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ROLE OF MECHANICAL VENTILATION IN CIRCUMVENTING POTENTIAL ENVIRONMENTAL HAZARDS AND RISKS IN THE MORTUARY

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ABSTRACT

It is well known that the mortuary personnel is more exposed to hazards and risks daily in comparison to other staff in the hospital premises because they stay in an environment full of such hazards and risks while working there. The chances of getting them affected by some disease on exposure to such hazards and risks are very high as very often the ante mortem medical, personal and family histories of the corpses are not available and adequate safety measures are not in place. In Indian setup, non scientific infrastructure and improper ventilation system installed in majority of the mortuaries could significantly add up to such risks. This paper focuses on the role of ventilation facility in the mortuary which is the basic prerequisite for improving environmental health and circumventing such type of hazards and risks to their as well as to the public health.

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INTRODUCTION

Mortuary is a space in the hospital premises, used for the storage of bodies, and may include, body viewing area, body preparation room and an autopsy suite. Autopsy suite is used for the performance of investigations into the cause of death. Facilities and their staff involved in mortuary services have a clear obligation to look after the deceased in accordance with the community expectations. Many of the Standards and Commentaries relating to the design, construction and provision of services, are implemented where new mortuaries are being designed as they represent best practices. The ventilation system for the autopsy suite must minimize the spread of airborne pathogens ideally by being isolated from other ventilation systems.

Medicolegal autopsy facility is an entity in itself, distinct from the rest of the hospital and medical education facility. In USA there are architecture and engineering firms that specialize in Forensic market and include those who also look at medicolegal autopsy facility. No such specialized groups exist in most of the countries across the world and the mortuary facilities are far from ideal in most of the places. It is in these circumstances when a new Mortuary is planned, it is an opportunity to explore what one can best have with the available resources, skills, expertise, expenses and the time. Despite the constraints, one has to take into consideration the workload, working conditions, occupational safety, employee comfort and demand for quality work and precision.

Mortuary has potential hazards and risks for the health personnel as well as attendants² as its environment is exposed to a number of infectious agents through aerosols, splashes and fumes released from bone saws and sectioning of tissues, especially lungs or intestines. E.g. tuberculosis, including multi-drug-resistant tuberculosis, viral hepatitis, human immunodeficiency virus (HIV)^{3,5}, cholera, plague and anthrax³ transmissible spongiform encephalopathies such as variant Creutzfeldt - Jakob disease etc., chemicals (e.g. formaline, cyanide, organophosphates etc.)⁴ or physical factors (e.g. temperature, noise and radiation etc.)

In the simplest terms the ventilation means removing and replacing the stale air in a particular environment with the fresh air. It may be achieved simply by opening windows and doors or by providing an open space. On the other hand, the mechanical ventilation system is a more controllable method to remove, contain or dilute smells and contaminants and also to control temperature, humidity and cleanliness of that place. It also provides an effective isolation of one space from another allowing a desired air-flow path of a clean to a less clean area.

There is a need to be aware of the ventilation requirements of individual departments as they are not all the same. Air flows and pressure regimes for individual departments are extremely important as they set the invisible barriers to infection and are the first line of containment in the Healthcare Premises.⁵ The ventilation controls the quality of environment inside the mortuary and is necessary to control the exposure to different

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contaminants. Ventilation also helps to maintain a comfortable and appropriate thermal environment for the autopsy. Mechanical ventilation should be provided for the post-mortem room, all rooms in direct communication with it e.g. body store, dirty utility/instrument store, specimen store etc. All other areas should be naturally ventilated. Most of the mortuaries outside big cities (80%) lack their own facilities and did not have a separate well-ventilated autopsy room where they could keep putrefied corpses.⁶

Protocols for working in the Mortuary

There should be at least 6 room air changes per hour, local exhaust ventilation over bone cutting saws or band saws, use of adequate personal protective equipment (PPE), effective clean up and decontamination procedures in place, and regular monitoring of the staff and environmental control measures. While in high risk cases, air changes inside the mortuary should be enhanced to at least 12 per hour along with the maintenance of negative pressure differential and use of HEPA filtration and draught ventilation.⁷

Factors affecting the need of ventilation in mortuary

The factors that determine the ventilation requirements of a workspace include human habitation, the activities of the department, extraction of odours, aerosols, gases, vapours, fumes and dust, dilution and control of airborne pathogenic material, thermal comfort, the reduction of the effects of solar heat gains and the reduction of excessive moisture etc.⁸ Most of the mortuaries in our country are not up to the mark for post-mortem examination resulting in hazards to the mortuary staff.⁹

Natural Vs Mechanical Ventilation

Very broadly, ventilation in buildings can be classified as 'natural' or 'mechanical'. Mechanical (or 'forced') ventilation tends to be driven by fans. Natural ventilation is driven by 'natural' pressure differences. Natural ventilation by fly-proof screen windows and fresh air inlet grills is adequate except in the post-mortem room where a mechanical exhaust system is necessary.¹⁰ Natural ventilation is generally preferable to mechanical ventilation due to lower capital, operational and maintenance costs. However there is a range of circumstances in which natural ventilation may not be possible e.g. presence of high levels of contaminants, where mechanical ventilation can be provided with a ceiling fan, a vacuum system, or by a balanced system that uses both the inlet and extract fans. In commercial developments, mechanical ventilation is typically driven by air handling units (AHU). Where mechanical ventilation includes heating, cooling and humidity control, this can be referred to as Heating Ventilation and Air Conditioning (HVAC).¹¹

Cost / benefit of Ventilation system in the Mortuary

Mechanical ventilation systems are expensive in terms of capital and running costs, and planning solutions should be sought which take maximum advantage of natural ventilation. Mechanical ventilation if designed into the plans of the building is a great concept and definitely has merits over natural ventilation, but the issue come to retrofitting a solution to a building, which could add quite a bit to the cost. This is why if possible mechanical ventilation is designed into the

building plans, so that the costs of implementation can be kept to a minimum.¹² Though planning with this angle may lead to rise in the project cost but it has overall benefit of providing a good working environment and reducing the hazards and risks. Installation and particularly maintenance costs of the operation of a mechanical ventilation system may be very high and also may lead to sick building syndrome.¹³ However, ventilation cost can be minimised where practicable, reserving it for core areas requiring the mechanical ventilation most.

Technical Specifications

The design should allow for an adequate flow of air into any space. Ventilation supply plant should include air filters having a minimum arrestance of 85% and a minimum average dust spot efficiency of 25%, when tested in accordance with BS6540. Filters must be readily accessible to replacement and maintenance purposes, and be provided with a pressure-differential indicator in addition to the "filter fault" alarms. External discharge arrangements for extract systems should be protected against back pressure from adverse wind effects and located to avoid re-introduction of exhausted air into the building through air intakes and windows. Special consideration should be given to the exhaust air from the post-mortem suite. It is essential to avoid the escape of offensive odours from the working areas to other parts of the accommodation, and other parts of the building and no naturally ventilated space should communicate with the postmortem room without an intervening lobby or corridor.¹⁴ The mortuary entire complex should be air conditioned with a separate system for the autopsy rooms to prevent spread of foul air to other areas and there should be no air recirculation in the mortuary to ensure a clean air environment.¹⁵

Local exhaust ventilation (LEV)

LEV is a term used to describe systems installed to prevent hazardous substances from entering the general atmosphere of the room in which they are being used. Their primary function is to protect the working environment around. Mortuaries and dissection suites may have LEV systems incorporated within the equipments like bone saw which release a large number of contaminants. Though it does not eliminate the need to have specialized ventilation but it does reduce the dependency and pressure on specialized ventilation to provide a fresh air environment. Formaldehyde, an air contaminant found in many indoor air investigations, poses distinct occupational exposure hazards in certain job categories (e.g., mortuary science).¹⁶ LEV is a more cost effective means for achieving control of formaldehyde emissions during the embalming process.¹⁷ Breathing zone concentrations of volatile materials emanating near the table surface were measured at four exhaust flow rates and two different levels of enclosure of the source. Test results showed mean reductions of 83–93 percent with exhaust flow rates of 1.4–4.2 m³/min (50–150 cfm) compared with no local exhaust ventilation, and a reduction of 100 % at 7.1 m³/min (250 cfm).¹⁸

Ventilation of post-mortem suite

The ventilation of this suite should be arranged so that air flows towards the post-mortem room from the adjoining transit area/staff changing area and the body storage area. This will

usually be achieved by air leakage via the doors between the post-mortem room and these spaces. The ventilation of the dirty utility/instrument store should be arranged so that this space is at a negative pressure in relation to the post-mortem room to minimize possible diffusion of offensive odours back into the postmortem room. When not in use, the ventilation system for the postmortem room can be shut down, always provided that the system is allowed to run on for a limited period (a minimum of 30 minutes) after final cleaning of the room to purge residual odours and to assist in the drying of washed surfaces. The ventilation system provided for the specimen store should continue to run at all times because of the potential risks arising from formalin used for the preservation of tissue.¹⁴ Some mortuary units are spacious and well-designed while others generally need improvement.¹⁹ The autopsy room study findings support the importance of primary containment for protecting autopsy staff and secondary containment for protecting environment from infectious agents at autopsy room.²⁰ The settle plate counts increased from a maximum of 5 bacterial colonies during a sample period of 60 minutes when the room was empty to 140 colony forming units(all coliforms) on the plate beneath the table when a post mortem examination was in progress in the absence of ventilation²¹.

Components of mechanical ventilation (Fig:1)-

1. **General-** No materials used in construction and assembly must be a source or sustain any kind of biological or combustion activity to avoid any kind of infection or fire hazards.
2. **Air inlet-** Position, cleanliness of surrounding area and protection from unwanted entry of materials or organisms through it are important factors of consideration along with supply of fresh air.
3. **Air Outlet-**Position and decontamination of extractants are important factors before they are released in to the environment.
4. **Dampers-**For controlled circulation of air.
5. **Duct system-**Made up of appropriate material like galvanized steel, aluminum, polypropylene etc.
6. **Fan** –For pushing the air in the desired direction.
7. **Attenuator/silencer-**For reducing any kind of noise.
8. **Filter** -For capturing and holding particles being carried in the air stream. The filters could be primary filters for larger particles or secondary filters for finer particles or high efficiency particulate air filters (HEPA/ absolute) to remove virtually all particles from air. Activated carbon filters are used to reduce odours.
9. **Humidifier-**For adding moisture to the air.
10. **Chiller-**For reducing temperature and also to condense moisture out of the air.
11. **Eliminator-**For removing aerosols and water droplets.
12. **Drainage system-**For removing water from ductwork and disposing of it safely.
13. **Access doors and observation ports-**For routine maintenance and cleaning.
14. **Transfer grille:** To make adequate provision for air to move from room to room.
15. **Pressure stabilizers:** To maintain pressure differentials between adjacent rooms to prevent reversal of air flows
16. **Heater coil/ Battery:** to recover heat.

17. **Energy recovery**
18. **Diffuser**
19. **Odour control system**

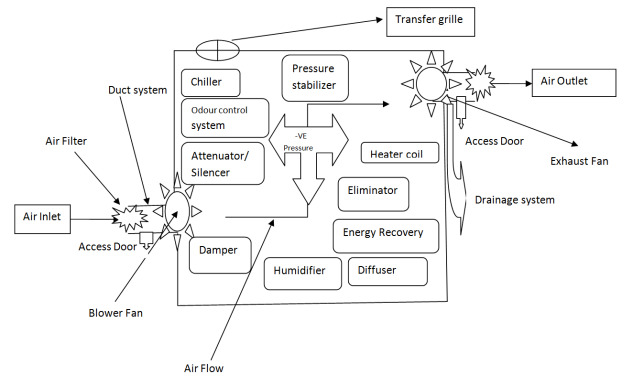


Fig 1-Basic structure of Mechanical ventilation in a mortuary

Validation. A process of proving that the system is fit for purpose and achieves the operating performance originally specified. The performance of ventilation system must be checked at regular intervals.

Problems associated with the Mechanical Ventilation

Mechanical ventilation is expensive to install and maintain in isolation rooms. It often does not deliver the recommended ventilation rate and may fail to maintain negative pressure.²² In addition, a number of problems related to the use of mechanical lack of active collaboration between medical and technical personnel including ventilation can arise from the building repair, lack of proper integration into the building design, and often poor knowledge of medical staff of the intended operational performance of ventilation systems.²³ Other problems with mechanical ventilation include the loss of negative pressure differential in isolation rooms due to the opening of the doors; clogged filters; and adjacent, negatively pressurized spaces.²⁴

Designing consideration of a building -The building ventilation has three basic elements: ventilation rate, airflow direction and air distribution or airflow pattern.²⁴ It is a good idea to have appropriate design at the construction phase itself to accommodate the specialized ventilation requirement of a particular place and also to avoid future alteration in the unfit designs as architectural design, in particular the source of ventilation air, does influence the diversity and composition of the built environment microbiome.²⁵ and the indoor climate can influence human health through direct effects on microbial populations.²⁶ While undertaking the design of a space for properly accommodating a specialised ventilation, along with all the statutory and standard requirements ,local exhaust ventilation, comfort, infection control, source and protective isolation, room air-flow pattern, air-change rate, differential pressures, air quality, room air-condition, noise limits, distribution system, fire control, electrical safety leaks, insulation, cleanliness, filtration, drainage, energy management, environmental conditions, control sequence logic, air-flow rates, air velocities, air quality, installation standard, need of routine maintenance must be considered.

Planning constraints of a building’s shape and/or the functional relationships adversely affect ventilation and necessitate a deep planning starting from conceptual level with proper attention

on design & operational requirements, technical specifications and output. The construction and procurement must follow them accordingly with right installation of components of mechanical ventilation at right places. The operational and maintenance requirements must be paid appropriate attention to provide the best suitable and effective ventilation to a building. The efficiency and effectiveness of any ventilation depend largely on the zoning and control of the installation.

DISCUSSION

The mortuary can be a dangerous place to the forensic experts²⁷, pathologists and anatomical pathology technicians and have the highest rate of necropsy related morbidity,²⁸ visitors and handlers of the dead body. The embalming procedures are also associated with the risk of spread of AIDS and other infectious diseases.²⁹ The human body is host to many organisms, only some of which are pathogenic. When the body dies, the environment in which pathogens live, can no longer sustain them. However, this does not happen immediately and transmission of infectious agents from a cadaver to a living person may occur.³⁰ Autopsy surgeons are cognizant of the fact that many high risk cases go unnoticed in the guise of accidental deaths or homicides and the postmortem examination is not denied even in the known highly infectious deaths.³¹ The risk of infection for health workers depends on the prevalence of disease in the patient population and the nature and frequency of exposures.³²

Studies have confirmed that with the cessation of life, certain pathogenic bacteria are released, which if left unchecked, may prove hazardous to the personnel dealing with them. Further, the forensic medicine personnel often works on dead bodies that are in various stages of decomposition³³ and high risk necropsy causing them serious illness and/or death³⁴.

A national study of tuberculosis in the United States of America found that funeral home directors had higher tuberculosis morbidity³⁶ and higher tuberculosis mortality.³⁷ This suggests that even handling intact cadavers presents an increased risk of tuberculosis. Also, residual air in the deceased's lungs may be exhaled when the body is moved.³⁸

Autopsies performed on bodies with suspected or confirmed TB disease can pose a high risk for transmission of M. tuberculosis, particularly during the performance of aerosol-generating procedures (e.g. median sternotomy).³⁹ Reni Laennec (1781-1826; inventor of the stethoscope) died of the disease having acquired it from the dissection of tuberculosis cadavers.⁴⁰ Xavier Bichat (1771-1802) regarded as the 'Father of Histology' and performed 600 necropsies in the year of his death, also succumbed to the disease.⁴¹ That tuberculosis poses a serious threat to post mortem room workers is further highlighted by Collius and Graugin in their review which found that, in contrast to patients with open tuberculosis, even very brief exposure during a necropsy carries a very high risk of infection. It suggests that the patient with tuberculosis may be more infectious at necropsy than during life. Templeton *et al* reported that none of the 40 Mantoux negative clinical staff caring for a patient that died of unsuspected tuberculosis showed a skin test conversion, whereas all five non-reactors

present at the necropsy converted from negative to positive and two of these developed positive spectrum cultures. Kantor *et al* observed a similar preponderance of nosocomial infection among postmortem workers.⁴²

A Medical examiner can become ill from inhaling infectious aerosols, airborne particles that remain suspended in the air for long periods of time. An autopsy can efficiently spread, in as brief as 10 minutes, tuberculosis from the cadaver to everyone present in the suite. The Syracuse Medical examiner's office and the Los Angeles Coroner's office experienced outbreaks of autopsy transmitted tuberculosis, due to inadequate ventilation, in the 1990s. Prions are another serious risk to Medical examiners during autopsy.⁴³ Medical Examiners and their staff are also occasionally exposed to cyanide when they perform autopsies on people that ingested this chemical compound. Long term inhalation of formaldehyde has been associated with an increased risk of cancer.

Medical examiners even died of diseases like Marburg, Ebola and Lassa hemorrhagic fevers exposed during autopsies. Documented increase in risk of respiratory pathogen transmission in autopsy exists in epidemiological studies on tuberculosis.⁴¹ Bodies may be contaminated by radioactive materials during medical treatment,⁴⁴ or during explosion of atomic devices or working in the nuclear industry.⁴⁵ Release of airborne chemicals can rapidly affect wide areas, leading to exposures that may adversely affect public health⁴⁶.

The postmortem room is a source of potential hazards and risks, not only to the pathologist and anatomical pathology technician, but also to visitors to the mortuary and those handling the body after necropsy. Those involved in postmortem practice have a statutory duty not only to ensure that they are aware of the hazards and risks associated with such work, but also to take steps to minimise these risks.³⁵ The dead body for autopsy is a big sized good culture media, contaminated with microorganisms, and other materials, and it must be decontaminated before its safe removal from the containment area.⁴⁷ The general background count was higher in unventilated rooms and ventilation system was helpful in removing bacterial aerosol and smell apart from providing a reasonable working condition to staff and requires the need for a careful design in place.⁴⁸

While there is no national or global consensus on biosafety requirements for medicolegal facilities, it is clear that there is a greater awareness of the inherent biological risks associated with these types of facilities. In the U.S., the Centers for disease control (CDC) and the National Institutes of Health (NIH) provide some guidance in this area. In Canada, the Public Health Agency of Canada provides the requisite expertise in biocontainment. The overriding design goal is to isolate highly infectious pathogens in a high-containment zone to protect personnel, the public, and the environment. Of the four biosafety level (BSL) designations assigned to facilities that work with hazardous biological agents, BSL-2 and BSL-3 are acknowledged as the most suitable for medico legal occupancies.⁴⁹ There is a considerable body of literature and legislation pertaining to the design and provision of a safe working environment.⁵⁰ There is a role for both species-neutral processes such as dispersal as well as niche-based processes

such as environmental filtering in the assembly of the built environment microbiome.⁵¹

A review of the literature suggests that the proportion of waste produced in mortuaries in developing countries may have significance in planning and environmental management as almost all of the waste produced by the mortuaries is hazardous. The individuals involved in the mortuary should be aware of the hazards and risks associated with such work not only for them, but also for public health and for the environment.⁵² The decline in mortuary acquired infections such as tuberculosis and blood borne hepatitis in the past 25 years can be largely attributed to the increased awareness and adoption of safe working practices.^{53,54} There is need for a modern Mortuary in all the ways including the ventilation aspect.⁵⁵ If workers are to participate in activities to safeguard their health, they must be aware of the risks at work however there was no association found between awareness of hazards and practice of universal safety precautions⁵⁶.

Various induction programs, workshops, conferences and continued medical education on safe autopsy practice can be helpful in protecting the concerned workers and the environment from the potential risks associated with morgues.⁵⁷ The physical design of a hospital is an essential component of its infection control measures to reduce the spread of infectious diseases in the light of new emerging infectious diseases. It is the fundamental requirement to adopt a holistic view of the design and management of hospitals to prevent their spread to open, public spaces.⁵⁸ Therefore as a part of the planning process for constructing a new facility, an infection control risk assessment should be conducted to determine the potential risk for transmission of microorganisms within the hospital.⁵⁹ It is also the legal, moral and ethical responsibility of the mortuary staff to be familiar with different preventive measures and precautions for safely dealing with the dead and the laws related to the proper management and disposal of the bio-medical waste produced during the procedures.⁶⁰

Recommendations

1. There should be standard protocol and procedures to be followed by mortuary staff while working in the mortuary.
2. The Standard precautions must be taken while dealing with highly risk autopsy cases.
3. There must be adequate ventilation protocol and technology installed in such places
4. There must be regular monitoring of the environment of such places and health of the mortuary staff.
5. There must be some research carried out on such environment and devising technologies to provide adequate working environment to the mortuary staff.
6. The planning and designing of mortuary building must accommodate a space for mechanical ventilation.
7. The Care must be taken to ensure that the exhaust air does not re-enter hospital buildings or discharge to public places, especially at ground level.
8. Permission of autopsy must be granted to only those mortuaries which are fulfilling the basic standard of ventilation.

The detailed policy and protocol for construction of mortuary infrastructure needs to be framed and made implementable in all the hospital mortuaries to provide a healthy working environment to the mortuary staff and circumventing various associated hazards and risks. Mechanical ventilation and natural ventilation have many applications where they are used, but in most modern intelligent design both are used for the best effectiveness and efficiency. The planning and designing of mortuary building must pay enough attention on mechanical ventilation to avoid unnecessary and unfit alterations later on. The decision whether to use mechanical or natural ventilation for infection control should be based on needs, the availability of the resources and the cost of the system to provide the fully fresh air for improving the environmental health and achieving an optimum control on the hazards and risks associated with such a vitiated environment to the individual health of mortuary personnel as well as to the public health.

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CONCLUSION

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