An Operation Theatre (OT) complex is the heart of any surgical hospital. The outcomes of surgical interventions depend on a range of factors like- Good surgical skills, scientific design of the OT, proper sterilization/ disinfection techniques and infection control practices. A well equipped OT with the above mentioned factors generally results in fewer Hospital Acquired Infections (HAIs). The present article lays emphasis on the various methods of sterilization and disinfection presently available. A variety of sterilants and disinfectants are being used in health care facilities across the world. Merits and demerits of various currently used sterilization and disinfection techniques have been discussed. Of the available techniques for disinfection of OT, fumigation using formaldehyde is no longer recommended. Fogging has widely been accepted as an alternate method as it is less labor intensive and quicker and poses minimal health hazard to the health care personnel. Microbiological sampling and surveillance of OT is also recommended to prevent HAIs.

few of the significant points with regard to the OT are:
(Harsoor and Bhaskar 2007; Sapna et al., 2011; Fridkin et al., 1996; ESCR Endophthalmitis Study Group 2007)

1. The OT should have an efficient Heating, Ventilation and Air Conditioning (HVAC) system, which can control the temperature, humidity, degree of microbial and dust contamination.
2. Positive air pressure of 5 cm of H₂O from the 2 ceiling downwards and outwards is maintained in the OT to ensure the airflow from the OT to the outside. Interchange of air movement between one OT and another is to be avoided.
3. Laminar air flow reduces the amount of bacterial load in the environment. Laminar air flow fitted with High Efficiency Particulate Air (HEPA) filters which are effective in ensuring removal of particles more than 0.3 μ should be commissioned to ensure the supply of filtered air within the OT. The air exchange in an OT is maintained at 20 – 30 per hour.
4. The temperature within the OT is to be maintained between 18 – 24°C and the humidity between 50 – 55%.
5. The movement of sterile and contaminated items between the central supply sterile department (CSSD) and OT should be planned in such a way that they do not cross the path of each other. Dedicated lifts or closed trolleys should be provided for sterile and unsterile items.
6. Management of biomedical waste (BMW) conforming to local and national guidelines for segregation, transportation and treatment of BMW.

In the operation theatre, the source of infection may be either endogenous (from the patient himself) or exogenous from the...
theatre environment. To prevent these infections the following techniques are generally used in the operation theatre.

**General cleaning**

Cleaning is the removal of all foreign material (dirt and organic) from the object being reprocessed. Two key points of cleaning are friction to remove foreign matter and fluids to remove or rinse away contamination. Spot cleaning of walls and ceiling should be undertaken as needed every day. Open shelves need to be cleaned daily using detergent while closed cabinets may be cleaned once weekly. The floor should ideally be sprayed and wet vacuum pick up used after each surgical procedure and at the end of the day schedule. (Sapna et al., 2011) The air conditioning (AC) ducts are mechanically cleaned using robotic machines, wet vacuum with detergent or by fogging with approved disinfectants. Cleaning may be achieved either by manual or mechanical means. Manual cleaning is accomplished by the use of water, detergents and mechanical action. Detergent is essential to remove and dissolve proteins and oil that can reside on instruments and equipment after use.

Mechanical cleaning involves application of ultrasonic cleaners or washers/disinfectors.

- Washing machine gives cold rinse followed by a hot wash at 71° C for 2 minutes. This is followed by 10-second hot water rinse at 80-90° C and then by drying by a heater or a fan at 50-75°C
- Washer/disinfector is used for anesthetic equipment. It runs a cycle of washing and cleaning plus a 2-minutes cycle with water at 80-100° C and with a detergent solution. Ultrasonicator is sophisticated and expensive equipment. It uses high power output of 0.44 W/cm² and dislodges all organic matter. (Rutala and Weber 2012; Miller et al., 1993; Ransjo et al., 2001).

**Disinfection of items used in OT**

Medical and surgical devices based on the risk from contamination of a patient are classified according to Spaulding classification in to ‘Critical’, ‘Semi-critical’ and ‘Non critical’. CDC modified the same by adding another category ‘environmental surfaces’ which can be further divided in to medical equipment surfaces (e.g., knobs or handles on haemodialysis machines, x-ray machines, instrument carts, and dental units) and housekeeping surfaces (e.g., floors, walls and tablespots). (Spaulding 1968; Spaulding 1970; Spaulding 2001; Favero and Bond 2001; Schulster and Chinn 2003) Based on Modified Spaulding’s classification, items used in OT and their decontamination techniques can be listed as mentioned in Table 1.

The disinfectant used for the treatment of devices and surfaces not requiring sterilization are classified by Spaulding in to “High-level”, “Intermediate-level” and “Low-level”. The basis for these levels is that microorganisms can usually be grouped according to their innate resistance to a spectrum of physical and chemical germicidal agents. The levels of disinfection and their spectrum of action has been depicted in the following table (Table – 2). (Rutala and Weber 2012; Spaulding 1971; Spaulding 2001)

**Sterilization of items used in OT**

Sterilization destroys all microorganism including spores on the surfaces of an article or fluid to prevent pathogen transmission associated with the use of that item. A number of procedures are followed for the sterilization of delicate, heat labile equipment. These include exposure to:

**Table 1. Decontamination techniques for items used in areas according to risk involved**

<table>
<thead>
<tr>
<th>S.No.</th>
<th>Non critical</th>
<th>Semicritical</th>
<th>Critical</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Definition</td>
<td>Items that come in contact with normal or intact skin</td>
<td>Items that come in contact with mucous membrane on non intact skin</td>
</tr>
<tr>
<td>2</td>
<td>Items</td>
<td>Wall, floor, ceiling, furniture, sink, blood pressure cuffs, crutches, bed rails, linens</td>
<td>Respiratory equipment, flexible endoscopes, laryngoscopes, spatula, endotracheal tube, thermometer, similar instruments</td>
</tr>
<tr>
<td>3</td>
<td>Decontamination</td>
<td>Cleaning and low level disinfection</td>
<td>Cleaning and High level disinfection or sterilization</td>
</tr>
</tbody>
</table>

**Table 2. Levels of disinfection and spectrum of action**

<table>
<thead>
<tr>
<th>Level of disinfection</th>
<th>High</th>
<th>Intermediate</th>
<th>Low</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Types</td>
<td>Boiling, Most heat at 70-100° C</td>
<td>Chlorine containing compounds (e.g., Sodium hypochlorite)</td>
<td>Quaternary ammonium compounds, Some phenolics, Some Iodophors.</td>
</tr>
<tr>
<td>2 Representative agents</td>
<td>Formaldehyde, Glutaraldehyde 2% for 20 min, Orthophthalaldehyde (OPA) for 5-12 min, Peroxid acid 0.2-0.35% for 5 min, Hydrogen peroxide 6%-7.5% for 20-30min</td>
<td>Iodophors, Alcohols, Some phenolics</td>
<td>Hand rub in between cases (cetrimide). Environmental surfaces-housekeeping surface Microscope except lens (15% cetrimide and 3% chlorhexidinegluconate)</td>
</tr>
<tr>
<td>3 Scenario of usage</td>
<td>Sutures, Sharp instruments including razor blade (Glutaraldehyde), Cryoprobe, Vitrectomy cutter, Cauterywire (formaldehyde)</td>
<td>Head of the microscope (Alcohol mixture)</td>
<td></td>
</tr>
<tr>
<td>4 Cidal activity against</td>
<td>Vegetative bacteria, Mycobacteria, Spores, Fungi, Enveloped (Lipid) medium sized viruses Nonlipid and small size viruses</td>
<td>Vegetative bacteria, Mycobacteria, Fungi, Enveloped/Some Nonlipid viruses</td>
<td>Vegetative bacteria, Enveloped (Lipid) medium sized viruses, Some Nonlipid viruses</td>
</tr>
</tbody>
</table>
OT Sterilization/ disinfection

Environment Protection Agency (EPA) approved disinfectants or chemical sterilants can be used for the regular cleaning of the OT table, floor and wall. (Rutala and Weber 2012) The following are available modes of OT sterilization/ disinfection.

a) Formaldehyde fumigation

Commonly used to sterilize the OT and other rooms. After sealing the windows, switch off fans and A.C. Formaldehyde gas is generated by adding 150g of KMnO₄ to 280mL of formalin for every 1000 cubic feet (28.3 cu.m³) of room volume. The reaction produces considerable heat, and so heat resistant vessels should be used. When formalin vapour is generated, doors should be sealed and left unopened for 48hours. Before entry into the OT the next day morning, 300mL of 10% ammonia solution is kept for 2-3 hours to neutralize formalin vapours.

Mode of Action

Formaldehyde inactivates microorganisms by alkylating the aminoacid and sulfhydryl groups of proteins and ring nitrogen atoms of purine bases.

Disadvantages

Occupational Safety and Health Administration (OSHA) has indicated that Formaldehyde should be handled in the workplace as potential carcinogen and has set an employee exposure standard for Formaldehyde that limits an 8-hour time-weighted average exposure concentration of 0.75ppm. Fumigation of OT using formalin is not recommended by the CDC. (Sapna et al., 2011; Ananthanarayan et al., 2013)

b) Baccilocidrasant

A newer and effective compound in environmental decontamination with very good cost/benefit ratio, good material compatibility, excellent cleaning properties and virtually no residues. It has the advantage of being a Formaldehyde-free disinfectant cleaner with low use concentration.

Active ingredients: Glutaral 100 mg/g, benzyl-C12-18-alkyldimethylammonium chlorides 60 mg/g, didecyldimethylammonium chloride 60 mg/g.

Advantages

- Provides complete asepsis within 30 to 60 minutes.
- Cleaning with detergent or carbolic acid not required.
- Formalin fumigation not required.
- Shutdown of O.T. for 24 hrs not required.⁷

c) Aldekol

A new method of fumigation has been evolved using ‘Aldekol’, a mixture containing 6% formaldehyde, 6% glutaraldehyde and 5% benzalkoniumchloride. (Sapna et al., 2011)

d) Permanganatemethod

Five ounces of potassium permanganate for every 1000 cu.ft. of space are placed in a jar and on top of this 10-15 ounces of 40% formalin diluted with an equal amount of water is poured.

Table 3. Merits and demerits of sterilization technologies adopted in OT

<table>
<thead>
<tr>
<th>Sterilization Method</th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Steam</td>
<td>Nontoxic, Cycle easy to control, monitor and rapidmicrobicidal action, Penetrate medical packing and lumens of devices</td>
<td>Deleterious for heat sensitive instruments Microsurgical instruments damaged by repeated exposure May leave instrument wet causing them to rust Potential for burns</td>
</tr>
<tr>
<td>Hydrogen peroxide, gas plasma</td>
<td>Nontoxic, Cycle time ≤28 minutes, Used for heat and moisture sensitive items, Compatible with most medical devices</td>
<td>Cellulose/paper,linens and liquid cannot be processed Endoscope or medical device restriction based on luminal size Requires synthetic packing and special container</td>
</tr>
<tr>
<td>100% Ethylene oxide (ETO)</td>
<td>Penetrate packing material and device lumen, Simple to operate and monitor, Compatible with most medical devices</td>
<td>Toxic, Carcinogen and flammable, Lengthy cycle and aeration time</td>
</tr>
<tr>
<td>ETO mixtures</td>
<td>Penetrates medical packing and many plastics, Cycle easy to control and monitor</td>
<td>Toxic, Carcinogen and flammable, Lengthy cycle and aeration time</td>
</tr>
<tr>
<td>Vaporized hydrogen peroxide</td>
<td>Safe for the environment and health care workers, Non Toxic, Fast cycle time, Used for heat and moisture sensitive items</td>
<td>Medical device restriction based on luminal size Requires synthetic packing and special container Limited clinical use</td>
</tr>
<tr>
<td>Ozone</td>
<td>FDA cleared for metal and plastic instruments, including some instruments with lumen</td>
<td>Limited clinical use and limited microbial efficacy</td>
</tr>
</tbody>
</table>
As soon as the reagents are mixed, a violet effervescence takes place and formaldehyde is set free. (Ananthanarayan et al., 2013)

e) Paraform method

On heating formalin, the aldehyde changes into the solid polymeride - paraform. Gas is generated by heating paraform tablets. 25-30 tablets are required for every 1000cu.ft of space. (Ananthanarayan et al., 2013)

f) Virkon method

A Chemical compound - VIRKON is gaining importance as a non-Aldehyde compound. Virkon is proved to be a safe virucidal, bactericidal, fungicidal, mycobactericidal less effective against spores and fungi than some alternative disinfectants. It contains oxone (potassium peroxymonosulphate), sodium dodecylbenzenesulfonate, sulphamic acid; and inorganic buffers. It is typically used for cleaning up hazardous spills, disinfecting surfaces and soaking equipment. It is nontoxic. Several other compounds are emerging in the market for safer use, may need better resources for utility and implementation. (Gasparini et al., 1995)

g) Fogging method

Fogging involves nebulization of a disinfectant in a seated patient room until all surfaces were wet, followed by wiping off residual fluid from surfaces by masked and gowned personnel. Fogging as a method of OT disinfection involves initial investment in the form of fogging machines, but are reportedly more beneficial in the long term. (Rutala and Weber 2012; Shwetha et al., 2012) The following table (Table – 4) enumerates various chemicals used for fogging. (Shwetha et al., 2012; StafinTuski et al., 2009)

<table>
<thead>
<tr>
<th>Evaluation method</th>
<th>Glucoprotamane</th>
<th>Formaldehyde</th>
<th>Glutaraldehyde</th>
<th>Hydrogen Peroxide</th>
<th>Silver Nitrate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Microbial Action</td>
<td>Broad Spectrum</td>
<td>Broad Spectrum</td>
<td>Broad Spectrum</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reaction Time</td>
<td>30 mins</td>
<td>1 hr</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Residual effect</td>
<td>Long</td>
<td>Moderate</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Material Compatibility</td>
<td>Non-Corrosive</td>
<td>Non-Corrosive</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tolerance to Skin</td>
<td>Non-Irritant</td>
<td>Irritant to Skin and Eyes</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Carcinogenicity</td>
<td>Non-Carcinogenic</td>
<td>Carcinogenic</td>
<td></td>
<td></td>
<td>Non-Carcinogenic</td>
</tr>
<tr>
<td>Dilution Percentage</td>
<td>1%</td>
<td>2%</td>
<td></td>
<td></td>
<td>20%</td>
</tr>
</tbody>
</table>

Conclusion

The OT forms a crucial area in a hospital, which also exposes the patients to grave infections in the absence of proper architectural design and infection control measures. The present article reviews the various disinfection techniques which are available to limit infections associated with OT. Various chemical sterilants are commercially available which are effective, minimal time consuming and pose negligible safety hazard for use. Fogging as a method of OT disinfection has gained widespread acceptance across the globe and is recommended especially in high turnover OTs, keeping in mind the effectiveness, ease of use, time required for OT disinfection and minimal health risk for hospital personnel.

Microbiological sampling and surveillance of OT is also recommended to prevent HAIs.

REFERENCES


Dorsch JA and Dorsch SE. Operating room design and equipment selection. Understanding Anaesthesia Equipment, 4th edition; Williams and Wilkins 1999 : 1015-16


Fridkin SK, Kremer FB, Bland LA, Padhye A, McNeil MM, Jarvis WR. Acromoniumkliensenendphthalmitis that occurred after cataract extraction in an ambulatory surgical centre and was traced to an environmental reservoir. Clin Infect Dis 1996;22:222-27


Harsoor SS, Bhaskar SB. Designing an ideal operating room complex. Indian J Anaesth 2007;51:193


*******