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Effect of mobile laminar airflow units on airborne bacterial contamination during neurosurgical procedures

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SUMMARY

Background: Surgical site infections (SSIs) after neurosurgery are potentially life-threatening and entail great costs. SSIs may occur from airborne bacteria in the operating room, and ultraclean air is desired during infection-prone cleaning procedures. Door openings and the number of persons present in the operating room affect the air quality. Mobile laminar airflow (MLAF) units, with horizontal laminar airflow, have previously been shown to reduce airborne bacterial contamination.

Aim: To assess the effect of MLAF units on airborne bacterial contamination during neurosurgical procedures.

Methods: In a quasi-experimental design, bacteria-carrying particles (colony-forming units: cfu) during neurosurgical procedures were measured with active air-sampling in operating rooms with conventional turbulent ventilation, and with additional MLAF units. The MLAF units were shifted between operating rooms monthly. Colony-forming unit count and bacterial species detection were conducted after incubation. Data was collected for a period of 18 months.

Findings: A total of 233 samples were collected during 45 neurosurgical procedures. The use of MLAF units significantly reduced the numbers of cfu in the surgical site area ($P < 0.001$) and above the instrument table ($P < 0.001$). Logistic regression showed that the only significant predictor affecting cfu count was the use of MLAF units (odds ratio: 41.6; 95% confidence interval: 11.3–152.8; $P < 0.001$). The most frequently detected bacteria were coagulase-negative staphylococci.

Conclusion: MLAF successfully reduces cfu during neurosurgery to ultraclean air levels. MLAF units are valuable when the main operating room ventilation system is unable to produce ultraclean air in infection-prone clean neurosurgery.

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Introduction

Surgical site infections (SSIs) are defined as infections that occur within 30 days after surgery, or within one year in patients receiving implants. SSIs are classified according to whether they involve the incision area or organ/spaces. Incisional SSIs are further divided into superficial (involving skin or subcutaneous tissue) or deep SSIs (involving fascial, muscle or other deeper tissues) [1]. There are several exogenous (procedure-related) factors that influence the risk of SSI. One important factor is the microbiological quality of the air in the operating room, since airborne microbes may contaminate the wound by direct sedimentation, or indirectly by contaminated surgical instruments [1].

Deep neurosurgical SSIs most usually present as meningitis, subdural empyema, bone flap osteomyelitis and/or brain abscess, which entail high morbidity and are potentially life-threatening [2,3]. Previously studies have shown that coagulase-negative staphylococci (CoNS), *Staphylococcus aureus* and *Propionibacterium* species are the most frequently offending organisms in SSIs after neurosurgical procedures [2,3]. When costs associated with SSI from a hospital perspective were evaluated between high-volume surgical specialties, the greatest mean cost was found among neurosurgery patients [4]. Most neurosurgical procedures are classified as infection-prone clean surgeries since artificial implants are used, and ultraclean air ($\leq$10 colony-forming units (cfu) per m^3) in the operating room is desired.

Airborne contamination is related to the dispersal of skin particles from the persons present in the operating room. Each person releases $\sim 10^4$ particles per minute when walking, whereof 10% carry viable micro-organisms [5]. Thus, the more people in the operating room, the more bacteria-carrying particles in the air [6]. Door openings in the operating room defeat the positive air pressure and allow possibly contaminated air to flow in, resulting in unacceptable numbers of airborne cfu during surgery [7,8].

Operating-room air ventilation with laminar airflow ceiling canopy reduces the airborne cfu, and is predominantly used in orthopaedic procedures. However, these systems are expensive to install, and studies have failed to produce convincing evidence of decreasing SSI rates [9]. Mobile laminar airflow (MLAF) units significantly reduce airborne cfu in experimental studies [10,11], as well as during surgical procedures [12,13]. Although the consequences of SSI after neurosurgical procedures often are severe and sometimes life-threatening, no previous studies have been undertaken to assess the effectiveness of MLAF during neurosurgical procedures.

The aim in this study was to assess the effect of MLAF units on airborne bacterial contamination during neurosurgical procedures.

Methods

The study was conducted at a neurosurgical operating suite at a University Hospital in Stockholm, and a quasi-experimental design was used, shifting MLAF units monthly. Table I shows characteristics of the operating rooms, Table II the use of MLAF units, and samples collected. All operating rooms were equipped with turbulent ventilation with air supply in the ceiling and exhaust air devices close to the floor.

Table I
Characteristics of operating rooms

Characteristic	Operating room		
	1	2[a]	3
Size (m^3)	153	175	173
Air changes/hour	14.9	21.7	15.2

[a] Closed from July 2015 due to reconstruction.

The additional MLAF units consisted of Operio and SteriStay (Toul Meditech AB, Västerås, Sweden). Each unit consists of a table, a high-efficiency particulate air (HEPA) filter, and a laminar airflow (LAF) screen (0.6 × 0.45 m). Ambient air is passed through the HEPA filter and the LAF screen, which produces a turbulence-free airflow that pushes potentially contaminated air forwards, away from the sterile zone with an airflow velocity of 0.4–0.5 m/s (400 m^3/h). The single-use LAF screen has a unique bar code, that is recorded in the control system of the equipment, to ensure proper use. The HEPA filter should be replaced every 2000 h. The airflow is locally distributed and has no impact on the regular ventilation system. Operio works as a mayo stand with the LAF screen over an integrated foldable instrument tray, and should be directed towards the surgical site, aiming to keep the sterile integrity over the surgical site and instruments. The airflow is efficient up to 120 and 50 cm width, provided that the airflow is not blocked by equipment or staff. SteriStay is an instrument table with the LAF screen at one of the short sides, with a table work surface of 1.33 × 0.6 m. The airflow of SteriStay is pressed against a larger area, thus spreading the clean airflow for a greater length compared to Operio.

Surgical team

In neurosurgery, the surgical team generally consists of one or two surgeons, one scrub nurse, one circulating nurse, one nurse anaesthetist and/or one anaesthetist. Each member of the surgical team was dressed in a reusable Mertex P-3477 clean air suit, disposable surgical hoods that were tucked into the neckline, disposable facemasks, private socks and shoes. The surgeons and the scrub nurse were in addition using single-use sterile gowns.

Baseline sampling for pre-study conditions

Baseline sampling was conducted to assess pre-study conditions with the conventional turbulent ventilation concerning cfu/m^3, numbers of staff, and door openings. Data were collected during 11 neurosurgical operations, collecting 55 samples. The cfu results from the baseline sampling were approximately normally distributed and ranged 6–59 cfu/m^3 (mean: 23.6; standard deviation: 13.1). Numbers of staff ranged 6–10 (median: 8; interquartile range (IQR): 6–8) and door openings 0–4 (median: 2; IQR: 1–2) and were not normally distributed. Since the baseline sampling did not differ from the sampling in the study, nor in the types of neurosurgical procedures, the baseline cfu samples were included in the results.

Sampling methods

Active air sampling was performed according to Swedish guidelines during neurosurgical procedures; in ordinary

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