

### **Bacterial contamination in a modern operating suite. 3. Importance of floor contamination as a source of airborne bacteria**

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#### SUMMARY

The redispersal factor for bacteria-carrying particles from a contaminated floor was determined after mopping, blowing and walking activity. Walking gave the highest redispersal factor,  $3.5 \times 10^{-3} \text{ m}^{-1}$ , which was three times higher than for blowing and 17 times higher than for mopping. The mean die-away rate for the bacteria-carrying particles used was 1.9/h without ventilation and 14.3/h with ventilation. It was calculated that in the operating rooms less than 15% of the bacteria found in the air were redispersed floor bacteria.

#### INTRODUCTION

Hospital floors become contaminated by sedimentation of airborne bacteria and by contact with shoes, trolley wheels, and other solid objects. These have generally been assumed to be an important reservoir for pathogenic bacteria and much effort and money has been spent on dust-suppressive measures to prevent contamination of floors. Before bacteria in dust can cause an airborne infection they must be redispersed into the air by air currents from ventilation, by traffic, or by cleaning procedures. Investigations by Brunskill (1966) and Ayliffe *et al.* (1967) seem to indicate that only small numbers of bacteria are redispersed from floors by air movements.

The purpose of this investigation has been to try to measure the redispersal of bacteria from the floor in an operating room by the use of three experimental models. The die-away rate for bacteria-carrying particles due to sedimentation and ventilation was also determined since knowledge of this is necessary to calculate the proportion of airborne bacteria derived from resuspension under other conditions.

#### MATERIALS AND METHODS

##### *Redispersal of bacteria from floor; experimental design*

A room in the operating suite was used for the experiments. It had a vinyl floor of about 35 m<sup>2</sup> and the height of the room was 3.2 m. During the redispersal experiments the ventilation was turned off and as far as possible all air leaks were sealed.

Before the experiments the floor was cleaned with 70% ethyl alcohol. It was then contaminated with *Staphylococcus aureus* by shaking clothes worn by staff in

the operating suite or blankets used by burn patients. After sedimentation for 4 to 12 h, redispersal of bacteria was attempted in three different ways:

(1) By directing a jet of cold air from an electric hair-dryer systematically along all parts of the floor for 10 min.

(2) By cleaning the floor with a moist mop for 10 min.

(3) By having 4 people move around the floor for 30 min.

To avoid contamination of the air by *Staph. aureus* from clothing, the persons taking part in the experiments changed from their ordinary clothes to a set of protective clothing before contaminating the floor by shaking staff clothes or blankets. They also changed to a sterile set of operation clothing when the experiments were performed.

#### *Experimental determination of the die-away rate*

Blankets used by burn patients infected with *Staph. aureus* were shaken and the concentration of *Staph. aureus* in the air was measured by taking 5 min samples continuously during 1 h after shaking. The same room was used as in the redispersal experiments. Experiments were made with the ventilation turned off and air leaks sealed and also with functioning ventilation. The ventilation rate was about 12 turnovers per hour.

#### *Floor sampling*

Twelve Rodac impression plates were taken from the floor before contamination and immediately before each redispersal experiment.

#### *Air sampling*

Air samples were taken with a Casella slit sampler (capacity 700 l/min) at the following times:

- (1) For 10 min after the initial alcohol cleaning.
- (2) For 5 min after sedimentation just before redispersal experiments.
- (3) During the entire 10 min period of blowing.
- (4) During the entire 10 min period of mopping.
- (5) During 5 min after 10 and 25 min of walking.

#### *Bacteriology*

Baird Parker medium with egg yolk and tellurite (Oxoid) was used for sampling of *Staph. aureus* with impression plates. Blood agar plates were used for air sampling. The plates were incubated at 37 °C for 48 h. Presumptive *Staph. aureus* were confirmed with DNase test.

## RESULTS

#### *Determination of the redispersal factor*

For each experiment a redispersal factor was calculated as the ratio between the concentration of *Staph. aureus* (c.f.u./m<sup>3</sup>) during the floor disturbance and the concentration of *Staph. aureus* (c.f.u./m<sup>2</sup>) on the floor (Chamberlain, 1967).

In Table 1 the mean floor and air contamination as well as the mean redispersal

Table 1. Experimental redispersal of *Staphylococcus aureus* from floors

Type of experiment	No. of <i>Staph. aureus</i>		Redispersal factor $m^{-1}$ mean value*
	c.f.u./ $m^2$ mean value	c.f.u./ $m^3$ mean value	
Blowing	$1.5 \times 10^3$	1.46	$1.2 \times 10^{-3}$
Mopping	$1.6 \times 10^3$	0.25	$2 \times 10^{-4}$
Walking	$3.4 \times 10^4$	89.2	$3.5 \times 10^{-3}$

\* Mean of redispersal factors from 7 to 10 experiments.

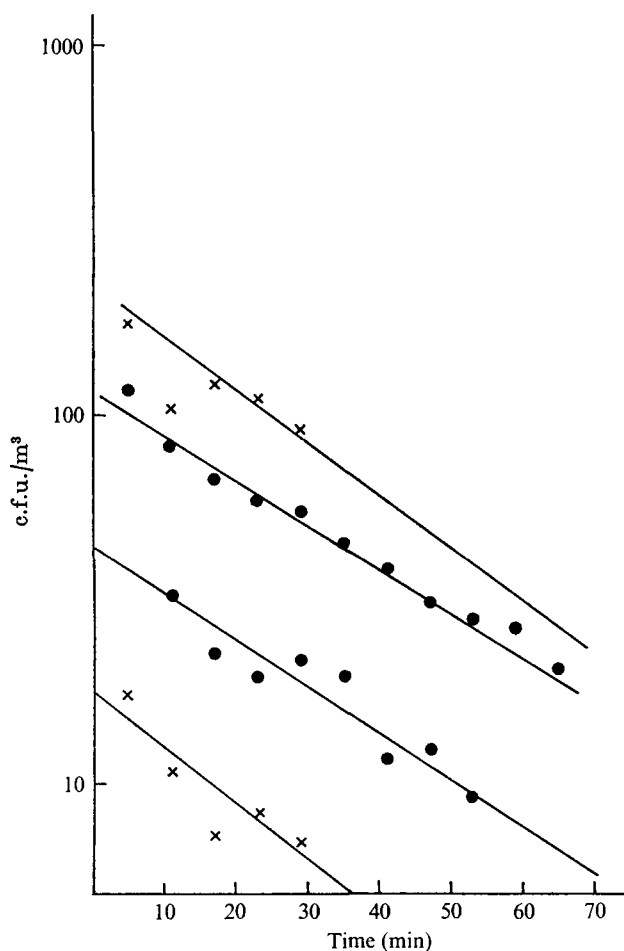


Fig. 1. Die-away rate for bacteria-carrying particles in an operating room without ventilation.

factor is given for the three different types of experiments. The values are mean values of 7-10 experiments. The floor contamination varied between  $1.5$  to  $3.4 \times 10^4$  c.f.u./ $m^2$  in the different experiments. The redispersal factor was calculated for each experiment and the mean value was  $1.2 \times 10^{-3} m^{-1}$  and  $2 \times 10^{-4} m^{-1}$  for blowing and mopping, respectively, and  $3.5 \times 10^{-3} m^{-1}$  for walking.

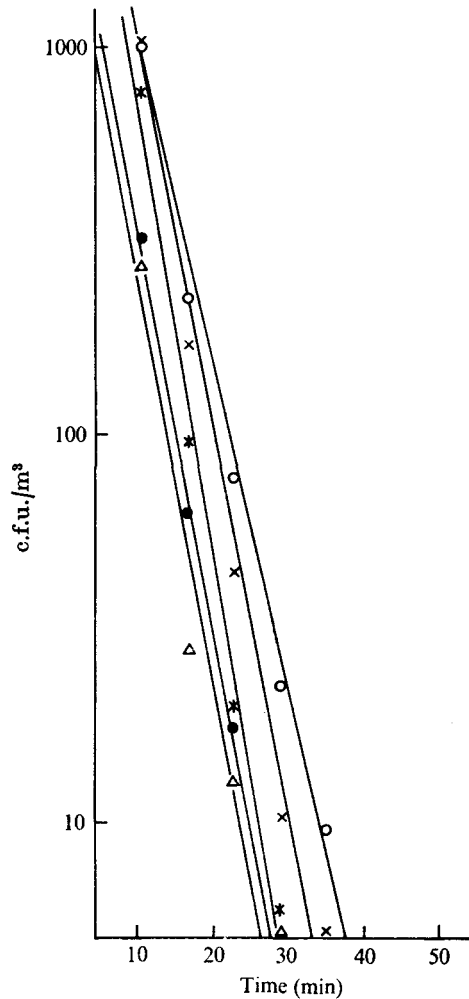


Fig. 2. Die-away rate for bacteria-carrying particles in an operating room with ventilation.

#### *Determining the die-away rate*

In Fig. 1 the die-away rates found in four experiments without ventilation are presented. The lines represent the fall in concentration found during the second hour after shaking the blankets since the number of bacteria on the plates from samples taken earlier was too high to count. The mean die-away rate is 1.9/h. In Fig. 2 the die-away rates found in five experiments with ventilation are presented. These samples were taken during the first half hour after shaking. The mean die-away rate is 14.3/h.

#### DISCUSSION

In order to evaluate the importance of floor bacteria as a source of cross infection in an operating suite attempts were made to redisperse *Staph. aureus* from a contaminated floor. The redispersal factor was low in all experimental models tested.

It was highest in the walking experiments,  $3.5 \times 10^{-3} \text{ m}^{-1}$ , which was three times that found when blowing and 17 times that found when mopping. Although every possible precaution was taken to avoid dispersal from the clothes of those taking part in the experiments this source cannot be totally excluded. This risk would be greater in the walking experiments, where four people took part, than in other experiments, where only one person took part. However, in a few walking experiments when floor contamination was very low there was no air contamination at all. People walking around may produce some kind of turbulent air currents that are more effective in moving particles upwards than a jet of cold air directed along the floor.

Most studies on redispersal have been made with radioactive dust. Chamberlain (1967) found a redispersal factor of  $10^{-6}$  to  $5 \times 10^{-5} \text{ m}^{-1}$  for plutonium oxide, which is lower than we found. Only few experiments on redispersal of bacteria have been made. From a floor contaminated with dirty clothing Brunskill (1966) had a redispersal factor of  $2 \times 10^{-3} \text{ m}^{-1}$  which is consistent with our findings. In a few experiments made by Ayliffe *et al.* (1967) the redispersal was also low but varied considerably, which makes comparisons with our findings difficult.

The die-away rate found when there was no ventilation was very low, 1.9, which corresponds to a sedimentation rate of 0.1 m/min. This is less than usually found for bacteria-carrying particles in hospital wards (Noble, Lidwell & Kingston, 1963). The reason for this is probably that sheets contaminated by burn patients were used. It has been shown that a high proportion of small particles, 3–6  $\mu\text{m}$ , are shed by this type of patient (Hambraeus, 1973). The samples were also taken rather a long time after the room had been contaminated when the larger particles had probably sedimented already. With ventilation the experimentally determined die-away rate was 14.3/h. The designed number of air changes for this room was 12/h and adding the effect of sedimentation the die-away rate would be 13.9/h which corresponds well with that found experimentally.

Assuming that the redispersal found in the experiments in the unventilated room represents a steady state it is possible to calculate the redispersal factor under other conditions. The equilibrium level of air contamination is given by  $N_e = B/(R+S)$  where  $B$  is the rate of dispersal,  $R$  the ventilation rate and  $S$  the rate of loss due to sedimentation, 1.9/h in these experiments (Bourdillon, Lidwell & Lovelock, 1948). Hence the redispersal factor will be inversely proportional to the rate of removal,  $R+S$ . In the room studied with ventilation at 12 air changes/h, the redispersal factor, for walking, would be  $3.5 \times 10^{-3} \times 1.9/(1.9+12) = 4.8 \times 10^{-4}$ .

In the operating room described in another paper (Hambraeus, Bengtsson & Laurell, 1977) the ventilation rate is about 20 turnovers/h. This would give a redispersal factor of  $3.5 \times 10^{-3} \times (1.9/21.9) = 3.0 \times 10^{-4}$ . The mean number of *Staph. aureus* c.f.u. in that study was about 90/m<sup>2</sup> which would give a redispersal into the air of 0.03 c.f.u./m<sup>3</sup>. The actual measured contamination in the air was 0.2 c.f.u./m<sup>3</sup>. The contribution of contamination from the dust would therefore be about 15%. Since the size of particle carrying *Staph. aureus* was probably smaller and the people were moving around more vigorously in the experimental study, it is likely that the redispersal factor is smaller under normal conditions and 15%

thus represents a maximum value. The conclusion would therefore be that redispersal of *Staph. aureus* from floor dust to air hardly increases the risk for airborne infection of operation wounds.

## REFERENCES

- AYLIFFE, G. A. J., COLLINS, B. J., LOWBURY, E. J. L., BABB, J. R. & LILLY, H. A. (1967). Ward floors and other surfaces as reservoirs of hospital infection. *Journal of Hygiene* **65**, 515.
- BOURDILLON, R. B., LIDWELL, O. M. & LOVELOCK, J. E. (1948). Studies in air hygiene. *Medical Research Council Special Report Series*, no. 262.
- BRUNSKILL, R. T. (1966). Quoted by Lidwell, O. M. (1967) in: Take-off of bacteria and viruses. *Symposium of the Society for General Microbiology*, no. 17, p. 133.
- CHAMBERLAIN, A. C. (1967). Deposition of particles to natural surfaces. *Symposium of the Society for General Microbiology*, no. 17, p. 138.
- HAMBRAEUS, A. (1973). Dispersal and transfer of *Staphylococcus aureus* in an isolation ward for burned patients. *Journal of Hygiene* **71**, 787.
- HAMBRAEUS, A., BENGTSSON, S. & LAURELL, G. (1977). Bacterial contamination in a modern operating suite. 1. Effect of ventilation on airborne bacteria and transfer of airborne particles. *Journal of Hygiene* **79**, 121.
- NOBLE, W. C., LIDWELL, O. M. & KINGSTON, D. (1963). The size distribution of airborne particles carrying micro-organisms. *Journal of Hygiene* **61**, 385.