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Protective Efficacy of Surgical Clothing Systems without and with Textile Knee-length Boots and Airborne Microorganisms based on Results from Measurements in a Dispersal Chamber and during ongoing Orthopedic Surgery

Bengt Ljungqvist[1], Berit Reinmüller[1] and Catinka Ullmann [1, 2]

1Chalmers University of Technology, Sweden
2Industri AB Ventilator, Sweden

Abstract

The main source of airborne microorganisms in an operating room is the staff and the patient. To reduce airborne bacteria-carrying particles from the staff, it is of importance that the surgical team wears functional clothing systems. Here results are compared from measurement studies of the protective efficacy, i.e., the source strength, of a surgical clothing system without and with textile knee-length boots. The studies were performed in a dispersal chamber and during ongoing surgery. The results show that the use of knee-length boots or not, have considerable influence of the source strength, i.e., microbial air cleanliness in the operating room.

Keywords: Ultraclean operating rooms, surgical clothing systems, source strength, microbiological air cleanliness, colony-forming unit (CFU).

Introduction

The hospital environment is contaminated by microorganisms and some of them are antibiotic resistant. The number of airborne bacteria-carrying particles in the operating room is considered as an indicator of the risk of infections to the patient undergoing surgery susceptible to infections. To reduce surgical site infection, it is desirable to keep the bacteria-carrying particles at a low number in the operating room air, especially during orthopedic prosthetic surgery. The main source of microorganisms in an operating room is usually the personnel and the patient. The surgical staff wears clothing system suitable for ultraclean air environment. The purpose of this paper is to compare data of the protective efficacy, i.e., source strength, of a clothing system when people are using shoes without and with textile knee-length boots over the shoes, respectively. The source strength is here described as the mean value of the number of airborne bacteria-carrying particulates per second emitted from one person. Measurements have been performed in a dispersal chamber as well as during ongoing surgery and been described by Ullmann et al (2017).

Material and Methods

Apparatus

Airborne viable particles were collected using a slit-to-agar sampler, FH3®, and sieve sampler, MAS-100®. The sampling periods for the two instruments were 10 min. The sampling volume per period become for the FH3® sampler 0.5 m^3 and for the MAS-100® sampler 1m3. The two samplers in comparison to the other impaction samplers have been discussed by Ljungqvist and Reinmüller (1998, 2008) and Romano et al (2015). Both instruments have a d50-value (cut-off size) less than 2µm and were operated according to the manufacturers´ instruction. Thus, the results from the two samplers are comparable.

Microbial growth medium for all tests was standard medium Tryptic Soy Agar (TSA) in 90 mm Petri dishes. The TSA plates were incubated for not less than 72 hours at 32 ˚C followed by not less than 48 hours at room temperature. After incubation the number of colony-forming units (CFU) were counted and recorded as aerobic CFU/m^3.

Dispersal chamber

Tests in the dispersal chamber have been carried out to evaluate two Olefin surgical clothing systems with textile hoods, one with shoes and the other system with textile knee-length boots over the shoes. Concentration of airborne bacteria-carrying particles as aerobic CFUs were measured in the exhaust air of the dispersal chamber, where the air is turbulently mixed, by using the FH3® slit sampler, see Ljungqvist and Reinmüller (2004, 2014) and Romano et al. (2016). The principal arrangement of the dispersal chamber is shown in Figure 1.

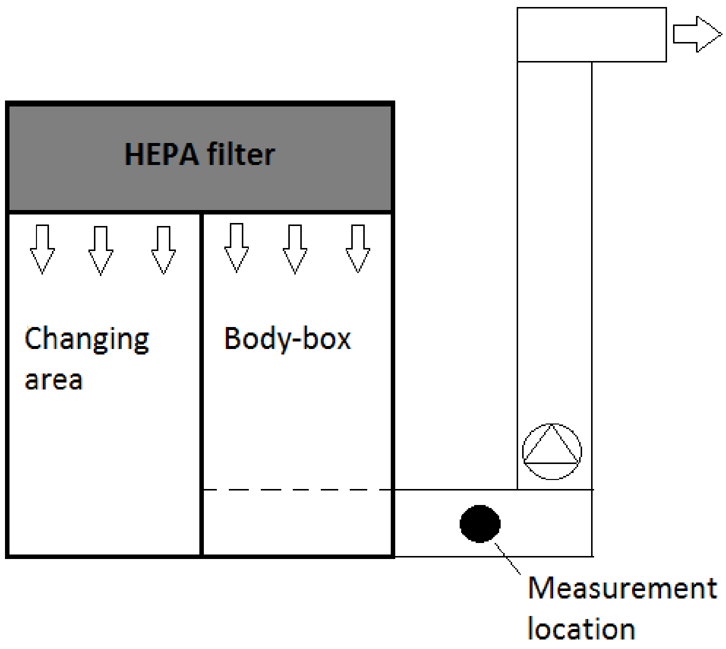

Figure 1. Principal arrangement of dispersal chamber (body-box).

During the measurements the male test subjects performed standardized cycles of movements that included arm movements, knee bends and walk in place at a set speed. These movements are, in principle, comparable with those described in IEST-RP-CC003.4 (2011). Prior to each cycle of movement, the test subject stood still to avoid the influence of particle generation from the previous test cycle. The evaluated clothing systems each had five test subjects performing the standardized cycles of movements four times, see Ljungqvist and Reinmüller (2004, 2014). The activity level in the dispersal chamber is considerable higher than that of orthopaedic surgery.

Operating rooms

The measurements were performed in operating rooms at a hospital in the Stockholm area. The tests were performed during ongoing orthopaedic surgery in operating rooms, where the air movements could be characterized as mixing air, i.e., the dilution principle is applicable. The supply air was HEPA-filtered with air volume flows of about 0.7 m^3/s, which give about 20 air changes per hour. The surgical clothing systems used during the surgical procedures were the same clothing systems used during the dispersal chamber tests.

The measurements were performed either with FH3®slitsampler or with the MAS-100® sieve sampler. The probes of the two air samplers were placed just beside the operating table with a distance of approximately 0.8 - 1.2 m to the wound site at two alternative locations depending on the position of the surgical team. The sampling probe was positioned just above the operating table 1.2 m above the floor. Figure 2 shows the principle arrangements of the location of the sampling probe.

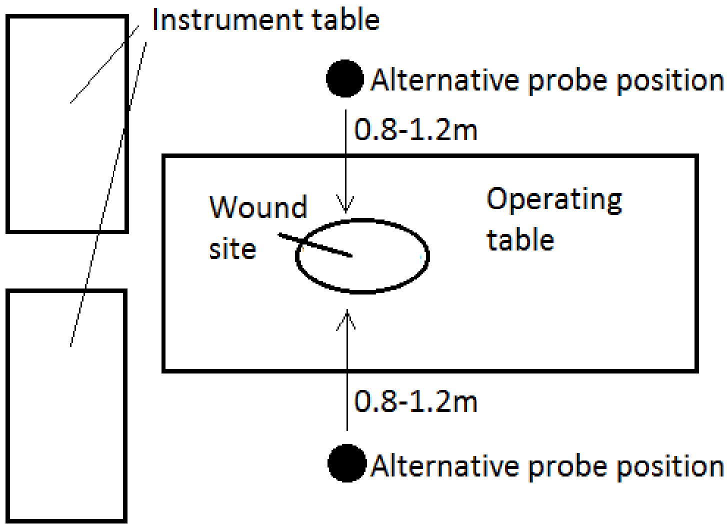

Figure 2. Principal arrangement of the alternative placement of the sampling probes beside the operating table.

Clothing Systems

The surgical clothing systems used were two systems made of synthetic fibre olefin. During surgical procedures the surgeon and the surgical nurse wore an additional disposable sterile coat over the surgical clothing system. The fabric olefin is consisting of 98% olefin and 2% carbon fiber, not antimicrobial treated. The blouse with cuffs at arms and neck, and trousers with cuffs at the wrists, were laundered ca 20 times. The weight is 125gram per square meter. Textile hoods with cuffs at the face and buttons below the chin were laundered ca 20 times, sterile disposable face-masks, and disinfected gloves were worn. None of the tested components were sterilized. The difference between the two Olefin clothing systems is the footwear. One clothing system had clean socks of cotton and disinfected plastic shoes while the other system had textile knee-length boots over the shoes. The textile knee-length boots with zip at the back of the leg were laundered approximate 10 times. Figure 3 shows the surgical team dressed in the Olefin surgical clothing system with knee-length boots.

Figure 3. The surgical team dressed in the Olefin surgical clothing system with hood and knee-length boots.

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):

$$Qs = c\ Q/n \qquad (1)$$

where qs = 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)

In the dispersal chamber there is only one person during the tests, why n=1 in Equation (1). 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 CFUs per second from one person, is a valuable tool in describing the protective efficacy of clothing systems against bacteria-carrying particles (Ljungqvist and Reinmüller, 2004).

Results

Dispersal chamber

Source strength mean values of aerobic CFU from dispersal chamber tests with five test subjects are shown in Table 1,where the values are given when the test subjects were dressed in the Olefin clothing systems with textile hood, without and with textile knee-length boots.The air volume flow in the body-box part of the dispersal chamber was 0.23 m^3/s during all tests.Table 1 shows that the reduction of the number of aerobic CFUs with boots compared to without boots is about 57%.

Table1 Source strength mean values of aerobic CFU from dispersal chamber tests with five test subjects dressed in Olefin clothing systems with textile hood. Additionally, were worn open plastic shoes (sandals) without and with textile knee-length boots.

Test subject	Source strength mean values (CFU/s)*	
	Without boots	With boots
1	1.4	1.2
2	0.7	0.2
3	3.1	0.8
4	2.4	0.6
5	3.8	2.3
Grand mean value	2.3	1.0
Min – max	0.7 – 3.8	0.2 – 2.3

* Numbers are given with one decimal. Source strength values are calculated from data given by Ljungqvist and Reinmüller (2016).

Ongoing surgery

Table 2 shows concentrations of aerobic CFU and estimated source strengths during ongoing orthopaedic surgery in an operating room with dilution mixing air and an air flow of 0.7 m^3/s. The surgical team (5-6 persons) were dressed in Olefin clothing systems with textile hood, without and with textile knee-length boots. Measurements were performed during three operations and the sampling time of airborne CFUs was 10 min/sample. **Table 2** shows that the reduction of the number of aerobic CFUs with boots compared to without boots is about 67%.

Table 2. Concentration of aerobic CFUs and estimated source strength during ongoing orthopedic surgery in an operating room with dilution mixing air and an airflow of 0.7 m^3/s. The surgical team was dressed in Olefin clothing system with textile hood and private shoes without and with textile knee-length boots. Measurements were performed during three operations and the sampling time of airborne CFUs was 10 min/sample.

Air sample No	Without boots			With boots		
	No of persons (No)	Concentration (CFU/m^3)	Source strength* (CFU/s)	No of persons (No)	Concentration (CFU/m^3)	Source strength* (CFU/s)
1	6	4	0.5	5	<2	<0.3
2	6	10	1.2	5	<2	<0.3
3	6	10	1.2	5	2	0.3
4	6	14	1.6	5	6	0.8
5	5	12	1.7	-	-	-
Mean value	5.8	10	1.2	5	<3	0.4

* Source strength values are given with one decimal.

Conclusions

Even if the number of measurements during ongoing surgery is limited, the results indicate that the reduction during ongoing surgery (67%) is in the same range as in the dispersal chamber tests (57%).

Reinmüller (2001) describes tests in an aseptic filling room for pharmaceutical production, where the operators were dressed in cleanroom coveralls with hoods. The effect of knee-length boots compared to normal cleanroom shoes was evaluated. When knee-length boots were used a reduction of airborne particles and aerobic CFUs of approximative 90% was achieved. The high reduction with cleanroom clothing system might depend on the cleanroom operator being better covered than a person with surgical clothing, who has partly uncovered arms.

It should be noted that it is possible to achieve concentration values less than 10 CFU/m^3 during ongoing orthopaedic surgery in operating rooms with air flows of 0.7 m^3/s (around 20 air changes per hour) when proper surgical clothing systems and additional components are used.

A dispersal chamber test can be a valuable tool in the development of new clothing systems and the estimation of the protective efficacy. In summary, in operating rooms for surgery susceptible to infections, the selection of clothing systems for the operating room personal should no longer only be considered in terms of comfort but also in terms of patient safety.

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