Prevention of the spread of infection during highly infectious autopsy using a craniotomy box

Zapobieganie rozprzestrzenianiu się infekcji podczas sekcji zwłok o wysokiej zakaźności przy użyciu skrzynki do kraniotomii

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Abstract
In cranial autopsies, the post-mortem examination requires the use of a saw for the removal of the skull cap. In these procedures, sawing of bone becomes a critical source of infectious aerosols which spread instantaneously in the immediate environment, generating liquid aerosols including droplets of cerebrospinal fluid and blood, and leading to exposure of all autopsy personnel. In high-risk cases like prion disease, tuberculosis, severe acute respiratory syndrome (SARS), COVID-19, etc. where the skull would require sawing, the prime concern is the saw operator's exposure to these pathogens. Therefore, the author suggests the use of an ingenious ergonomic semi-circular craniotomy box during skull cap and brain removal in the autopsy procedure to successfully prevent the contamination of the entire autopsy hall. A transparent acrylic plastic box has been customized, which is semi-circular in shape having three walls, one semi-circular dome without a floor, a front wall with adjustable zipper closure, and a hind wall with circular holes with sleeves made of 5-layer fabrics. The dome contains one outlet for a vacuum suction pipe on the side, two holes on each side of the dome with non-woven fabric arms for the saw operator, and assistants' arms for performing skull opening procedures. The use of this box allowed the author to prevent and limit the spread of the generation of infectious aerosols in the autopsy hall as the bone dust collected in the vacuum ensures the safety of autopsy surgeons.

Keywords
Aerosols, Craniotomy box, High-risk autopsies, Infectious disease, Occupational hazard, Workplace safety

Streszczenie

W przypadku sekcji czaszki wymagane jest użycie piły w celu usunięcia sklepienia. Podczas tych procedur przepiłowanie kości staje się krytycznym źródłem zakaźnych aerozoli, które natychmiast rozprzestrzeniają się w bezpośrednim otoczeniu, wytwarzając ciekłe aerozole zawierające kropelki płynu mózgowo-rdzeniowego i krwi, co prowadzi do narażenia całego personelu przeprowadzającego sekcję zwłok. W przypadkach wysokiego ryzyka, takich jak choroba prionowa, gruźlica, ciężki ostry zespół oddechowy (SARS), COVID-19 itp., gdy czaszka wymaga piłowania, głównym problemem staje się narażenie operatora piły na patogeny wywołujące te choroby. Dlatego autorzy sugerują zastosowanie ergonomicznej, półokrągłej skrzynki do kraniotomii podczas usuwania sklepienia czaszki i mózgu w czasie sekcji zwłok, aby skutecznie zapobiec zanieczyszczeniu całej sali sekcyjnej. Dostosowano przezroczyste pudełko z tworzywa akrylowego, które ma kształt półkola i posiada trzy ściany, jedną półokrągłą kopułę bez podłogi, ścianę przednią z regulowanym zamkiem błyskawicznym i tylną ścianę z okrągłymi otworami z rękawami wykonanymi z pięciowarstwowej tkaniny. Kopuła posiada z boku jeden wylot na rurę ssącą z podciśnieniem, po dwa otwory po każdej stronie kopuły z ramionami z włókniny dla operatora piły oraz ramiona asystenta do wykonywania zabiegów otwierania czaszki. Zastosowanie tej skrzynki pozwoliło autorom ograniczyć rozprzestrzenianie się zakaźnych aerozoli w sali sekcyjnej, ponieważ zbieranie w próżni pyłu kostnego zapewnia bezpieczeństwo lekarzom przeprowadzającym sekcję.

Słowa kluczowe

Aerozole, Skrzynka do kraniotomii, Sekcje zwłok wysokiego ryzyka, Choroby zakaźne, Ryzyko zawodowe, Bezpieczeństwo w miejscu pracy

Introduction

In the 1980s, after the human immunodeficiency virus (HIV) appeared, the safety of autopsy personnel came into consideration, and then 'universal precaution' was established for the prevention of infection (1). With time, mechanical and electro-mechanical tools have been used more frequently on operating the human body. The saw used for bone cutting produces airborne, fine bone dust aerosols which are infectious and hazardous when inhaled. Health risk does exist in high-risk airborne transmissible infectious pathogens such as severe acute respiratory syndrome (SARS) or tuberculosis (TB) or Covid19, however, aerosolization of the infectious pathogen in blood, skin, or other bodily material remains uncertain and it still is the health risk (2). In the case of anisotropic agents, even if a specific mode of transmission (such as aerosols) is responsible for a relatively small number of cases, it may still be necessary to interrupt that route of transmission if it is associated with the most severe cases (3). During the autopsy of a skull, the cap removal procedure is done with the saw (oscillating or hand saw) which generates a large quantity of sharp-edged, irregular, fibrous, or roundish bone dust, and the spread of this infectious bone dust over a distance of 8 meters has been demonstrated (4). The particles thus generated during bone sawing not only comprise dry bone dust but also aerosols composed of cerebrospinal fluid (CSF) and blood. However, the blade of the oscillating saw has the property of spinning and due to its variable speed, it generates an enormous amount of bone and liquid aerosols which are likely to be of minute size being highly respirable or may include huge droplets and bone particles which may cause a direct impact on prosector's face (5).

There are several aerosol-transmitted infections caused by various pathogens. Some notable examples include: (3,6)

1. COVID-19: The coronavirus disease (COVID-19) is primarily transmitted through respiratory droplets generated when an infected person coughs, sneezes, talks, or breathes. These droplets can contain the SARS-CoV-2 virus and can be inhaled by individuals in close proximity or through airborne transmission in certain situations.
2. Rabies: Rabies is a viral zoonotic disease that affects the central nervous system. It is primarily transmitted through the saliva of infected animals, usually through bites or scratches. In rare cases, rabies can also be transmitted through infected tissues and bodily fluids during autopsy procedures. The risk of transmission is highest when handling the central nervous system, including the brain and spinal cord, as these tissues can harbor the virus. Handling tissues suspected of being infected with rabies should be done with extreme caution, and autopsies on suspected rabies cases should be performed in biosafety level 3 (BSL-3) facilities, if available.
3. Tuberculosis: Tuberculosis (TB) is caused by Mycobacterium tuberculosis bacteria and primarily affects the lungs. It is primarily transmitted through airborne droplet nuclei when individuals with active pulmonary TB cough or sneeze. Prolonged close contact is typically required for transmission.
4. Prions: Prions are abnormal proteins that cause neurodegenerative diseases known as transmissible spongiform encephalopathies (TSEs), such as Creutzfeldt-Jakob disease (CJD) in humans or bovine spongiform encephalopathy (BSE) in cattle. Prions are highly resistant to standard

disinfection methods and can remain infectious for extended periods. In rare cases, prion diseases can be transmitted through contaminated instruments or tissues during autopsy procedures.

5. Hemorrhagic Fever Viruses: Hemorrhagic fever viruses, such as Ebola virus, can cause severe and often fatal infections characterized by bleeding and organ failure. These viruses are primarily transmitted through direct contact with infected body fluids or tissues. During autopsy procedures, there is a risk of exposure to these viruses if adequate precautions are not taken.
6. Viral Encephalitis: Encephalitis refers to inflammation of the brain, often caused by viral infections. Certain viral encephalitis cases may pose a risk during brain dissection, especially if the infection is highly contagious.
7. Bacterial Meningitis: Meningitis is an infection that causes inflammation of the meninges, the protective membranes surrounding the brain and spinal cord. In some cases, the infection can spread to the brain tissue, leading to bacterial brain abscesses.

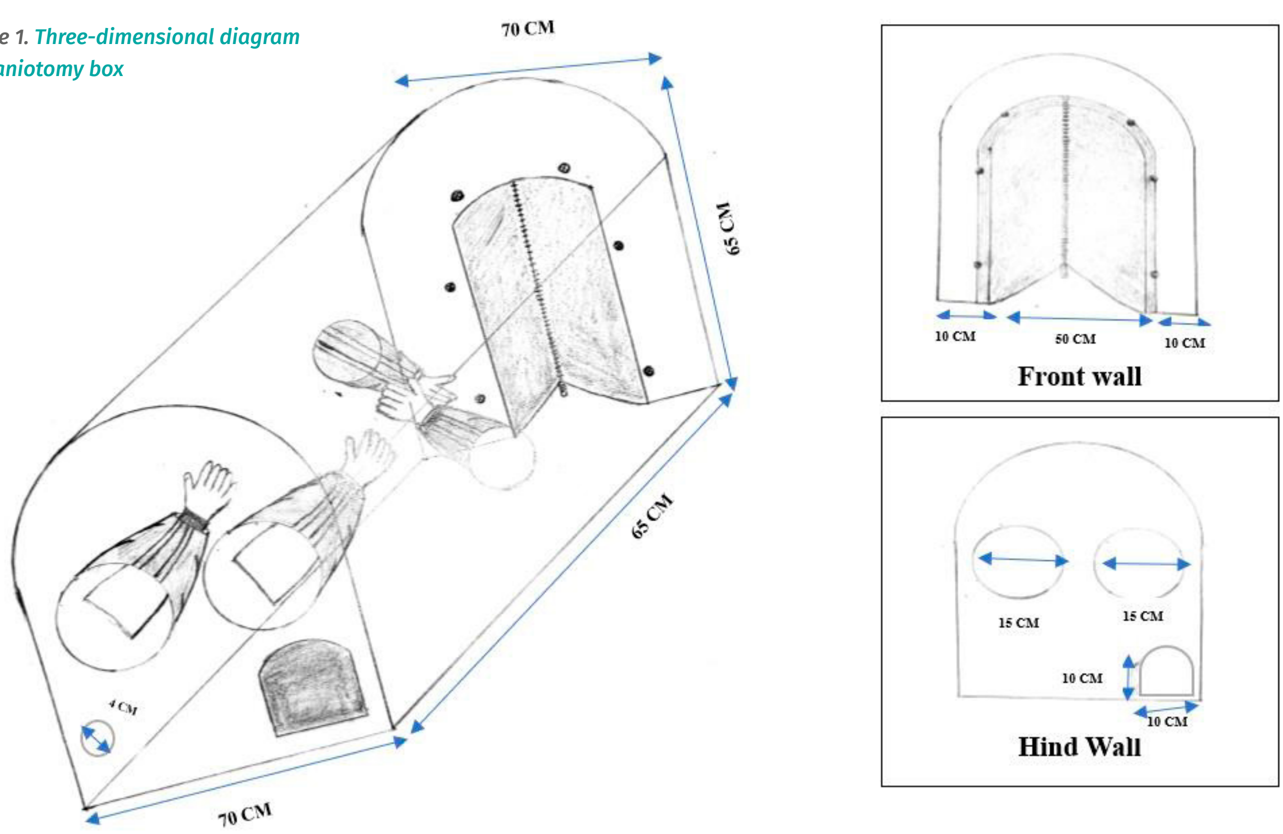
It is important to note that the transmission dynamics and specific precautions for each aerosol-transmitted infection may vary and authorities should carefully assess the different modes of transmission and prioritize interventions based on their impact on disease severity.

The autopsy execution in high-risk cases is highly infective and dangerous so that on the one hand it requires properly skilled personnel and proper personal protective equipment (PPE). but on the other hand, it requires autopsy to be performed quickly and as soon as possible after death to prevent the infectious aerosol generation and limiting its spread outside the autopsy room (7). Therefore, it is a priority to take care of autopsy personnel and provide safety to those who handle and manage the dead. They must be protected from exposure to aerosols, contaminated objects, and infected bodily fluids, and prevent the surrounding environment from contamination. This study focuses on limiting the spread of aerosol generated when skull bone sawing is performed during the autopsy procedure. This study demonstrates the use of an ergonomically suited plastic-based acrylic craniotomy box for skull bone sawing at the time of autopsy. The use of the box is to prevent infectious aerosols and limit their spread while removing the skull and brain during autopsy and providing extra safety to autopsy personnel from lethal infection.

Methods and Material:

The custom-made craniotomy box is an ingenious transparent plastic-based acrylic apparatus measuring a diameter of 70 cm, length of 65 cm, and height of 65 cm. The box has one semi-circular dome with two walls, and the floor of the box is open. There are four circular holes of a diameter of 15 cm, two of which are present on the hind wall and two on the sides.

Figure 1. Three-dimensional diagram of craniotomy box



Each hole is placed in such a way that the prosector and assistants can position their arms into the box (fig. 1). The front wall has a semi-circular hole of a diameter of 50 cm with a chained flap fitted over the thorax of the deceased (fig. 1). An opening has been provided at the sidewall of the dome having a diameter of 4 cm for vacuum suction and a gated semi-circular hole in the corner of the hind wall of the box for accommodation entrance of saw/instruments. To further reduce the risk of infection the prosector holes are fixed in non-woven fabric arms to accommodate the saw operator and assistants' arms for performing skull opening procedures. The walls of the box with their semi-circular holes have 5-layer fabrics with bacterial filtration efficiency (BFE) of 95% as shown in images 1, 2 & 3.

Image 1. ***Shows the handling of cadaver in the box through armholes***

Image 2. ***Shows a labeled top view of the box with its structures during an autopsy***

1,4: Arm holes on the side walls; 2,3: Arm hole on the hind wall; 5: Gated hole for the entrance of saw/ instruments; 6: Hole on the lower corner of dome wall for vacuum

Image 3. ***Shows the front wall of the box with zipper closure adjusted according to the body***

Safety considerations

The complete autopsy should be conducted by a professionally skilled team of autopsy surgeons and assistants having intricate knowledge regarding the handling of high-risk infectious cadavers. The team should be wearing a full personal protective equipment kit including a coverall with attached neck and head cover and the front flap covering with zipper with self-adhesive tape, one pair of long shoe covers, double surgical gloves, one n-95 mask, and one face shield. If the autopsy hall is equipped with a powered air-purifying respirator (PAPR) and air conditioner, they must be switched off.

Decontamination of the box

Hypochlorite solutions can be used to decontaminate the acrylic box. The following procedure for cleaning should be followed (8,9):

a) Dilution: Prepare a dilute solution of hypochlorite by mixing bleach with water. The exact concentration will depend on the specific product and the desired level of disinfection. Generally, a 1:10 dilution of bleach with water is recommended for disinfection purposes.
b) Application: Apply the hypochlorite solution to the acrylic sheet using a spray bottle. Ensure that the entire surface is adequately covered with the solution.
c) Contact Time: Allow the hypochlorite solution to remain in contact with the acrylic sheet for the recommended contact time. This can vary depending on the concentration of the bleach and the specific instructions provided by the manufacturer. Typically, a contact time of 10 to 15 minutes is suggested.
d) Rinse and Dry: After the contact time, thoroughly rinse the acrylic sheet with clean water to remove any residual bleach. Ensure that all traces of the solution are completely removed. Use a soft cloth or towel to dry the surface thoroughly.

It is important to note that while hypochlorite solutions can effectively disinfect acrylic surfaces, they may cause discoloration or damage if used at high concentrations or for prolonged periods. It is recommended to test the solution on a small, inconspicuous area of the acrylic sheet before applying it to the entire surface.

Results

A simulation exercise was conducted to check how useful a semi-circular craniotomy box is during an autopsy procedure. During the autopsy, the author assessed the comfort level of the prosector's position of hand and arm movements in both hands and oscillating sawing of the skull bone. A complete autopsy procedure was performed as per standard protocol guidelines for high-risk cases in a full personal protective equipment kit by a perfectly skilled team of five personnel consisting of an autopsy surgeon, two resident doctors, one assistant, and one mortuary technician. During a complete post-mortem examination as per routine protocols, skull bones were sawed and the brain was subsequently removed. An oscillating saw was used for sawing and a vacuum suction was used along with it to check the feasibility and functional efficacy of the craniotomy box.

After the opening of the skull using a saw, bone specks of dust and aerosols were collected in the vacuum suction cabin as evident from the particles settled on the inside surface of the box. The bone dust and aerosols generated during the procedure were confined to the walls of the box and could be seen as shown in images 4 & 5. However, during the study and observation, the amount of bone dust generated was significantly greater by using an oscillating saw but its spread in the autopsy hall was prevented by using the ergonomic craniotomy box. The box was thoroughly cleaned with hypochlorite solution for decontamination after the completion of the procedure.

Image 4. ***Shows a close-up view of collection of bone dust visible***

Image 5. ***Shows the removal of the skull cap in the box***

The utilization of a craniotomy box for the removal of the skull cap provides a convenient approach for prosectors during autopsies. This method allows for the collection of samples for various purposes, including advanced research or retrospective diagnoses. The ease of using the craniotomy box enhances the efficiency and accuracy of the autopsy procedure, enabling comprehensive examination and analysis of the brain tissue.

Discussion

The procedure of skull cap removal by unprotected bone sawing in open space is capable of producing minute particles, bone dust, and aerosols in large quantities which can invade the respiratory system, stay retained in the lungs, and can consequently be hazardous in many ways. This procedure first generates bone dust and fluid droplets that could transmit infection via droplets of CSF and blood that could be containing infectious agents, or the infectious agents being inside the interstices of the bone matrix. Several pathogens have been implicated in causing infections in autopsy personnel in various studies. Mycobacterium tuberculosis is the archetypal infectious agent known to be transmitted by aerosols generated during autopsy (10). Templeton et al demonstrated that the patients who did not spread tuberculosis before death unexpectedly released more bacteria after death (11). Other infections that may spread during autopsy include rabies, plague, legionellosis, meningococcemia, rickettsioses (e.g., Q fever), coccidioidomycosis, and anthrax (10). These infections, if diagnosed in the deceased, constitute the indications for the use of the box.

The protection of forensic pathologists (or prosectors) during high-risk autopsies is of paramount importance to ensure their safety and minimize potential hazards. Here are some measures that are commonly employed to protect prosectors during such procedures (12):

1. Personal Protective Equipment (PPE): Prosectors should wear appropriate PPE, including gloves, goggles or face shields, masks, disposable gowns or coveralls, and shoe covers. The specific type of PPE may vary depending on the anticipated risks involved.
2. Respiratory Protection: In situations where there is a risk of airborne contaminants, prosectors should wear respiratory protective equipment such as N95 masks or respirators to prevent the inhalation of harmful particles or pathogens.
3. Controlled Environment: High-risk autopsies should be conducted in a controlled environment, such as a negative pressure room or a biosafety cabinet. These facilities help contain any potential biohazards, preventing their spread to the surrounding areas.
4. Engineering Controls: Engineering controls, such as ventilation systems, can help maintain air quality and minimize the concentration of airborne contaminants within the autopsy suite. Separate rooms should be allotted for high-risk autopsies, wherever possible.
5. Decontamination Procedures: Following the completion of a high-risk autopsy, thorough decontamination of the equipment, surfaces, and the prosectors themselves is crucial. Specific protocols should be followed to ensure proper disinfection and removal of potential contaminants.
6. Training and Education: Prosectors should receive specialized training in handling high-risk autopsies, including knowledge of proper infection control practices, safe handling of hazardous materials, and the use of PPE. Regular training updates and continuing education are essential to stay informed about the latest safety protocols.
7. Teamwork and Communication: Clear communication and coordination among the prosectors, support staff, and any other personnel involved in the autopsy process are crucial to maintaining safety. Everyone should be aware of potential risks, emergency protocols, and effective communication channels.
8. Risk Assessment: A thorough risk assessment should be conducted before each high-risk autopsy to identify potential hazards and develop appropriate strategies to mitigate them. This assessment should take into account factors such as the nature of the case, the presence of infectious agents, and any special circumstances.

It is important to note that the specific measures for protecting prosectors during high-risk autopsies may vary based on the nature of the risk, the infectious agents involved, and local regulations or guidelines. Adhering to the best practices outlined by relevant health authorities or professional organizations is crucial to ensure the safety of prosectors and maintain a high standard of forensic work (12).

In high-risk cases, aerosols generating procedure during autopsy can be minimized by proper handling of the body by skilled personnel, using appropriate personal protective equipment kit, wearing the n-95 mask, using blunt-ended PM40 blades, round-ended blunt scissors thereby reducing the use of sharps in the workspace and, at a time single operator working in the body cavity is also advisable. For organ dissection, the organ should be stabilized with a sponge on the chopping hardboard. In the post-mortem examination, for prevention of infectious aerosol generation and limiting its spread at the time of skull bone sawing, the authors designed an ingenious ergonomic semi-circular craniotomy box. The box is designed in a way that it enhances the prosector's efficiency, safety, and the ergonomics of autopsy procedure that includes:

1. Accessibility and Reach: The box should provide easy access to the area of the cranium being worked on. It should allow the prosector to comfortably reach and maneuver their hands and tools without excessive stretching or strain.

2. Adequate Space: The box should offer sufficient space inside to accommodate the oscillating saw and other instruments required for the craniotomy procedure. There should be enough room for the prosector to work comfortably and perform the necessary tasks.
3. Proper Lighting: Adequate lighting within the craniotomy box is crucial to ensure clear visibility of the surgical site. Proper illumination reduces eye strain and enhances the precision of the prosector's work.
4. Hand Rests and Supports: The box should include ergonomic hand rests or supports to minimize fatigue and provide stability for the prosector's hands during the procedure. These features help maintain steady and controlled movements while reducing the risk of accidental slips or injuries.
5. Adjustable Features: The craniotomy box should be adjustable to accommodate different prosectors with varying heights and preferences. Adjustable height, angle, and tilt options allow for customization and ensure optimal positioning for each individual.
6. Ease of Cleaning and Maintenance: The box should be designed for easy cleaning and disinfection to maintain a hygienic environment. Smooth surfaces, removable parts, and accessible corners facilitate efficient cleaning and reduce the risk of contamination.
7. Overall Comfort: The ergonomics of the craniotomy box should prioritize the comfort of the prosector during the procedure. A comfortable and supportive working environment promotes better concentration, reduces fatigue, and minimizes the risk of musculoskeletal strain or discomfort.

The craniotomy box is transparent. Due to transparency, the visibility of the prosector is not compromised while performing the skull removal procedure. It is imperative to note that using strong disinfectants like sodium hypochlorite or wiping with a rough cloth can eventually cause matting of the acrylic material. Therefore, it is essential to take the following precautions while handling the box:

1. Proper Handling: Handle acrylic sheets with care to minimize the generation and introduction of micro-fragments. Avoid dragging or sliding objects across the surface, as this can create abrasions and increase the risk of matting.
2. Protective Film: Acrylic sheets often come with a protective film or masking that should be kept intact until the sheet is ready for use. The film provides a barrier against micro-fragments and helps maintain the surface quality of the acrylic.
3. Cleaning Techniques: Use non-abrasive cleaning methods and gentle cleaning solutions specifically formulated for acrylic surfaces. Avoid using rough or abrasive materials, as they can cause scratching and contribute to matting.
4. Soft Cloth or Microfiber: When cleaning the acrylic sheet, use a soft cloth or microfiber cloth to gently remove dust and debris. This minimizes the risk of micro-fragments scratching or roughening the surface.
5. Regular Maintenance: Implement a regular maintenance routine to keep the acrylic sheet clean and free from micro-fragments. Regularly inspect the sheet for any signs of matting or surface damage and address them promptly.
6. Avoid Harsh Chemicals: Harsh chemicals, solvents, or cleaners containing ammonia can damage the acrylic surface and increase the likelihood of matting. Stick to mild, acrylic-safe cleaning solutions.

Accommodation of hand inside the box, hand movements, and operating saw is not impaired and as per the standard protocol of autopsy procedure performing skull sawing is maintained in the box. The semi-circular craniotomy box provides an adequate amount of room for hand movements and easily operates both hand saw and oscillating saw during autopsy. It is conveniently decontaminated and cleaned on both the inner and outer surfaces after an autopsy procedure. For decontamination, the box is cleaned with hypochlorite solution after the autopsy. Even though the box is reusable and washable, the sleeves of the arms are disposable and can be discarded after decontamination with a hypochlorite solution. During the autopsy, bone dust and aerosols were collected in the vacuum suction cabin and could also be seen settled on the inner surface of the semi-circular dome. The bone dust and aerosols generated were restricted to the confines of the box and could be visualized. This proves that the box greatly decreases the likelihood of transmission of infection to autopsy-performing personnel. This proposal of a semi-circular craniotomy box that is functionally convenient and practically suitable is very useful in protecting the autopsy personnel from acquiring possible direct infection from the cadaver during autopsy.

Conclusion

Introducing the craniotomy box to forensic experts for high-risk autopsies is an innovative solution that can significantly decrease the risk of infection and offer ease of use, practicality, and sufficient space for hand movements and maneuvering of the saw. The box provides extra safety to autopsy personnel, prioritizing their well-being and minimizing unnecessary infections.

References

1. Wetli CV. Autopsy Safety. Lab Med. 2001 Aug 1;32(8):451–3.
2. Pluim JME, Loeve AJ, Gerretsen RRR. Minimizing aerosol bone dust during autopsies. Forensic Sci Med Pathol. 2019 Sep;15(3):404–7.
3. Tellier R, Li Y, Cowling BJ, Tang JW. Recognition of aerosol transmission of infectious agents: a commentary. BMC infectious diseases. 2019 Dec;19(1):1-9.
4. Kernbach-Wighton G, Kuhlencord A, Rossbach K, Fischer G. Bone-dust in autopsies: reduction of spreading. Forensic Sci Int. 1996 Dec 2;83(2):95–103.
5. Green FHY, Yoshida K. Characteristics of Aerosols Generated During Autopsy Procedures and Their Potential Role as Carriers of Infectious Agents. Appl Occup Environ Hyg. 1990 Dec 1;5(12):853–8.
6. Pluim JM, Jimenez-Bou L, Gerretsen RR, Loeve AJ. Aerosol production during autopsies: the risk of sawing in bone. Forensic science international. 2018 Aug 1;289:260-7.
7. Carpenito L, D'Ercole M, Porta F, Di Blasi E, Doi P, Fagara GR, et al. The autopsy at the time of SARS-CoV-2: Protocol and lessons. Ann Diagn Pathol. 2020 Oct;48:151562.
8. World Health Organization. Cleaning and disinfection of environmental surfaces in the context of COVID-19: interim guidance, 15 May 2020. World Health Organization; 2020.
9. Chongloi N, Sachdeva S. Disinfection of Environmental Surfaces and Articles Used for COVID 19 Patient. International Journal of Clinical and Developmental Anatomy. 2021;7(1):18-22.
10. Nolte KB, Taylor DG, Richmond JY. Biosafety considerations for autopsy. The American journal of forensic medicine and pathology. 2002 Jun 1;23(2):107-22.
11. Templeton GL, Illing LA, Young L, Cave D, Stead WW, Bates JH. The risk for transmission of Mycobacterium tuberculosis at the bedside and during autopsy. Annals of internal medicine. 1995 Jun 15;122(12):922-5.
12. Lucas S. Autopsies on people with high-risk infections. The hospital autopsy: a manual of fundamental autopsy practice. 3rd edition. London, UK: Hodder Arnold. 2010 Jun 25.

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