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Major article

Traffic flow in the operating room: An explorative and descriptive study on air quality during orthopedic trauma implant surgery

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Background: Understanding the protective potential of operating room (OR) ventilation under different conditions is crucial to optimizing the surgical environment. This study investigated the air quality, expressed as colony-forming units (CFU)/m^3, during orthopedic trauma surgery in a displacement-ventilated OR; explored how traffic flow and the number of persons present in the OR affects the air contamination rate in the vicinity of surgical wounds; and identified reasons for door openings in the OR.

Methods: Data collection, consisting of active air sampling and observations, was performed during 30 orthopedic procedures.

Results: In 52 of the 91 air samples collected (57%), the CFU/m^3 values exceeded the recommended level of <10 CFU/m^3. In addition, the data showed a strongly positive correlation between the total CFU/m^3 per operation and total traffic flow per operation ($r = 0.74$; $P = .001$; n = 24), after controlling for duration of surgery. A weaker, yet still positive correlation between CFU/m^3 and the number of persons present in the OR ($r = 0.22$; $P = .04$; n = 82) was also found. Traffic flow, number of persons present, and duration of surgery explained 68% of the variance in total CFU/m^3 ($P = .001$).

Conclusions: Traffic flow has a strong negative impact on the OR environment. The results of this study support interventions aimed at preventing surgical site infections by reducing traffic flow in the OR.

The prevention of surgical site infection (SSI) after orthopedic implant surgery is a hot topic for politicians, hospital administrators, and clinicians, given the enormous amount of resources these infections consume in terms of extra costs of medications, reoperations, and extended length of hospital stays.[1-4] Adding the human perspective, a recent study indicated that afflicted patients suffer deeply, both physically and emotionally, from the consequences of a deep SSI for a prolonged period.[5]

Strategies to minimize the risk of SSI can be focused on 3 major areas: the patient, the surgical technique, and the surgical environment. Optimizing the patient preoperatively by applying current knowledge about the risks associated with smoking, malnutrition, ongoing infections and wounds, diabetes, and other underlying diseases and conditions compromising immunologic defense systems can improve postoperative outcomes significantly.[6-9] Optimizing the surgical technique by not exceeding the estimated 75th percentile of surgery time based on the type of surgical procedure reduces the risk of SSI and also minimizes blood loss, thereby avoiding the need for (allogeneic) blood transfusions and eliminating postoperative hematomas.[10-15]

The present study focused on strategies aimed at optimizing the surgical environment, in particular the air quality in the operating room (OR). Enhancing air quality by reducing airborne contamination has been shown to be of great importance, especially in relation to implant surgery.[16-18] It has been suggested that levels be maintained at <10 CFU/m^3 during implant surgery, and that clinical

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benefits can be expected by reducing it to 1 CFU/m^3,[18] given that very low levels of clinically relevant coagulase-negative staphylococci can initiate a device-related infection.[19] A landmark study found a strong linear relationship between the level of bacterial air contamination and the prevalence of deep SSI.[20]

The most common ventilation systems in use today are turbulent, displacement, and laminar airflow (LAF) systems. Whereas turbulent and displacement ventilation systems differ primarily in the methods used to supply clean air, both are incapable of opposing heat emissions from people and lamps. Both types of systems are sensitive to movement, leading to the formation of local eddies.[21] The most important source of airborne contamination is related to the dispersal of particles from persons present in the OR and their movements.[22-24] Clothing OR staff in scrubs with lower air permeability compared with conventional scrubs can reduce the dispersal of microorganisms by the OR staff, thereby significantly reducing the airborne contamination.[23,25,26] An experimental study has indicated that the protective ability of tightly woven clothing systems can deteriorate after repeated washing and sterilization.[27] Another study concluded that unnecessary conversation in the OR can contribute to an increased risk of airborne contamination,[28] and a pilot study indicated a possible association between high levels of noise during surgery and SSI.[29] The impact of OR door openings on air quality has been investigated in several studies,[30,31] but clinical tests of this have proven difficult. Ritter et al[32] found no significant difference in OR airborne bacterial counts between closed doors (mean, 15.2 CFU) and swinging doors (mean, 14.5 CFU). Stocks et al[13] reached the same conclusion. Only one study to date has reported a correlation between OR door openings and elevated airborne bacterial counts[33]; however, that result was based on 69 passive samples (on settle plates) and only 13 active samples (single-stage slit impact) placed outside the surgical wound area. The aims of the present study were to investigate the air quality, expressed as CFU/m^3, during orthopedic trauma implant surgery in a displacement ventilated OR; to explore how traffic flow and the number of people present in the OR affect the air contamination rates in the vicinity of the surgical wound; and to identify reasons for door openings in the OR.

METHODS

Setting

The study was performed at a Swedish university hospital that performs approximately 9,000 surgical procedures annually. Data was collected in 3 parallel ORs of equal size (39 m^2), each equipped with an upward air-displacement system supplying cool air (2-3°C below room temperature) above the floor in each of the 4 corners of the room. By thermal convection, the air is evacuated via 4 exhaust fans installed in the ceiling. Each OR is supposed to be maintained at positive air pressure by adjusting the inflow rate to exceed the outflow rate; however, the desired difference in pressure between the outer hall and the OR is not specified. Normally the pressure difference is ~3 kPa, and an alarm is activated if the pressure falls so that the difference is neutralized. Each OR has only a single entry point, with the door opening inward, leading directly to the outer hall. The OR teams wore conventional cotton/polyester 50/50 mix shirts and trousers, long surgical hoods tucked in, and private shoes and socks. The scrubbed team also wore reinforced disposable sterile gowns, facemasks (RII), and double-sterile gloves. Adherence to this practice was recorded for every operation. During almost half of the operations, at least one of the air inlet supply devices was partially blocked by medical equipment.

Data were collected during 30 consecutively selected full-length orthopedic trauma operations involving different types of closed-fracture surgery using plates and screws, intramedullary nails, or hemiarthroplasty. Sampling and data collection were done during the daytime and in most of the cases once a week, over a 7-month period from April to November 2010, with the exception of the holiday month of July.

Air sampling method

A Sartorius MD-8 air scanner (Sartorius Mechatronics, Göttingen, Germany) was used to collect airborne microorganisms. Air was sampled at a flow rate of 3 m^3/hour (0.83 L/second) in 20-minute periods continuously during the operations. The instrument was placed outside the sterile zone, and a sterilized flexible hose was extended to reach the wound area, with a filter holder attached to the end. The filter holder with a gelatin filter (3 μm pore size; 80 mm diameter) was placed 20-40 cm from the wound. The filters were placed vertically ($n = 60$), slightly upward ($n = 23$), slightly downward ($n = 17$), or horizontally ($n = 3$). In those cases in which the OR nurse had problems attaching the filter holder close to the wound ($n = 13$), the holder was placed on the Mayo stand. Data on filter placement was absent in 4 cases. The filter was changed every 20 minutes by the scrub nurse or the assistant and given to the researcher, who immediately placed it on a nonselective Colombia agar base plate with 5% horse blood. Agar plates were incubated at 30°C for 4 days, after which the total aerobic bacterial count was measured. Microbiological results are expressed as CFU/m^3. A total of 116 samples were analyzed; 4 samples were accidentally contaminated and thus excluded from the analysis. Filters and plates were handled using strict aseptic technique. To evaluate the technique, filters that had not been used for air sampling were placed on agar plates and incubated in the same way as the used filters; no bacterial growth was detected.

Observational method

Data was collected using a pretested, structured observation form. The following variables were included: date and time, OR, room temperature, type of surgery and fixation method. The period from incision time to wound closure was divided into 20-minute intervals corresponding to the ongoing air sampling. During 119 intervals (each interval corresponding to 20 minutes of air sampling), traffic flow was measured, as well as the reasons for door openings, and the current step in the surgical procedure was recorded. The number of people present in the OR, patient and researcher excluded, was recorded.

Data analysis

Primary analyses showed that CFU/m^3 could not be considered a variable with a normal distribution. For this reason, the linear relationship between CFU/m^3 per 20-minute interval and traffic flow per 20-minute interval was investigated using Spearman's rho. To investigate the strength and direction of the linear relationship between the total traffic flow per operation and the total CFU per operation, partial correlations were conducted, enabling the removal of duration of surgery as a potentially confounding variable and thereby giving a more accurate description of the relationship between the variables. Investigations of correlations between normally distributed variables (ie, traffic flow, duration of surgery, and number of people present) were performed using Pearson's product-moment correlation coefficient. Significance was defined as $P < .05$. All tests were 2-tailed. In relation to hierarchical multiple regression analysis, preliminary analyses were conducted to ensure no important violations of the assumptions of normality, linearity, and multicollinearity.