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Comparison of three ventilating systems in an operating room

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INTRODUCTION

There is evidence to support the proposition that surgical wounds can be infected by the sedimenting into them of pathogenic organisms which have been dispersed into the air from persons entering the operating room and from non-sterile materials brought in with the patient (e.g. Blowers, Mason, Wallace & Walton, 1955; Shooter, Taylor, Ellis & Ross, 1956). Some controversy has arisen as to whether downward displacement ventilation, the so-called piston system, might be substantially more effective than other methods of ventilating operating rooms in reducing the risk of contamination of surgical wounds by airborne organisms.

An attempt was made to resolve this controversy by installing alternative ventilation systems in one operating room in such a way that a change could be made from any one to any other in a matter of minutes. It was then possible to examine the differences due to the ventilation systems uncomplicated by the many other differences, for example in the methods of work and in the carrier states of the surgical team, which are inevitably involved in a comparison between different hospitals or even between different operating rooms in the same hospital.

Theoretical considerations, and some evidence from experiments with tracer gases, suggest that in an operating room ventilated by an effective downward displacement system the exposure of the wound to bacterial contamination arising from the activities of persons in the operating room would differ substantially according to the position in the room of the person dispersing the organism and according to whether the major part of the dispersion occurred from the upper or from the lower parts of the body (Lidwell & Williams, 1960). The directed air movements should ensure that contamination dispersed peripherally in the room did not reach the sensitive area over and around the operation wound, and that contamination dispersed at a low level did not rise to this region. On the other hand, the generally low rates of air movement might result in an undue exposure to contamination dispersed from the upper part of the bodies of the surgical team clustered around and leaning over the patient. Some observations on the dissemination of bacteria into the air of a cubicle from volunteers dressed in surgical clothes have been published (Bethune, Blowers, Parker & Pask, 1965). Dispersal from below the waist accounted for two-thirds or more of the total.

By sampling the air simultaneously at the centre of the room, as near as possible

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to the operation site, and peripherally, near the point at which the ventilating air was discharged from the room, and by relating organisms recovered to the sources from which they had been dispersed, it should be possible to demonstrate the practical importance of the different sites of dispersion and the effectiveness of the ventilation system in protecting the wound from them. Similar observations made with a ventilation system giving a high degree of turbulent mixing of the air throughout the room would not be expected to show any substantial difference between the organisms recovered from the two sampling points whatever the site and location of dispersion.

METHODS

The installation

During alterations to the operating suite at the West Herts. Hospital, Hemel Hempstead, Hertfordshire, ventilation equipment was installed in one of the twin operating rooms in the suite so that it was possible to select, from within the operating room itself, any of three alternative systems of air supply.

The arrangement of the ventilating fittings and some other details of the construction and lay-out of the operating room and suite are shown in Fig. 1.

The three systems were:

System A. Downward displacement. The ventilating air was introduced through six diffusers A 1–A 6 spaced, as far as possible, evenly over the ceiling.

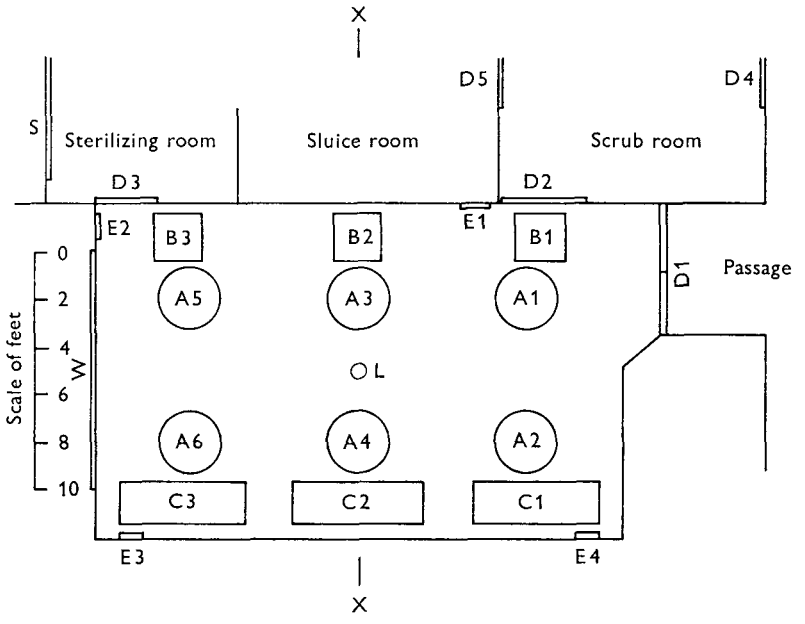
System B. Moderate velocity turbulence. The air entered the room through three grilles B 1–B 3 fitted with directional deflectors. These deflectors were adjusted so as to direct all three air streams towards and above the operating table. The velocity of air movement 1 ft. above the table averaged around 25 ft./min. when the rate of air supply was 1400 ft^3./min.

System C. Low velocity turbulence. The air was introduced vertically downwards at low velocity through three large grilles C1–C3 in the ceiling along one side.

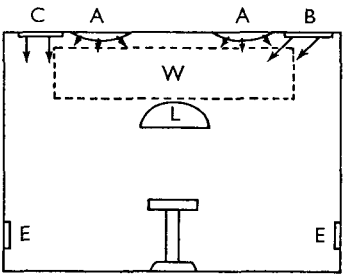
The rate of air supply through any of the three systems could be varied up to a maximum of about 1700 ft.^{3}/min. (with clean filters). The air flow at any time could be read off from an indicating meter connected in the common ductwork for the three systems. Air temperatures were indicated by remote reading thermometers placed in the operating room with sensing elements in the inlet air duct and in one exhaust port, E 3. The majority of the observations were made with air flows within the range 1200–1500 ft^3./min. In this room (volume 3,200 ft^3.) these corresponded to 22–28 air changes per hour.

Initially the six ceiling diffusers fitted for the downward displacement system were circular flush-fitting types, consisting of a set of concentric truncated cones. Diffusers of this type, however, are inherently bistable. According to the disposition of the conical sections the issuing air takes the form either of a downward directed jet, which loses momentum by entrainment from above, or of a sheet flowing horizontally immediately below the ceiling with entrainment from below in the form of a rising air column immediately below the centre of the fitting. Diffusers producing this second pattern of air flow have commonly been employed in 'downward displacement' systems and were initially fitted in this operating

room. Neither pattern of air flow, however, produced anything like a uniform descending air flow or 'piston'. The best approach to uniform air distribution a foot or two below ceiling level, without using an all-over perforated ceiling, is



Plan of operating room
(a)



Section of operating room X–X
(*b*)

Fig. 1. Plan and section of the operating room showing the position of the various ventilating fittings. A 1–6, Ceiling diffusers, originally flush fitting concentric conical diffusers (Hospital pattern Airmaster, Fairitt Engineering Co. Ltd.) replaced during the third period of observation by octagonal hemi-elliptical diffusers, 30 in. in diameter, of metal sheet perforated with a regular pattern of $\frac{3}{16}$ in. diameter holes at $\frac{13}{16}$ in. centres; B 1–3, deflecto grilles (Richard Crittall Marine Ltd.), 24 × 22 in., having, one behind the other and at right angles to each other, two sets of individually adjustable blades. C 1–3, deflecto grilles, 62 × 22 in.; E 1–4, exhaust ports, 12 × 12 in., fitted with pressure stabilizers in the form of an adjustable pivoted and weighted flap (Ivo Engineering and Construction Co., Ltd., type 2/S), D 1–5, doors; L, operating lamp; S, autoclaves; W, window, double-glazed, 10 ft. long × 2 ft. high immediately below the ceiling. The blades in grilles B and C were adjusted to direct the ventilating air along the lines indicated by arrows in the figure.

obtained from perforated diffusers of generous dimensions. For this investigation we constructed a set of diffusers each in the form of a hemi-elliptical shell 30 in. in diameter and 8 in. deep assembled from eight quarter elliptical segments pierced with a uniform pattern of $\frac{3}{16}$ in. diameter holes at $\frac{13}{16}$ in. centres. The polygonal shape where these met the ceiling assisted even distribution by promoting entrainment at the angles at ceiling level. With this design and an air supply of 200–250 ft.^{3}/min. to each diffuser substantially even distribution of air was obtained with no residual downward jet or upward induction.

Experiments with tracer gas

Owing to engineering and other difficulties it was only after the plant had been in use for over a year that satisfactory functioning was achieved. Observation with smoke and with a tracer gas (nitrous oxide, see Lidwell, 1960) then showed that even with the redesigned diffuser system the downward displacement arrangement produced only a very imperfect piston-like effect, as is demonstrated by the figures given for system A in Table 1 compared with those to be expected

Table 1. *Air mixing within the operating room with the three ventilating systems*

(Values of the performance index* using nitrous oxide as a tracer gas.)

System	Turbulent air velocity 1 ft. above operating table (ft./min.)	Tracer found over table. Tracer liberated at			Tracer liberated around table at 3 ft. level. Tracer found at		
		5 ft. 6 in. level	3 ft. level	1 ft. 6 in. level	5 ft. 6 in. level	3 ft. level	1 ft. 6 in. level
A	9	3·6	1·1	0·4	0·6	0·9	2·3
B	25	1·6	1·1	0·4	1·3	1·4	*ca.* 2·0
C	9	Not done	1·0	Not done	0·6	0·7	*ca.* 2·8
[P]	Small	Large	Near unity	Very small	Very small	Small	Large
[M]	Large	1·0	1·0	1·0	1·0	1·0	1·0

These measurements were made during the third period of the investigation when good temperature control had been established and the improved diffusers (perforated metal shells) had been fitted to the downward displacement system (system A). The row of the table labelled [P] shows the values that would be expected in an effective downward displacement system. That labelled [M] those which would result from complete turbulent mixing.

* The performance index is the ratio of the quantity of tracer recovered at the sampling point to that quantity that would have been recovered, with the same volume of ventilating air, if air turbulence in the room had been high enough to ensure perfect mixing of air in the room at all times. A low value, therefore, corresponds to less gas reaching the sampling point (Lidwell, 1960).

from an effective downward displacement system. When the tracer gas was liberated at a low level, 1 ft. 6 in. above the floor, in the vicinity of the operating table nearly half as much (performance index 0·4) reached the area immediately above the table as would have been expected if there had been complete turbulent mixing of the air in the room. That there was some layering and restriction of mixing at levels higher than 3 ft. above the floor is indicated by the high value of the performance index over the table (3·6) for tracer liberation at high level in the vicinity of the table and the reduced value (0·6) found at the 5 ft. 6 in. level when tracer was liberated at table level (3 ft.). This experience conforms with our observations

on similar systems installed in other hospitals. Thermal convection currents derived from differences in wall temperatures are usually the dominant factor in determining the patterns of air movement observed.

An air supply of 1200–1500 ft.^{3}/min. evenly distributed, would produce a downward displacement velocity of only about 4 ft./min. in this operating room. The velocities of thermally induced circulation currents are usually substantially greater than this. In this room the outside walls and especially the window, although this was double glazed, were usually one or two degrees centigrade cooler than the central air temperature and produced air movements, including transverse movements a few feet above floor level, which substantially modified the downward displacement pattern.

Table 1 also shows that a certain amount of layering and imperfect mixing also occurred, though to a reduced extent, with the moderate velocity turbulence system B, while the low velocity turbulence system C was in this respect practically indistinguishable from the downward displacement system.

Under all conditions, the ventilation rate, measured by the die-away of the nitrous oxide tracer, was less than the measured air change rate. The difference was usually about 10–15 %. Such a difference can easily arise with the imperfect mixing which is often obtained at high ventilation rates. The increased clearance rate, however, which would result from a true displacement ventilation (Blowers & Crew, 1960) was not observed.

Bacteriological observations

Observations were made during, or in relation to, 323 operating sessions.

Sampling of the operating room air

Air samples were taken simultaneously at a rate of 4 ft.^{3}/min. by two samplers, one placed at the side of the room near to the exhaust outlet E3, and other sampling from near the operation site (usually within 18 in. of the wound). This second sample was taken through a sterilized horizontal aluminium tube $1\frac{1}{4}$ in. in diameter and either 12, 18 or 24 in. long, which was changed for each operation. The tube was attached to a conical expanding section which was itself connected to the sampler through a right-angle bend, on a 9 in. radius, in a tube 2 in. in diameter. The dimensions of these were calculated to give minimal losses of particles in the connections at the air sampling rate used (Bourdillon & Lidwell, 1948) and tests showed that any losses of this kind amounted to less than 10 %. The samplers, which were specially constructed for this experiment, were modifications of the large slit sampler described by Bourdillon, Lidwell & Thomas (1948) and could take up to 6 samples in sequence automatically on 6 separate plates. The airborne bacteria were collected by impaction on to $5\frac{1}{2}$ in. diameter Petri dishes containing nutrient agar to which 5 % of horse serum and 0·01 % phenolthphalein phosphate had been added. The plates were incubated for 18 hr. at 37° C. and were then exposed to ammonia vapour. Colonies which reddened as a consequence of phosphatase production and had the colonial appearance of *Staphylococcus aureus* were

tested for coagulase production and the coagulase-positive strains were phage-typed. Total colony counts were also made.

Sampling was begun as the first incision was made and was normally concluded when the wound was closed. Individual samples were not collected over a longer period than 20 min. (about 80 ft^3.).

During some sessions, samples were also taken of the bacteria settling on similar plates exposed on the top of the air sampler at the side of the room and as near to the wound as possible. Only total counts of all colonies grown after 24 hr. at 37° C. were made from these plates. Some plates were exposed over the period from wound closure until the time the patient was removed from the room as well as during the operation itself.

Examination of patients and staff

Nasal and skin swabs were taken regularly from all the operating room staff, and from the patients when on the operating table. Members of the staff were swabbed weekly from both nostrils and from the back of the right hand for the first 4 weeks of observations and subsequently at intervals of not more than 1 month. Swabs were taken from the patient's nose, one hand, one axilla, the perineum, and from the skin of the operation site before skin preparation, and from the wound edges before closure at the end of the operation.

Nasal swabs were taken with a cotton wool swab moistened in nutrient broth. Skin swabs were taken with a gauze swab on a $6 \times \frac{3}{4}$ in. wooden spatula moistened with broth.

The swabs were placed in broth for return to the laboratory where they were plated on blood agar and incubated at 37° C. for 24 hr. The broth was incubated overnight and then plated on salt agar which was incubated for 48 hr. Colonies resembling *S. aureus* were tested for coagulase production and the coagulase-positive strains were phage-typed.

It was found possible by examination of the phage-typing patterns to locate probable sources for between 80 and 95 % of the staphylococci recovered from the air at different times during the investigation.

RESULTS

Bacterial contamination of the air

During the first period of observation, which covered 50 operating sessions, the rate of air supply varied substantially. Table 2 shows the degree of bacterial contamination of the air recorded over different ranges of air supply.

The extent of the reduction observed as the air supply was increased accords reasonably well with that to be expected, having regard to the particle size of the airborne bacteria-carrying material. No other analyses have been made of the results obtained during this period.

The second period of observation covered 157 operating sessions. During this time the rate of air supply varied only slightly, between 1200 and 1500 ft.^{3}/min. Temperature control of the incoming air was, however, not good and the flush

fitting conical type diffusers referred to earlier were in use with system A. A third and final period of observations covered 116 operating sessions when temperature control was satsfactory and the hemi-elliptical diffusers had been fitted for use with system A, the downward displacement system.

Table 2. *Effect of ventilation rate on bacterial air contamination*

No. of sessions	Ventilation rate (ft.³/min.)	Mean total count (per ft.³)	Rate of dispersal (colony forming units per minute)	Median *Staphylococcus aureus* count (per 100 ft.³)
8*	550–900	12·3	$13{\cdot}3 \times 10^3$	1·1
19*	1050–1400	5·5	$8{\cdot}5 \times 10^3$	1·0
23*	1420–1700	6·6	$12{\cdot}4 \times 10^3$	0·9
273†	1375 (mean rate)	5·7	$9{\cdot}6 \times 10^3$	—

* The first three rows of the table are derived from observations made during the first period of the investigation when, owing to mechanical difficulties with the plant, the ventilation rate varied substantially.

† The fourth row gives the mean results obtained during the second and third periods of observation, when the ventilation rate was relatively constant. The results for all three systems have been combined.

Rate of dispersal calculated from the formula

$$\text{rate of dispersal (colony forming units per minute)} = \text{colonies isolated per ft.}^3 \times \frac{\text{ventilation rate} + \text{floor area of room}}{}$$

This assumes complete mixing of the air in the room and a mean settling rate for the airborne particles of 1 ft./min. (see Table 6). The average number of persons present in the operating room during sampling was six so that the mean rate of dispersal (all species of organisms) arising from their activities was about 1600 colony forming units per minute per person.

Over a limited period records were kept of the activity of the operating room staff during sampling periods. The quantitative expression of activity in terms of movement around the room was necessarily somewhat arbitrary and does not include all actions likely to result in dispersal of bacteria, but the results (Fig. 2) show a significant correlation between movement and the level of air contamination.

The performance of the three ventilating systems, during the second and third periods, is compared in Table 3. The figures for total colony count show no significant differences either between the three systems or between the two periods of observation. The figures for *S. aureus* were significantly lower during the third period. This was almost entirely due to the reduced number of occasions when there was a heavy carrier present in the operating room while air sampling was going on. Fewer staphylococci were recovered from the air, during both periods, when the moderate velocity turbulent system, B, was in operation than when the downward displacement system, A, was employed. The differences are not, however, statistically significant.

As a consequence of the fairly high ventilation rate and only moderate dispersion by the staff, the numbers of coagulase positive staphylococci recovered from the air were rather small for detailed breakdown, especially since more than two thirds

of them were probably derived from a single staff carrier (who was usually one of the unscrubbed members of the team). No differences were, however, apparent between the figures obtained with system A (downward displacement) and with system B (moderate turbulence) in respect of the relative contribution of sources situated at the side of the room or around the operating table to the numbers

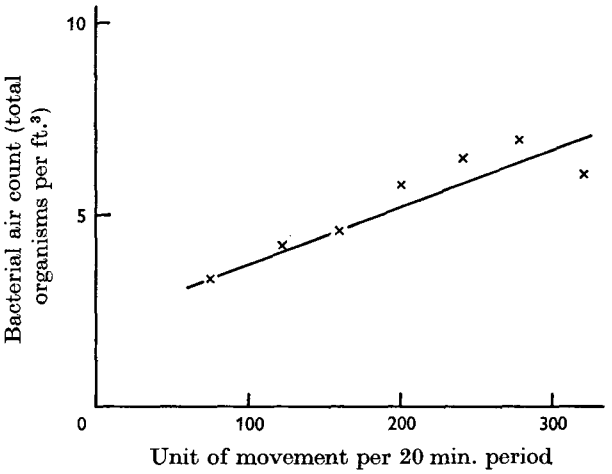


Fig. 2. Relationship between bacterial count in the air of the operating room and staff activity. A unit of movement was recorded each time any person in the operating room moved across the boundary of one of the 18 squares into which the floor of the room was arbitrarily divided. A complete circuit around the operating table produced 12 units of movement

Observations were recorded over periods of 20 min., this being the duration of the individual air samples. There were, on average, with little variation, six persons present in the operating room during these observations. The table is based on movement data collected by Mr D. Wyon whose help we acknowledge with thanks.

Table 3. *Bacterial contamination of the air*

	Second period, 157 operating sessions, about 36,000 ft.³ of air sampled				Third period, 116 operating sessions, about 27,000 ft.³ of air sampled			
Ventilation system	A	B	C	All together	A	B	C	All together
Average ventilation (ft.³/min.)	1380	1370	1390	1380	1290	1390	1420	1370
Total count (colonies/ft.³)								
At operating table	5·7	4·6	5·2	5·2	7·0	6·8	5·2	6·4
At side of room	6·7	6·0	5·1	5·9	6·2	5·9	4·4	5·5
Staphylococcus aureus (colonies/100 ft.³)								
At operating table	2·6	1·7	2·8	2·4	1·1	0·6	0·4	0·7
At side of room	3·7	2·2	2·4	2·8	1·1	0·7	0·7	0·8

During the second period temperature control of the ventilating air was poor. During the third period this had been remedied and improved diffusers (perforated metal shells) fitted to the downward displacement system (system A).

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recovered from the air over the operating table or from the air leaving the room. With both systems approximately 50 % more colonies were recovered from the table samples than from the side samples when the sources were staff working at the operating table. The side samples similarly contained about 50 % more colonies derived from staff working at the periphery of the room than did the table samples. The results obtained with system C (low velocity turbulence) showed less difference between the sites of sampling. What difference there was was in the opposite

Table 4. *Apparent rate of dispersal of* Staphylococcus aureus *into the operating room (colony forming units per carrier per hour)*

Carrier disperser	Ventilation system A	B	C	All together
Heavy carrier 'X' at operating table	2600	5300	2700	2900
at side of room	8900	3100	4400	5600
Other staff carriers at operating table	210	220	270	240
at side of room	360	270	290	300
Patients	530	110	640	440

The heavy carrier-disperser appeared to be the source of 75 % of the *S. aureus* colonies isolated during the second period of the investigation and of 41 % during the third period or of 70 % during the two periods taken together.

Rate of dispersal calculated from the formula

$$\text{rate of dispersal} = \frac{\text{no. of colonies isolated}}{\text{no. of hours carrier present}} \times \frac{\text{ventilation rate} + \text{floor area of room}}{\text{sampling rate}}.$$

For the average ventilation rate of 1375 ft.^{3}/min., a floor area of 320 ft.^{2} and a sampling rate of 4 ft^3./min.:

$$\text{rate of dispersal (colony forming units per carrier per hour)} = 420 \times \frac{\text{no. of colonies isolated}}{\text{no. of hours carrier present}}.$$

This formula assumes complete mixing into the air of the room and a mean settling rate for the airborne particles of 1 ft./min.

Table 5. *Percentage distribution of sources of* Staphylococcus aureus *recovered from the air*

Sampling site	Source: Patient	Staff at operating table	Staff at side of room	Uncertain or other	Unknown
At table	6	16	51	20	9
At side	5	12	55	20	8

Staff at the operating table comprised the scrubbed staff together with the anaesthetist. The source was uncertain when the same strain was carried by several individuals falling into more than one category.

sense to that found with the other systems. This was, presumably, a consequence of unplanned low velocity air movements. Combining together the samples taken at the operating table and at the side of the room during both the second and third periods of observation a comparison has been made between the three ventilating

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systems for those times during which carriers of *S. aureus* were known to be present in the operating room. This has been done by calculating (Table 4) the apparent rate of dispersal of this organism into the room by each carrier. If the ventilating system were more efficient than a fully mixed system this would be reflected in a lower value of the apparent rate of dispersal. It is clear that there is no obvious systematic advantage attributable to any of the three systems tested. It is notable that the one carrier who was also an active disperser was disseminating more than ten times as much as the average carrier. Individual differences of this order of magnitude or greater are not uncommon, a fact which considerably complicates any comparison between different operating suites or any attempt to define an acceptable level of airborne contamination. Table 5 shows the percentage contribution of sources situated in different parts of the operating room to the staphylococcal colonies actually collected in the air samples over the whole period of the investigation. As indicated above, the distribution recorded is dependent on the position in the operating room of the individual carriers encountered.

Table 6. *Numbers of organisms (all species) settling per square foot of exposed surface per minute*

		Ventilation system		
		A (downward displacement)	B (moderate turbulence)	C (low turbulence)
At table	during operation	4·4	6·2	3·1
At side	during operation	3·6	4·5	2·7
At table	after operation	20·2	25·6	16·6
At side	after operation	12·4	21·7	8·8

The numerical similarity between the rate of settling (per ft.²/min.) and the numbers of organisms recovered simultaneously from one cubic foot of air (see Table 3) indicate that the average settling rate of the bacteria-carrying airborne particles approximated to 1 ft./min.

Sedimentation of bacteria from the air

Settling plates were exposed during forty sessions in the third period of observation. As the numbers of coagulase positive staphylococci to be expected on these plates was very small only total counts were recorded.

Table 6 shows the numbers of colonies grown from the plates exposed to direct settling from the air. Any difference between the three systems is again small and not significant although, in these results, the settling rate was consistently greatest with the moderate turbulence system, B, and lowest with the low turbulence system, C. Settling was always greater near the table than at the periphery although the difference was only of the order of 25 % during the operation itself. As would be expected, the number of organisms settling on the plates rose considerably during the activities involved in preparing to remove the patient from the room and this rise was greatest near to the table, where this activity was centred.

Wound contamination and sepsis

Swabs were taken from the wound edges just before closure on 265 occasions. From 255 of these no coagulase positive staphylococci were isolated. From 8 a strain was recovered which was indistinguishable from that carried by the patient. Of the strains isolated from the remaining two, one appeared to be identical with the strain carried by the one active disperser previously referred to, no source could be identified for the other. This is very similar to the four swabs positive for staphylococci from 145 operations three of which were of the type carried by the patient recorded by McNeill, Porter & Green (1961). Burke (1963), on the other hand, who washed out his wounds before closure with sterile saline and cultured the total volume of fluid, recovered coagulase positive staphylococci from 46 out of 50 (92%). The average number of strains recovered per wound was almost six with an average of more than two colony forming units per strain. His method was clearly much more sensitive and indicates the degree of bacterial contamination of the wound which may occur, almost certainly in this case mainly by the airborne route. It is also apparent, however, that the number of carrier-dispersers present in the operating room during his investigation was substantially larger than in the present instance.

Only six instances of staphylococcal sepsis developing within 14 days of operation were recorded from the 391 operations covered by the period of the investigation. Some cases may have escaped observation but the total numbers were in any case too few for analysis in what was planned as a bacteriological investigation.

DISCUSSION

No evidence could be found from the results of this investigation to suggest that any one of the ventilation systems was significantly superior to the others in protecting a surgical wound from contamination with airborne bacteria. In spite of considerable efforts to improve the design of the diffusers and to control the thermal environment no effective downward displacement air piston was obtained. Although the incoming air was usually a few degrees warmer than the air in the lower part of the room the temperature differences between the walls, and between the walls themselves and the room air temperature were sufficient to generate circulating air movements which were strong enough to prevent the establishment of a slow downward displacement of air. This confirms our observations in other places and is in line with the conclusions of the Heating & Ventilating Research Association's study (Stanley, Shorter & Cousins, 1964). The volume of air supplied was by far the most important characteristic of the ventilation system in controlling the level of airborne contamination. Ventilation systems in which controlled direction of air flow reduces this below the levels obtained with turbulent mixing systems may be obtainable in practice under particular conditions but do not seem to be practicable unless the volumes of air flow relative to the space ventilated are several times greater than those normally envisaged at present. In order to overcome thermal currents, the directed velocities would probably have to reach 10 ft./min. or more. In an operating room similar to the one investigated

by us this would imply a ventilating air supply exceeding 3000 ft.^{3}/min. Experiments with very high flow ventilating systems are in progress in a number of centres in the United States, but in view of the low sepsis rates attainable with ventilating volumes of about 1000 ft^3/min it would seem that much larger rates of air supply could only be justified in exceptional circumstances and that further effort would be better expended in reducing bacterial dispersal by the operating team, for instance by eliminating unnecessary movement and by the use of clothing which is not permeable to bacteria shed from the skin (Blowers, 1963; Bernard, Speers, O'Grady & Shooter, 1965; Blowers & McClusky, 1965). The frequency of glove puncture is also disquieting. During the course of this investigation 15·1 % of the gloves used by the surgeon were found to be punctured by the end of the operation, although there is no evidence that this caused any wound infection. Since there is also good evidence (McNeill *et al.* 1961) that a high proportion of surgical infections are due to strains of organisms carried by the patient before operation finding their way into the wound, further consideration of skin preparation and the method of making the first incision might well be profitable.

SUMMARY

Observations on the bacteriological contamination of the air have been made in an operating room fitted with three alternative systems of ventilation.

These were; A, downward displacement 'piston'; B, moderate velocity turbulent; C, low velocity turbulent.

The volume of the ventilating air supplied was the only characteristic of the ventilation which affected the contamination levels reached during operations. No significant differences could be detected between the three ventilating systems in this respect.

Unavoidable temperature differences in the operating room render it generally impossible to produce effective downward displacement air movement with ventilating air supplies which do not exceed 1500 ft.^{3} per minute over a ceiling area of 300 ft.^{2}.

Great differences were observed between the several carriers of *Staphylococcus aureus* in the extent to which they dispersed this organism into the air when working in the operating room.

Our thanks are due to the N. W. Regional Hospital Board and to their Engineering Department, to the Hospital Secretary, to Mr R. Grainger, Mr P. Stringer and Dr G. A. Matthews, consulting surgeons and pathologist at the hospital, to all the other members of the operating room staff and to the hospital engineer.

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