

# Do room air temperature and human activity affect the particle concentration under real surgical procedures in operating rooms with mixing ventilation? - An experimental study at St. Olavs hospital

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**Abstract.** The objective of this study is to explore the effects of different room temperatures and different types of activities on the indoor air quality in the operating room during surgery. Three mock-up surgeries were performed at 21 °C, 23 °C, and 25 °C at St. Olavs hospital in Norway. The effects of the surgeon's activity and nurse's movement on the concentration of particulate matter at the surgical site and instrument table were compared. The results show that the concentrations of particles at both the surgical site and the instrument table are the lowest at room temperature of 23 °C. The activity of the surgeon was the main factor leading to the increase in the concentration of particulate matter with the size 0.3-0.5 µm at the surgical site, while the nurse movement led to the increase in the concentration of particulate matter with the larger size. At all room temperatures, the movement of the distribution nurse had a greater effect than the activity of the surgeon on the increase of the concentration of particles at the instrument table. In addition, the intensity of the particulate source may be factors affecting the concentration of particulate matter. Therefore, it is recommended that distribution nurses should avoid unnecessary activities during the operation.

## 1 Introduction

Airborne bacteria that enter open wounds during surgery can cause post-operative infections, commonly known as surgical site infections (SSI). SSI is the most common healthcare-associated infection among patients [1]. According to World Health Organization (WHO) guidelines for safe surgery, the incidence of serious complications in patients undergoing inpatient surgery in developed countries is 11.8% (1.2-23.6%), Extra hospital stay attributable to SSI was 9.7 days with increased costs of US\$ 20 842 per admission [2].

Air cleanliness in the operating room (OR) is one of the important factors affecting the incidence of SSI [3]. The study showed that skin scales on the surgical team were the main source [4]. Other studies seem to have found a linear relationship between CFU and the concentration of 5-10 µm particles of a specific size in the OR [5]. At present, the OR uses high ventilation volume, laminar ventilation, and high-efficiency filtration device to make the indoor air can achieve a cleaner state. These measures have been proved to be effective in improving indoor air quality and reducing the SSI rate to a certain extent.

In addition to some equipment and ventilation parameters, some human activities in OR are also thought to affect air quality in the operating room. Previous studies on influencing factors of air quality in the OR summarized the following important factors: 1. Activities of the surgical team [6], 2. Door opening [7, 8], 3. The movement of the distribution nurse [9], 4. Clothing [10], 5. Air change rate [11, 12]. Although some studies have discussed these influencing factors qualitatively, there is no quantitative analysis yet.

In addition, a recent study [13] showed that the surgical lamp irradiates the surgical site which creates a thermal plume above it may prevent particulate matter from settling. This phenomenon may have a protective effect on the surgical site, and the greater the velocity of the thermal plume, the stronger the protective effect. The intensity of the thermal plume is related to room temperature, and the lower the room temperature is, the stronger the thermal plume is [14]. The relationship between room temperature and air quality at the surgical site has not been described. Therefore, this study aims to reveal the influence of room temperature changes and personnel activities on the air quality of the surgical site and instrument table.

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## 2 Methods

### 2.1 The real operating room

The mock surgeries were conducted in an actual OR with Mixing ventilation (MV) in the Emergency, Heart and Lung Centre at St. Olavs Hospital in Trondheim, Norway, as shown in Fig.1. The OR has an area of 53 m<sup>2</sup> and a height of 2.9 m. The OR is equipped with four radial air diffusers located in the ceiling in each corner of the room (Figure 1). There are four exhaust grills in this OR. Two exhaust grills are installed on the wall of the entrance door, with one exhaust grill close to the floor and one close to the ceiling. The other two exhaust grills are installed in the same manner on the opposite wall. The total supply air flow rate was 3701 m<sup>3</sup>/h, and the average airflow rate in the exhaust was 3288 m<sup>3</sup>/h. The air change rate of the OR was 24 air changes per hour (ACH). The three mock surgeries were performed at 21°C (the lowest room air temperature), 23°C (room air temperature during normal surgery), and 25°C (room air temperature during surgery for infants).

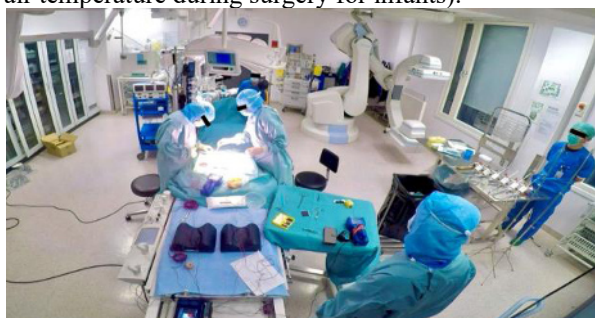


Fig. 1. The layout of the OR

### 2.2 Measurement procedure and equipment

Abdominal surgery is the most common type of surgery, such as caesarean deliveries, appendectomy, colon surgery, laparoscopic surgery. Therefore, the surgical site location in this study was abdomen [15]. Five experimenters simulated five different roles in the OR, which includes two surgeons, a sterile nurse, a distribution nurse, and an anesthesiologist. A 4 kg pork rib was placed on the operating table to simulate the patient. Among them, two surgeons and the sterile nurse wore a non-woven polyester/ tufted Surgical gown, Fulfilling the Requirements of EN13795-2:2019, Worn over a clean air suit, together with a Surgical face Mask (EN 14683 Type II approved). The distribution nurse and anesthesiologist wear a clean air suit and surgical face mask, and a correctly positioned surgical hood. Each mock operation is divided into four stages, a total of 60 minutes, divided into: 20 minutes of static, 10 minutes of surgeon activity, 20 minutes of static, 10 minutes of nurse movement. The surgeon cut and sutured the rib while the surgeon activity and the nurse walk around the operating table while the nurse moved. The purpose of 20 mins immobility is to stabilize the concentration of indoor particulate matter. This prevents the influence of pre-operative personnel activities on the

results, as well as the influence of surgeon activities on the results of nurse movement. Over 1 hour was arranged between each mock surgery to wait for the stability of the temperature.

The measuring points were the surgical site and instrument table. The measurement device is Aerotrack 9306, which supports to detect the concentration of particles of six different particle sizes. Flow rate 0.1 CFM (2.83 LPM) Accuracy ±5% / particle size range 0.3 to 15 µm. The sampling interval used in this study is 10s.



Fig. 2. TSI Aerotrack 9306

## 3 Results and discussion

We scheduled 20 minutes of inactivity at the beginning of each simulated operation. Since all the surgeons are waiting outside before the operation, their clothes can carry a large amount of dust. As we can see from the Fig.3., during these 20 minutes, we observed the concentration of particulate matter drop to between 1/12 and 1/5 of its initial level, with the final particulate concentration below 5000 numbers /m<sup>3</sup>. We observed significant increases in particulate matter concentrations in both surgeon activity and nurse movement.

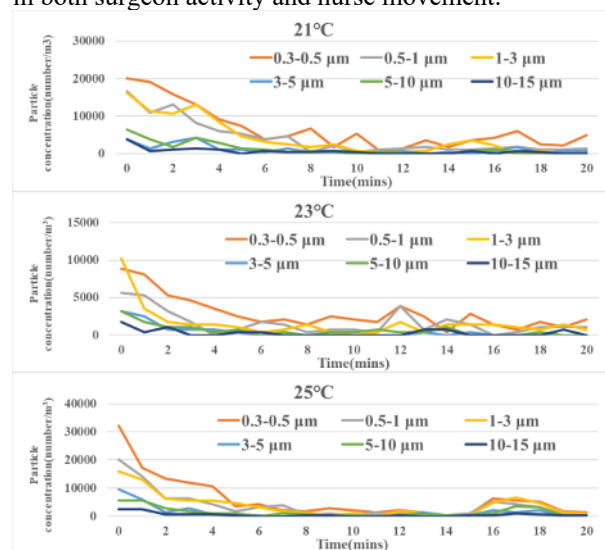
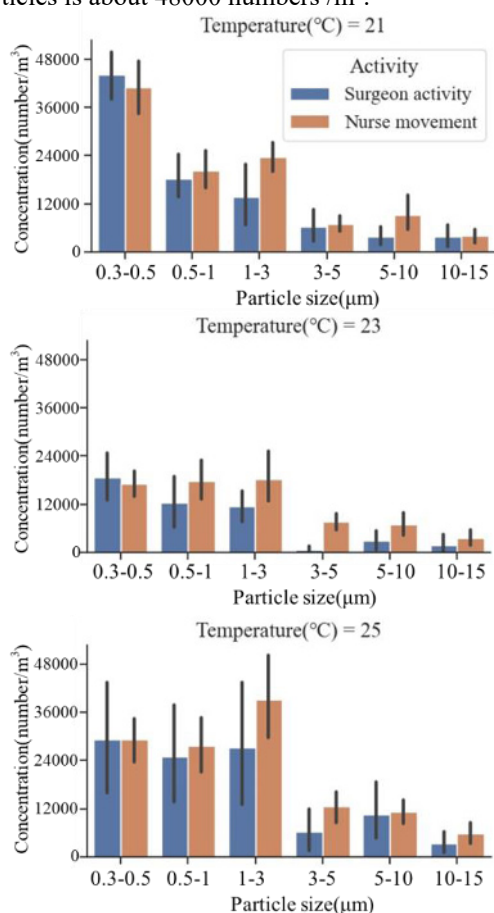


Fig.3. The drop in particle concentration at surgical site during first 20 minutes of every mock-up surgery

Fig. 4. shows the concentration results of particulate matter quantity at the surgical site at different room temperatures and different activities. As can be seen

from the figure, on the whole, the concentration of particulate matter at the surgical site when the nurse moved was greater than that when the surgeon activity. This phenomenon is obvious in particle size range larger than 0.3  $\mu\text{m}$ . For particles smaller than 0.3 microns, the effect of surgeon activity is greater. This may be because surgeons tend to have small movements, such as waving, bending, and turning. In contrast, nurses have a large range of movements. Although the active area is more than 1m away from the operating table, the airflow of the surgical microenvironment may be disturbed by it. The surgical lamp shines on the surgical site for a long time, heating it and creating an upward plume of heat. The upward air flow will prevent the deposition of particles above the surgical site, so it has a protective effect on the surgical site. Turbulence in the airflow may destroy it and leave it unprotected.

The concentration of particulate matter varies greatly at different room temperatures. It was observed that at room temperature of 23°C, the particle concentration of any size was below 24000 numbers /m<sup>3</sup>. When the room temperature was 21°C, the concentration of particulate matter was the highest. The concentration of 0.3  $\mu\text{m}$  particles is about 48000 numbers /m<sup>3</sup>.

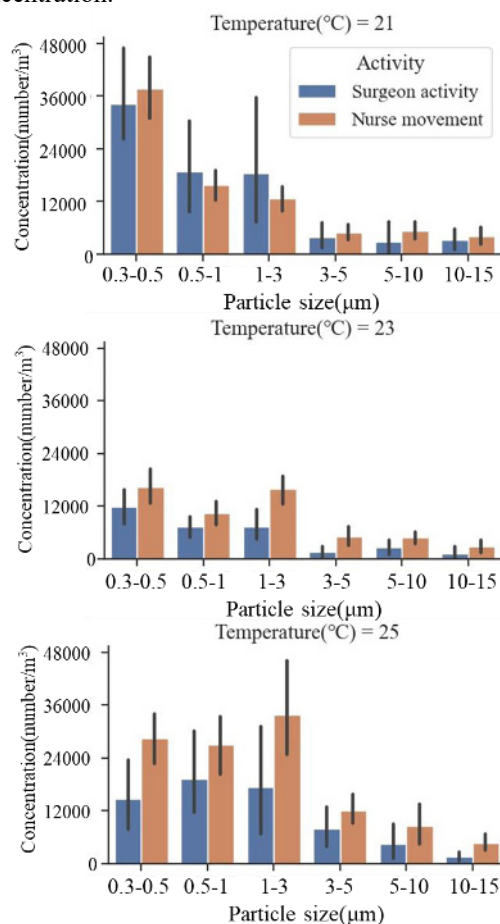


**Fig. 4.** Particle concentration at the surgical site

The Fig. 5. shows the concentration results of particulate matter quantity at the surgical site at different room temperatures and different activities. The impact of the nurse movement is greater than that of surgeon activities. The relative difference was greatest at 25°C, with the concentration during the nurse movement being twice as

much as the concentration of the surgeon activity. This could be interpreted as the fact that the nurse, who is a source of the particles, is closer to the instrument table than the surgeon during the nurse movement.

By comparing the results of different temperatures, we found that the particle concentration was the lowest at room temperature of 23°C. The particle concentrations of all particle sizes were lower than 24000 numbers /m<sup>3</sup>. This phenomenon is similar to the concentration of particulate matter at the surgical site. Combined with the results of particle concentration at the surgical site, we believe that the difference concentration under different room temperature may be caused by different emission source intensities. Before the mock operation at 21°C, all the experimenters stayed outside for a long time. After the start of mock operation, particulate matter was gradually diluted and removed by ventilation. However, before the mock surgery at 25°C, the experimenters left the OR again for a longer time than before the mock surgery at 23°C, carrying more particles. In addition, the influence of thermal plumes on the results can be ruled out, because there is no thermal plume above the instrument table, but the two measurement points show similar results at different room temperatures. Therefore, further studies are needed to reveal the direct relationship between room temperature and particulate concentration.



**Fig. 5.** Particle concentration at the instrument table

## 4 Conclusion

In this study experimental measurements were performed in simulated operation procedures in a real OR. This study investigated the influence of room air temperature and different surgical activities on the distribution of the concentration of particulate matter in the surgical site and instrument table. A few conclusions may be made as following:

- 1) Indoor particulate matter concentrations can be reduced to 1/12 to 1/5 of the initial value by 20 minutes with very low activity level. Therefore, it is recommended to reduce the movement of personnel in the OR for at least 20 minutes before the incision.
2. The source of particulate matter in the OR is medical staff, and the release rate of particulate matter source may have a crucial impact on the concentration of particulate matter in the surgical site and instruments.
- 3) The movement of the nurse increase the concentration of particulate matter at the surgical site and instrument table when the room temperature is higher. Therefore, it is an effective measure to reduce the concentration of particulate matter at the surgical site and instrument table by adopting a lower room temperature and avoiding unnecessary movement of circulating nurses as far as possible.

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