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A Comparison between Measured Values of Airborne Viable Particles and Theoretical Calculated Values with the Dilution Principle in Operating Rooms Equipped with Low Velocities Unidirectional Airflow Systems

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Abstract

Many of the recently installed unidirectional air flow systems for operating rooms have low velocities (≤ 0.3m/s). Measurements of airborne aerobic colony-forming units were performed in such operating rooms during on-going surgery. Results show that, during on-going surgery, calculations with the dilution principle is valid in the surgical zone.

Keywords: Ultraclean operating rooms, unidirectional air flow (UDF), dilution principle, microbiological air cleanliness, colony-forming unit (CFU).

Introduction

Operating rooms for patients undergoing surgery susceptible to infections often have unidirectional air flow (UDF) supply air systems. In the past 25 years, many UDF supply air systems installed in Europe have low air velocity, i.e., equal and below 0.3 m/s. Measurements of airborne viable particles (aerobic CFUs) were performed during on-going surgery in operating rooms with UDF ceilings at three different hospitals in Sweden

(Gandra et al 2017). Data from these measurements for three different types of UDF units will be discussed in the following. The measured mean value concentrations of bacteria-carrying particles (aerobic CFUs) in the operating rooms with UDF units are compared to theoretical calculated values with the aid of the dilution principle, i.e., total mixing air movements. Airborne viable particles were collected using a filter sampler (Sartorius MD8®) and to a slit-to-agar sampler (Klotz FH6®). The sampling volume per sampling period for the two instruments was 1m3. Both samplers were operating according to the manufacturers' instructions. These two microbiological test methods are described as accepted methods for active sampling of air in SIS-TS39:2015 (2015). For a more thorough description, see Gandra et al (2017).

Operating Rooms with UDF

As mentioned earlier, three types of UDF supply air systems, all with high efficiency particulate air (HEPA)-filtered air, were studied and will here be called Case 1, Case 2, and Case 3. Data from the three cases are shown in Table 1.

Table 1. Data from three types of UDF ceilings (Case1, Case 2, and Case 3).

	Air flow UDF (m^3/s)	Additional air flow (m^3/s)	Total air flow[1] (m^3/s)	UDF velocity Mean value (m/s)	Air filter
Case 1	2.54	-	2.54	0.25	H14
Case 2	3.6	0.7	4.3	0.3	H14
Case 3	2.75	-	2.75	0.27	H14

[1] Additional air is supply air outside the UDF ceiling.

Source Strength

With the assumption of no leakage into the operating room and the HEPA-filters having efficiency close to 100 percent, the simplest possible expression, which is applied on the dilution principle, describes the source strength, protective efficacy of surgical clothing system (outward particle flow):

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

Where q_s = Source strength, total particulates (number/s), bacteria-carrying particles (CFU/s)

c = Concentration; total particulates (number/m^3) bacteria-carrying particles (CFU/m^3)

Q = Total air flow (m^3/s)

n = Number of persons present (number)

The source strength is described as the number of total or viable airborne particulates per second emitted from one person. Data are given as mean values based on several persons dressed in specific clothing systems. The source strength, which is in this paper limited to the mean value of the number of aerobic CFU per second from one person is a valuable tool in describing the protective efficacy of clothing systems against bacteria-carrying particles. Ljungqvist et al (2004, 2014)

Clothing Systems

The same type of surgical clothing systems was used during the measurements of on-going surgery for the three cases. The clothing systems consisting of 50% cotton and 50% polyester were described by Erichsen Andersson (2013). The total number of air samples during surgery was 91. With the presented data from Erichsen Andersson (2013), calculation of source strength can be performed with the aid of Equation (1). Such calculations show that the mean value becomes 1.85 CFU/s and the 95 % confidence interval (t-distribution) for lower and upper level are estimated to be 1.5 CFU/s and 2.2 CFU/s, respectively. These values should be compared to the value of 2.0 CFU/s estimated by Nordenadler (2010).

Results

Comparison between theoretical calculated and measured CFU-values

When the air movements are total mixing, the dilution principle is valid. The theoretical mean value concentration of bacteria-carrying particles can be calculated if the total air volume flow is determined and the number of people in the operating room and their source strength is known. In this case, the CFU concentration (***c***) becomes:

$$c = \frac{n \cdot q_s}{Q} \qquad (2)$$

In Table 2 the mean value of number of people present, their source strength and the total air volume flow during on-going surgery are given. With these values the CFU mean value concentrations are calculated for the three cases. In Table 2 also the measured mean value, CFU concentrations are given.

Table 2. Comparison between theoretical calculated and measured CFU mean value concentrations. UDF ceilings, called Case 1, Case 2, and Case 3.

Case No	Number of people present (mean value)	Source strength (CFU/s)	Total air volume flow (m^3/s)	Concentration (CFU/m^3) Mean value	
				Theoretical* Equation (2)	Measured
Case 1	5	1.85	2.54	3.6	1-3**
Case 2	6.5	1.85	4.3	2.8	2
Case 3	5.6	1.85	2.75	3.8	2.9

* Concentration values are given with one decimal
** The value 3 CFU/m^3 was measured when the probe pointed slightly upwards.

The results from the three cases show that all mean value concentrations are less than 10 CFU/m^3 and that measured mean value concentrations of aerobic CFUs during on-going surgery in operating rooms equipped with UDF supply air systems (UDF ceilings) are little less, but in the same range as the mean value concentration calculated with the expression of the dilution principle (Equation (2)). When the air velocity of the UDF is low (≤ 0.3 m/s), this might depend on the fact that the air flow pattern above the operating table is affected by the presence of obstacles, such as operating lamps and monitors, and movements of the staff and their convection flows. This results in a disordered air flow pattern partly resembling that of mixing air. Figure 1 shows an operating room with UDF ceiling and equipment.

Figure 1. Operating room with UDF ceiling and installed equipment.

Activity Level

In Case 3 measurements of airborne viable particles were performed during on-going surgery at 11operations in five identical operating rooms with exactly the same type of UDF ceiling. The grand mean value of measured concentrations and the grand mean value of number of people present during the 11 operations are described by Gandra et al (2017) and given in Table 2. During the 11 operations there were different levels of staff activities, here called low staff activity and high staff activity. Tables 3 and 4 show concentrations of aerobic CFUs and estimated source strength with the aid of Equation (1) during different operations at low staff activity (Table 3) and at high staff activity (Table 4). Low staff activity occurred during on-going surgery when the staff were standing almost still and high activity was during on-going orthopaedic surgery.

Table 3. Concentration of aerobic CFU and estimated source strength (Equation (1)) during operations with low staff activity during on-going surgery in operation rooms equipped with UDF ceiling with an air volume flow of 2.75 m^3/s.

Operation (number)	Concentration* mean value (CFU/m^3)	Number of people* present (number)	Source strength* (CFU/s) (Equation (1))
1	1.0	7.0	0.4
2	1.8	6.4	0.8
3	1.0	5.5	0.5
4	1.4	4.0	1.0
5	2.3	5.0	1.3
6	5.3	6.5	2.2
Mean value	2.1	5.7	1.0

* Values are given with one decimal

Table 4. Concentration of aerobic CFU and estimated source strength (Equation (1)) during operations with high staff activity during on-going surgery in operation rooms equipped with UDF ceiling with an air volume flow of 2.75 m^3/s.

Operation (number)	Concentration* mean value (CFU/m^3)	Number of people* present (number)	Source strength* (CFU/s) (Equation (1))
7	9.3	5.3	4.8
8	6.3	5.0	3.5
9	1.1	6.6	0.5
10	1.0	4.0	0.7
11	1.0	6.5	0.4
Mean value	3.7	5.5	2.0

* Values are given with one decimal.

Tables 3 and 4 indicate that the source strength mean value during surgical procedures during low staff activity is half the mean value obtained at high staff activity at orthopedic surgery. The difference between low and high staff activity level is in agreement with data given by Ullmann et al (2017). The source strength mean values calculated for the same type of surgical clothing system with data from orthopedic procedures given by Erichsen Andersson (2013) and Nordenadler (2010) are in the same range as the source strength mean value given in Table 4 (high staff activity during orthopedic surgery).

Conclusions

As a first approximation, when calculating necessary air volume flows or predicting CFU concentrations in an operating room, one can assume that the dilution principle is valid in the operating room during on-going surgery. In such cases, beyond the total air volume flow, the number of people, their activity level during surgical procedures and the source strength of the selected clothing system should be taken into consideration. This is in agreement with results by Nordenadler (2010) and recommendations by SIS-TS 39:2015 (2015). To sum up, when the air volume flows are the same during on-gong surgery, there are little difference in measured CFU levels between the two room air distribution principles, UDF with low velocity and total mixing air flows (dilution principle). Other parameters, such as clothing system, number of people and their activity level, play a more important role than the room air distribution principle.

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