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Swedish survey and a summary of investigations in operating rooms

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Abstract

A survey is presented with data from 27 operating rooms in four county councils, where information from 111 ongoing surgical operations was given regarding air volume flows, measured concentration of airborne viable particles and used clothing systems. With results from the survey the mathematical expression describing the dilution principle was established to predict the concentration of airborne viable particles present in the operating room during ongoing surgery. As well supply air system as surgical clothing system used play here an important role.

Key words: Hospital ventilation, operating rooms, bacteria-carrying particles, Swedish survey

1. Introduction

A survey was performed and evaluated with data from 27 operating rooms, where 111 mean values of concentration of airborne bacteria-carrying particles, colony forming units (CFU/m^3), during ongoing operations were collected. In total close to 700 air samples were collected with active air samplers.

The air movements in the operating rooms were either turbulent mixing air or unidirectional air flow (UDF). The operating rooms could be divided in three different air flow intervals.

1. Air flows of 0.5 - 0.56m^3/s (1 800 - 2 000m^3/h), turbulent mixing air, filter F95.
2. Air flows of 2.9 - 3.9m^3/s (10 400-14 000m^3/h), UDF systems with air velocities of 0.25–0.35m/s, filter H14
3. Air flows of 4.4 - 5m^3/s (16 000 - 18 000m^3/h), UDF systems with air velocities of 0.4-0.5m/s, filter H14.

2. Material and methods

The questions, which were answered besides the data of the supply air systems in operating rooms, were briefly:

- Type of active air sampler used.
- Type of surgical clothing system used
- Number of persons in the operating room during the measurements
- Concentration of aerobic airborne bacteria-carrying particles (CFU/m^3) during ongoing surgery.

From the replies of these questions the source strength was calculated. The source strength is described as the mean value of viable airborne particles per second from one person. Different clothing systems give different source strengths.

In operating rooms with supply air systems creating turbulent mixing air, the dilution principle is applicable. The following expression, which is applied on the dilution principle, is describing the source strength, q_s (CFU/s):

$$q_s = \frac{c \cdot Q}{n} \qquad (1)$$

where *c* is the concentration, bacteria-carrying particles, (CFU)/m^3), *Q* is the total air flow, (m^3/s) and *n* is the number of persons, (no).

In the following a concise presentation of the survey is made. For a more thorough description, see Nordenadler (2010).

3. Results

The active air samplers used in the study were of two types and based on the filtration through gelatin filter and impaction on agar plates respectively. All samplers were operated according to the manufacturers' instruction.

During the 111 operations the persons in the operating rooms were dressed in tightly woven surgical clothing systems.

The results from the operating rooms with turbulent mixing air (air flows 0.5 – 0.56m^3/s) are used to give a first estimation of the source strength with aid of Equation (1).

The number of bacteria-carrying particles per m^3 (CFU/m^3) is in the range of 5-40 and the number of people in the operating rooms is mostly 6, the source strength for one person is estimated to be in the range of 0.4–3.7 CFU/s. The mean value of the source strength for one person dressed in tightly woven surgical clothing system seems to be in the range of 1-2 CFU/s,

The number of persons, who at the same time are present in the operating rooms, are typically between 4 and 8, where 6 persons is the mean value.

Three levels seem to be appropriate and with Equation (1) the following expressions are obtained:

Upper level	n=8	q_s=2.0 CFU/s	□c=16/Q CFU/m^3
Mean level	n=6	q_s=1.5 CFU/s	□c=9/Q CFU/m^3
Lower level	n=4	q_s=1.0 CFU/s	□c=4/Q CFU/m^3

These three levels and the 111 mean values of bacteria-carrying particles per m^3 (CFU/m^3) from ongoing operations are shown in Figure 1.

As mentioned earlier the number of persons in the operating room is mostly 6, but could be from 3 up to 19. Equation (1) was used to normalize the number of CFU/m^3 to six persons.

These normalized CFU concentrations were used in the statistical calculations, where the mean concentration of each operating room gives a base value. These base values were grouped in three air volume flow intervals, where the number of base values is different for the three intervals, see Table 1.

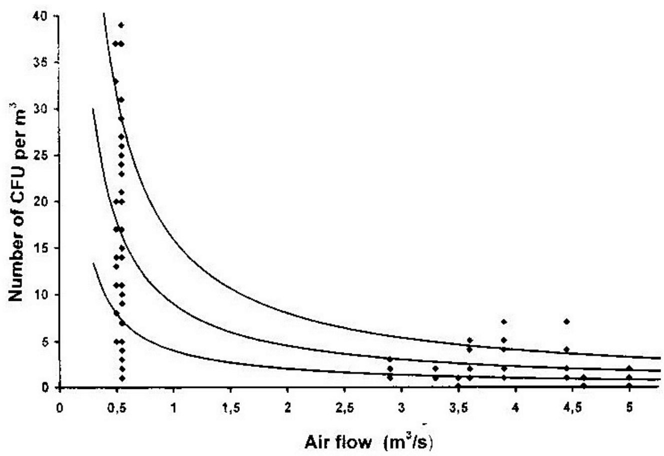

Figure 1. Comparison between calculated mean values with Equation (1) (upper level, mean level, lower level) and given values of the CFU concentrations during ongoing operations from the survey.

Table 1. Air flow intervals and the number of mean value concentration (base values) from 27 operating rooms.

Air flow interval (m^3/s)	Number of mean values
0.5 – 0.56	10
2.9 – 3.9	11
4.4 – 5	6

The calculations of 95% confidence intervals (t-distribution) were performed for the two air flow intervals of 0.5 – 0.56m^3/s and 2.9 – 3.9m^3/s, respectively. Due to limited number of values and several values less than 1 CFU/m^3 a calculation seemed not to be applicable to the air flow interval of 4.4 - 5 m^3/s.

Mean values, standard deviation and confidence intervals (t-distribution) are shown in Table 2.

The confidence intervals in Table 2 are shown in Figure 2 together with the normalized concentration curves of upper and lower level according to Equation (1), when the number of persons (n) are 6 and the source strength (q_s) is 1 CFU/s and 2 CFU/s, respectively.

4 Discussion and conclusions

The results from Figure 2 show that there is a good agreement between the values off confidence intervals that are received from the air flow intervals of 0.5 – 056m^3/s (turbulent mixing systems) and 2.9 – 3.9 m^3/s (UDF systems), respectively and theoretical relations given by Equation (1). The explanation seems to be that in these cases the dilution principle is valid during ongoing surgery.

When the air flows exceed 4.6m^3/s (16 600 m^3/h) the measured values mostly are lower than the values given by Equation (1). This might depend on that the air velocities in these UDF-units often exceed 0.4m/s, which can give steady velocities over the operating table creating a sweeping action of air. Similar results have been described by Whyte (1973). However, if the air velocity in the UDF-unit is less than 0.3m/s the air movements over the operating table during ongoing surgery tend to become turbulent mixing.

It should be noted that the values in Table 2 and Figure 2 indicate that the mean value of the source strength for tightly woven clothing systems is about 1.5 CFU/s.

A study of tightly woven clothing systems and common clothing systems of mixed material (cotton/polyester) is described by Tammelin et al (2000). The results show that during ongoing operations the concentration of bacteria-carrying particles were reduced by 64% by tightly woven clothing systems compared to common surgical clothing systems. This gives that the source strength for common surgical clothing systems of mixed material is about 4.2 CFU/s, which is in agreement with results described by Ljungqvist et al (2011, 2012).

If in Table 2 common clothing systems of mixed material were used instead of tightly woven clothing systems, the mean values of the concentration of bacteria-carrying particles for the air flow intervals of 0.5 – 0.56 m^3/s and 2.9 – 3.9 m^3/s should increase to be about 45 CFU/m^3 and 6 CFU/m^3, respectively.

To sum up, with the same number of persons in an operating room the concentration of bacteria-carrying particles depends on as well the supply air system as the surgical clothing system used.

Table 2. Mean values, standard deviation, and 95% confidence intervals (t-distribution) of number of CFU/m^3 during ongoing operations with 6 persons (tightly woven clothing systems) present in the operating rooms at different air flows.

Air flow interval (m^3/s)	Number of CFU/ m^3			
	Mean value	Standard deviation	Confidence interval	
			Lower	Upper
0.5 - .056	16.2	8.2	10.3	22.1
2.9 – 3.9	2.2	2.0	0.9	3.5
4.4 – 5	1.4	-[1]	-[1]	-[1]

[1] Not applicable

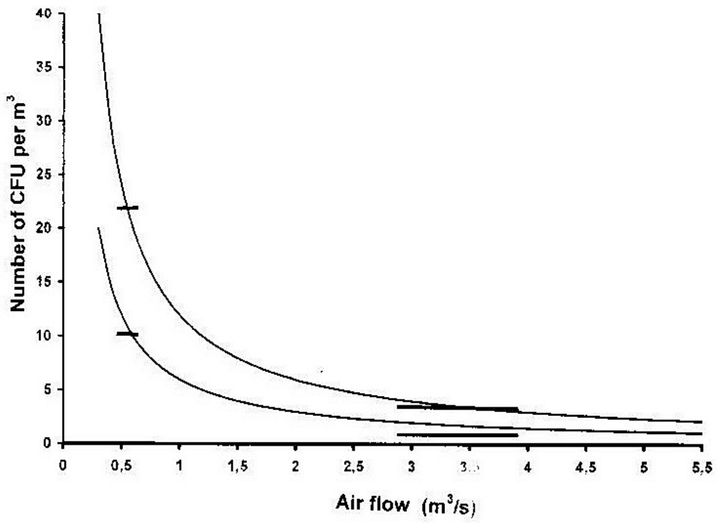

Figure 2. Comparison between calculated upper and lower confidence intervals shown in Table 2 and the CFU concentrations given by Equation (1) when n=6 and q_s=1CFU/s and qs=2 CFU/s, respectively (lower and upper curve).

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