slit sampler during five-year period in the operating suite*

Location	Empty: c.f.u./m^3 (standard deviation)	Empty: No. of samples	In use: c.f.u./m^3 (standard deviation)	In use: No. of samples
Bioclean operating room	0·1 (±0·3)	12	2·6 (±2·7[1])	5
Operating rooms	1·1 (±1·1)	25	42·5 (±25·1[1])	37
Clean area	—	—	31·3 (±25·1)	16
Semi-clean area	—	—	66·8 (±56·2[2])	10
Dirty area	—	—	147·2 (±57·3[3])	10

[1] Significant difference from empty, $P < 0{\cdot}005$.
[2] Significant difference from clean area, $P < 0{\cdot}05$.
[3] Significant difference from semi-clean area, $P < 0{\cdot}01$.

Table 2. *Mean total count of airborne bacteria collected by settle plates during five-year period in the operating suite*

Location	Empty: c.f.u./m^2/min (standard deviation)	Empty: No. of samples	In use: c.f.u./m^2/min (standard deviation)	In use: No. of samples
Bioclean operating room	0	17	2·8 (±2·8[1])	6
Operating rooms	1·5 (±3·1)	55	17·4 (±15·1[1])	68
Clean area	—	—	9·1 (±8·4)	45
Semi-clean	—	—	20·2 (±19·6[2])	37
Dirty area	—	—	45·4 (±38·1[2])	42
Dressing rooms	—	—	137·6 (±98·0[2])	30

[1] Significant difference from empty, $P < 0{\cdot}001$.
[2] Significant difference ($P < 0{\cdot}001$) between clean and semi-clean area, semi-clean and dirty area, dirty area and dressing rooms.

Table 3. *Mean total count of airborne particles during the latest five-year period and 1976 in the operating suite (measured particle size was 0·5 μm and/or larger)*

Location		Empty: Particle/l (standard deviation)	Empty: No. of samples	In use: Particle/l (standard deviation)	In use: No. of samples
BCOR	Filter face	0·1 (±0·1)	18	—	—
	Table	2·3 (±2·6)	18	—	—
	Air discharge	8·3 (±8·5)	18	—	—
OR	Filter face	0·5 (±1·3)	87	0·6 (±1·3[3])	60
	Table	56·9 (±55·4)	87	546·7 (±427·5[1])	60
	Air discharge	86·3 (±74·6)	87	755·2 (±525·0[1])	60
Clean area		—	—	334·7 (±250·0)	18
Semi-clean area		—	—	4714·1 (±2471·1[2])	45
Dirty area		—	—	5016·0 (±1451·6)	18
OR in 1976		3803·2 (±550·4)	8	4980·4 (±667·2[1])	8

BCOR; Bioclean operating room: OR; Conventional operating room.
[1] Significant difference from empty, $P < 0{\cdot}001$.
[2] Significant difference between clean and semi-clean area ($P < 0{\cdot}01$).
[3] No difference from empty.

Table 4. *Bacterial species collected by a slit sampler and settle plates during surgery in a conventional operating room*

Species	Slit sampler Number	Slit sampler %	Settle plates Number	Settle plates %	Total Number	Total %
Gram-positive cocci						
Coagulase-negative staph.	31	(39·7)	120	(70·6)	151	(60·9)
Micrococci	23	(29·5)	14	(8·2)	37	(14·9)
Staph. aureus	0		11	(6·5)	11	(4·4)
Streptococci	2	(2·6)	1	(0·6)	3	(1·2)
Others	9	(11·5)	14	(8·2)	23	(9·3)
Gram-positive rod						
Bacillus spp.	13	(16·7)	5	(2·9)	18	(7·3)
Others	0		3	(1·8)	3	(1·2)
Gram-negative rod						
Alcaligenes spp.	0		1	(0·6)	1	(0·4)
Others	0		1	(0·6)	1	(0·4)
Total	78	(100·0)	170	(100·0)	248	(100·0)

Airborne bacterial counts by settle plates

Settle plates samplings were carried out on 300 plates. Yearly variation of settle plates counts was relatively small except in dressing rooms which varied between 60 and 193 c.f.u./m^2/min. As shown in Table 2, the lowest count was zero in an empty BCOR in 17 samplings, and the highest count was 137·6 c.f.u./m^2/min in the dressing rooms. Settle plates counts displayed the same trends as slit sampler counts; the values in the clean area doubled in the semi-clean area and further doubled in the dirty area. In operating rooms the count in empty rooms increased by 12 times when in use. The staff numbers in the room varied between four and twelve. Statistical difference was significant at the level of 0·001 between all empty areas and those in use.

Airborne particles

The mean total count of particles is shown in Table 3. The quality of the ventilating system reflects directly on the particle count. In conventional operating rooms the count at the filter face was stable when empty and in use; the values at the operating table and air discharge vent in the empty rooms changed from 56·9 to 546·7/l and from 86·3 to 755·2/l during use respectively. The count in operating rooms empty and in use with the old ventilation system was 3803·2 and 4980·4/l respectively. These values were 67 and 9 times higher than the corresponding values in operating rooms with the new ventilation system. The values in a conventional operating room in use dropped to a level between the clean and semi-clean areas. The difference between clean and semi-clean area was significant ($P < 0·01$) but there was no difference between semi-clean and dirty area.

Bacterial species

Identification of 248 colonies collected during surgery in a conventional operating room was performed. As can be seen in Table 4, there was a moderate difference between bacteria collected by slit sampler and settle plates. Coagulase-negative staphylococci occupied 39·7 % in slit sampler and 70·6 % in settle plates. However, micrococci and *Bacillus* species were found far more frequently in the slit sampler. *Staphylococcus aureus* was found in settle plates (6·5 %), but none were observed with the slit sampler. Generally, the most frequently found species were coagulase-negative staphylococci, micrococci and *Bacillus* species, and they comprised 82·3 % of the total.

DISCUSSION

This study demonstrated two important measures in reducing airborne contamination in the operating suite. These are an efficient ventilating system and the restriction of the number of persons present in the operating rooms.

The importance of the ventilating system in reducing post-operative wound infection was clearly demonstrated by Charnley (1972) and Lidwell *et al.* (1982). The standard of air cleanliness in the bioclean operating room proposed recently by Whyte *et al.* (1983) suggests 0·5 c.f.u./m^3 at the filter face, 10 c.f.u./m^3 within 30 cm of the wound and 20 c.f.u./m^3 in the remaining area. The standard of air cleanliness in conventional operating rooms is not established as yet. However, a DHSS document on 'Ventilation of operating departments (1983)' indicates that aerobic cultures on non-selective medium should not exceed 35 bacterial particles per m^3 of ventilating air.

In our operating suite, an old ventilation system together with an electrostatic cleaner was replaced in 1978 by a new positive pressure ventilation system equipped with a HEPA filter. As a result, air cleanliness expressed by airborne particle count improved markedly both in the empty (67-fold) and in use states (9-fold). The quality of the ventilating system varies according to the cleanliness appropriate for each proposed zone. This resulted in a twofold difference between clean and semi-clean, and between semi-clean and dirty area in the airborne bacterial counts both by a slit sampler and settle plates.

The second important factor affecting air cleanliness demonstrated by this study was the number of persons present in the room. This effect was indisputably shown by all measurements in operating rooms either empty or in use; the values of slit sampler, settle plates and airborne particles in empty rooms increased by 39, 12 and 10 times while in use respectively. Fitzgerald (1979) also reported 18–19 times difference between operating rooms empty and in use.

Mean value of airborne bacteria measured by a slit sampler in operating rooms in use was reported to be 164 c.f.u./m^3 and ranged from 51 to 539 c.f.u./m^3 (Lidwell *et al.* 1983). On settle plates count Bengtsson, Hambraeus & Laurell (1979) reported 9·0–14·3 c.f.u./m^2/min during surgery. If we take the sedimentation rate of 0·3 m/min (Noble, Lidwell & Kingston, 1963) the settle plates counts correlate well with the slit sampler count in operating rooms in use, and in clean, semi-clean and dirty areas. However, in very clean areas such as the bioclean operating room and empty operating rooms, no such correlation was found.

As an indication of air cleanliness in an operating suite, the slit sampler and settle plates count is useful. However, particle count is not recommended due to the wide variation. Based on the present observations, the measurement of air cleanliness in an operating suite should be carried out when rooms are empty and in use. The measurement in the empty state indicate the efficiency of the ventilating system. The in-use state reflects the combined effect of the ventilating system and other contaminating factors such as the number of persons in the room, the frequency of door opening, as well as the activity and clothing of personnel.

Our results demonstrated a difference between bacteria collected by the slit sampler and settle plates. The former reflected environmental bacteria and the latter was mainly derived from personnel in the operating room.

The conclusions drawn from the present study agree with other reports. Improvement of the ventilating system and the restriction of persons in an operating room is essential if airborne contamination is to be reduced in an operating suite.

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