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Aerosols produced by high-speed cutters in cervical spine surgery: extent of environmental contamination

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Abstract High-speed cutters are used in the surgery of the cervical spine. Such high-speed devices can produce an aerosol cloud. As a patient can be a reservoir for pathogens, with aerosol-borne paths of transmission, such an aerosol has to be seen as a potential risk of infection for health care professionals present during the surgery and for patients if micro-organisms are transferred through the medical personnel. The study was performed in order to measure the extension of environmental and body contamination through contaminated aerosols produced by a high-speed cutter. Three laminectomies (C4–C6) were performed on an intact human cadaver with a high-speed 0.6-mm ball cutter. A complete surgical setup was arranged, including surgical draping and a barrier drape to the anesthesiologist's workplace. Body and environmental contamination was detected by the use of surveillance cultures. The irrigation solution was artificially contaminated with *Staphylococcus aureus* ATCC 12600. Following the surgery, staphylococci were detected in the operating room at an extension of 5×7 m. Everybody showed extensive face and body contamination with *Staphylococcus aureus*. The study showed that the use of high-speed cutters in surgery of the cervical spine produces an aerosol cloud that is spread over the whole surgical room and contaminates the theater and all personnel present. Such aerosols can be contaminated with pathogens if the patient was infected or colonized. Therefore, sufficient protective measures have to be recommended for everyone present in the operating room during such surgeries. In addition, efficient disinfection of the room and all mobile equipment is necessary after each surgery involving high-speed cutting devices.

Keywords High-speed cutter · Contamination risk · Surgical team · Aerosol

Introduction

High-speed bone burrs are standard instruments in surgical procedures in the cervical spine as well as in other bone surgeries. It is obvious that body fluids, tissue debris and irrigation fluids are spread by any rotating instrument. Due to the high speed of the rotating cutter, such bone burrs produce an aerosol with fluid droplets not visible to the observer. For detection of the aerosol and its extension over the operating room and people present, bacteriological methods of assessment can be applied.

For the surgical community, the risk of transmission of infections from infected or colonized patients to health care workers through skin-penetrating injuries is obvious and has been studied [8]. The same is true for direct contact of skin, mucous membranes and conjunctivae [3] with contaminated blood. For the field of spine surgery, Wong et al.

[13] reported a significantly higher risk of blood contamination but no higher risk of skin injuries for health care workers than in other surgical fields [12].

Concerning high-speed cutting devices in the field of cervical spine surgery, another path of transmission has to be considered. The transmission of pathogens, which can be expelled directly into the atmosphere by aerosols [4] and be inoculated through direct inhalation, and contact with mucous membranes [10] or small wounds.

This study was intended to determine, with bacteriological methods, the extension of the aerosol and the consequent environmental contamination of the operating theater and of the body contamination of the whole personnel present during the surgery.

Materials and methods

A complete surgical setup was arranged for a male human cadaver. The "patient" was draped with a surgical draping. A drape barrier at a height of 170 cm was installed in order to separate the operating table from the anesthesiologist's workplace at the head of the table. Through a median posterior approach, laminectomies at three levels (C4–C6) were performed (Fig. 1). All health care workers present during this investigation wore water-resistant and sterile surgical gowns, gloves, caps and Fluidmasks (Tecnol, Forth Worth, Tex.), covering the whole face. Laminectomies were consecutively performed by one of the authors (C.W.) from level C4 to C6 using a high-speed cutting device with a 0.6-mm ball cutter (Ultra Power System, Zimmer, Warsaw, Ind.) (Fig. 1). The standard irrigation system of the device was used, with a saline solution for irrigation. This fluid was contaminated with *Staphylococcus aureus* [American Type Culture Collection (ATCC) 12600] grown in tryptic soy broth (Merck, Darmstadt, Germany) under aerobic conditions at 37°C for 24 h. The final concentration of colony forming units (CFU) of *Staphylococcus aureus* in the test solution was obtained by a colony count. Samples were spread out on columbia blood agar (Becton Dickinson, Franklin Lakes, N.J.) and incubated at 37°C for 48 h. The resulting concentration was 2–4×10^6 CFU/ml of staphylococci.

For air sampling detection, 103 standard Petri dishes with Manitol Salt Agar (Merck) were used, which were exposed to the contaminated aerosol. The Petri dishes were placed at equal intervals in the room of 5×7 m at a height of 100 cm.

All three laminectomies were completed within 39 min. After the exposure, the Petri dishes were closed and collected. Surveillance cultures of bodies and faces were taken from the following: surgeon, assistant, scrub nurse, anesthesiologist, and the "patient's" head.

Everybody had remained in their usual working areas with no deviation, simulating the normal positions of the team members during a spinal surgery. Movements were only allowed to the extent that was necessary in order to simulate realistic cervical laminectomies.

After incubation of the Petri dishes at 37°C for 48 h, the microorganisms were differentiated by morphologic, physiologic, and serologic criteria. A commercial test kit (Pastorex Staph Plus; Sanofi Pasteur Diagnostics, Chaska, Minn.) and the classical tube coagulation test were used to identify *Staphylococcus aureus*. For each positive culture, the position of the Petri dish during the test was recorded.

Fig. 1 High-speed ball cutter during cervical laminectomy

Results

The surgeon and the surgical assistant showed a more severe contamination than other members of the surgical team. Yet, all persons investigated showed contamination of their faces and body contamination. Surveillance cultures revealed contamination with *Staphylococcus aureus* for the anesthesiologist and the "patient's" head as well. Bacterial growth for the surveillance cultures is listed in

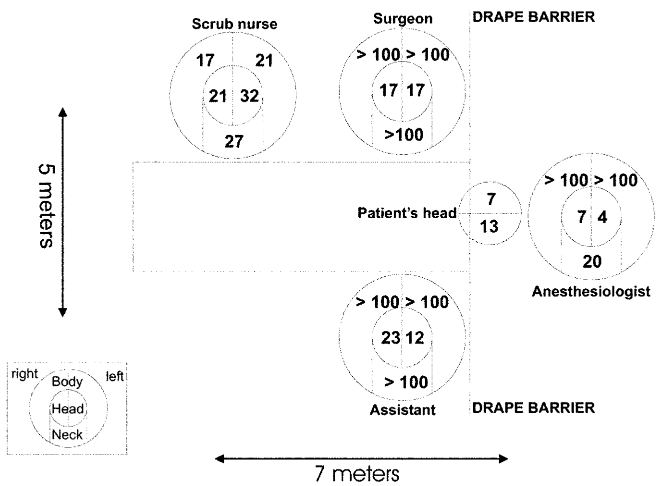

Fig. 2 Contamination of the operating room personnel (colony forming units/16 cm^2)

the schematic drawing, which shows the position of each person – including the “patient’s” head – during surgery and the extent of contamination (Fig 2). The drape itself, at the surgical side, was contaminated with *Staphylococcus aureus* to a level of more than 100 CFU/16 cm^2.

In the operating room, in the studied area of 5×7 m, all Petri dishes showed growth of *Staphylococcus aureus*, ranging from 10 to >100 CFU per plate for air sampling.

Discussion

In this study, *Staphylococcus aureus* was chosen as an example micro-organism. It is easy to culture and can easily be detected and differentiated from other bacteria. Contaminating the irrigation solution with *Staphylococcus aureus* made it possible to detect the extension of the aerosol and body contamination with standard microbiological methods. The measured extension of the contamination was not related to the contaminating micro-organism; it would be the same for any viral, bacterial or fungal agent.

It was shown that a high-speed cutting device like the one that was used in the current study produces an aerosol that spreads over a surgical theater with an extension of 5×7 m. The cutting head was rather small, with a diameter of 0.6 mm. As it was possible to detect the aerosol over the whole extension of the room, it has to be concluded that not only can the room itself be contaminated, but so also can all mobile equipment placed in the operating room. In particular, this contamination could be a source for transmission of infectious agent to consecutive patients through health care workers.

After performing cervical laminectomies at three levels within 39 min, not only environmental contamination was detected, but also body contamination of everybody present during the surgery. While a contamination of the surgeon and his assistants was to be expected, as they were in the vicinity of the cutter and were exposed to the direct spray produced by it, it is interesting to note that the level of contamination was comparably high for the anesthesiologist. The drape separating the surgical area from the anesthesiologist’s workplace at a height of 170 cm might protect persons working behind it against contact with the direct spray of the cutter, but it does not protect them against contamination through the aerosol. The drape on the anesthesiologist’s side and the “patient’s” head were also clearly contaminated, which indicates that contamination took place not through the direct spray, but through the extending aerosol cloud.

In the current study, a micro-organism load of $2–4\times10^6$ CFU/ml was used in the irrigation solution. While contaminating the irrigation solution is a limitation of the study design, as in vivo it is the patient’s blood, plasma and tissue that would be infected or colonized, the level of contamination compares to the load 22×10^6 CFU/ml of HIV-1 found in plasma of infected patients [7].

Infected or colonized patients can serve as primary reservoirs of viral pathogens or bacterial and fungal agents. Organisms must be transferred from a reservoir to an acceptable site on a host in sufficient numbers for infection [1]. Transmission through injuries with contaminated devices and direct contact with tissue and contaminated fluids has been reported for bacterial agents such as *Staphylococcus aureus* [10] and viral agents like hepatitis B and C [4, 5]. Transmission of organisms having an airborne phase in their route of dissemination has also been reported [1, 11], with evidence for such transmissions of *Mycobacterium tuberculosis*, methicillin-resistant *Staphylococcus aureus*, *legionella*, *varicella-zoster*, smallpox and influenza [2, 4, 9]. It can be concluded that there is a risk for health care workers in the operating room present during surgeries where aerosols are produced through high-speed milling or cutting devices. In addition to that risk for the surgical team, infections can be transmitted through colonized health care professionals to patients. Such transmission was reported by Isenberg et al. [6] for a single-source outbreak of *Candida tropicalis*. Micro-organisms on the fingertips and in the nasopharynx of the scrub nurse were identified as the source of infection.

In conclusion, the current study showed that a potentially contaminated aerosol is produced by a high-speed cutting device. This aerosol can be spread all over the operating room, and thus contaminates the animate and inanimate environment. The direct infection risk for health care workers might be lower than the risk from injuries with contaminated tools. However, a certain risk remains, especially in the case of inhalation of the contaminated aerosol or contact with conjunctival or mucous membranes [10]. Therefore, the authors conclude that protective measures against direct or indirect contact with contaminated droplets have to be mandatory for procedures in which high-speed devices are used. Every person present during the surgery should wear standard surgical gloves, caps and water-resistant surgical gowns with long sleeves, to avoid inoculation of contaminated fluids. Faces and eyes should be protected with standard surgical masks and eye-shields (such as Fluidmask; Tecnol). The number of people present in the operating room should also be reduced to the minimum necessary of sufficiently trained personnel. Air filtration in the operating theater should improve the safety of the personnel as well as the patient. Patients with known infections should be operated at the end of the day with no consecutive surgeries. After surgeries that involved the use of high-speed cutters, an efficient disinfection of the operating room, including all mobile equipment, is recommended.

Conclusion

The use of high-speed cutters in the surgery of the cervical spine produces an aerosol cloud that is spread over the whole surgical room and contaminates the operation theater, all mobile equipment and all personnel present. Such aerosols can be contaminated with pathogens if the patient was infected or colonized. Therefore, sufficient protective measures have to be recommended for everyone present in the operating room during such surgeries. In addition, efficient disinfection of the room and all mobile equipment is necessary after each surgery involving high-speed cutting devices.

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