ISSN: 0975-833X

Available online at http://www.journalcra.com

International Journal of Current Research
Vol. 6, Issue, 05, pp.6622-6626, May, 2014

INTERNATIONAL JOURNAL OF CURRENT RESEARCH

REVIEW ARTICLE

DISINFECTION AND STERILIZATION TECHNIQUES OF OPERATION THEATRE: A REVIEW

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ARTICLE INFO

Article History:
Received 05th February, 2014
Received in revised form
10th March, 2014
Accepted 15th April, 2014
Published online 20th May, 2014

Key words:

Sterilization,
Disinfection,
Fogging,
Operation Theatre.

ABSTRACT

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.

INTRODUCTION

The Centre for Disease Control (CDC) defines healthcare-associated infections (HAIs) as infections that patients acquire during the course of receiving treatment for other conditions or health careworkers (HCWs) acquire while performing their duties withina health care settings. The degree of concern regarding the inanimate environment as a source of HAI has changed markedly over the years. HAIs is caused by organism from inanimate environment depends upon many factors. The prevention of HAI depends upon several factors including effective cleaning, sterilization and disinfection procedures, performed carefully with goal of minimizing contamination by pathogens (http//www.cdc.gov/ncidod/dhqp/healthDis.html; Sax and Pittet 2002; Blot *et al.*, 2009). In the present article, special emphasis is laid on cleaning, disinfection and sterilization techniques used in the operation theatre.

Operation Theatre

An Operation Theatre (OT) complex is the heart of any surgical hospital. (Dorsch and Dorsch 1999) Good surgical skills have to be supported by scientific design of OT in predicting good outcomes. A modern operation theatre must fulfill the basic architecture with four zones of Outer, Restricted, Aseptic and Disposal zones with adequate ventilation. (Bridgen 1988)

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Few of the significant points with regard to the OT are: (Harsoor and Bhaskar 2007; Sapna *et al.*, 2011; Fridkin *et al.*, 1996; ESCRS 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 H_2O 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 ensures the reduction 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^{0}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 71º C for 2 minutes. This is followed by 10-second hot water rinse at 80-90º C and then by drying by a heater or a fan at 50-75ºC
- Washer/disinfector is used for anesthetic equipment. It runs a cycle of washing and cleaning plus a 2-minutes cycle with water at 80-100º C and with a detergent solution Ultrasonicator is sophisticated and expensive equipment. It uses high power output of 0.44 W/cm^{3}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'. CDCmodified 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 tabletops). (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

S.No.		Non critical	Semicritical	Critical
1	Definition	Items that come in contact with normal or intact skin	Items that come in contact with mucus membrane on non intact skin	Items that penetrate sterile areas such as body cavities and the vascular system
2	Items	Wall, floor, ceiling, furniture, sink, blood pressure cuffs, crutches, bed rails, linens	Respiratory equipment, flexible endoscopes, laryngoscopes, spatula, endotracheal tube, thermometer, similar instruments	Surgical instruments, cardiac, intravascular, urinary catheters, implants, ultrasound probes which are introduced into body cavities and vascular system
3	Decontamination	Cleaning and low level disinfection	Cleaning and High level disinfection or sterilization	Cleaning and Sterilization

Table 2. Levels of disinfection and spectrum of action

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

a) Low temperature steam and formaldehyde
b) Ethylene oxide
c) Gas plasma.

The following table (Table – 3) reviews sterilization technologies used in health care makes recommendations for their optimum performance in the processing of medical devises. (Rutala and Weber 2008; Association for the Advancement of Medical Instrumentation: 2010).

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

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

Sterilization Method	Advantages	Disadvantages
Steam	Nontoxic, Cycle easy to Control,monitor and rapidmicrobicidal action, Penetrate medical packing and lumens of devices	Deleterious for heat sensitive instruments Microsurgical instruments damaged by repeated exposure May leave instrument wet causing them to rust Potential for burns
Hydrogen peroxide, gas plasma	Nontoxic Cycle time is≥28minutes Used for heat and moisture sensitive items Compatible with most medical devices Requires electrical outlet	Cellulose(paper),linens and liquid cannot be processed Endoscope or medical device restriction based on luminal size Requires synthetic packing and special container
100% Ethylene oxide (ETO)	Penetrate packing material and device lumen Simple to operate and monitor Compatible with most medical devices	Toxic, Carcinogen and flammable Lengthy cycle and aeration time
ETO mixtures 8.6% ETO/91.4% Hydro Chloro Fluoro Carbon (HCFC) 10% ETO/90% HCFC 8.5% ETO/91.5% CO_2	Penetrates medical packing and many plastics Compatible with most medical devices Cycle easy to control and monitor	Toxic, Carcinogen and flammable Lengthy cycle and aeration time
Vaporized hydrogen peroxide	Safe for the environment and health care workers Non Toxic Fast cycle time Used for heat and moisture sensitive items Used for heat and moisture sensitive items	Medical device restriction based on luminal size Not used for liquid,linens,powders or any cellulose material Requires synthetic packing and special container Limited clinical use
Ozone	FDA cleared for metal and plastic instruments including some instruments with lumen	Limited clinical use and limited microbial efficacy

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 $KMnO_4$ to 280mL of formalin for every 1000 cubic feet (28.3 $cu.m^3$) 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

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 4. Comparison of various chemicals used for fogging

Evaluation method	Glucoprotamine	Formaldehyede + Glutaraldehyde	Hydrogen Peroxide + Silver Nitrate
Microbial Action	Broad Spectrum	Broad Spectrum	Broad Spectrum
Reaction Time	30 mins	1 hr	1 hr
Residual effect	Long	Moderate	Limited
Material Compatibility	Non-Corrosive	Non-Corrosive	Corrosive
Tolerance to Skin	Non-Irritant Non-Toxic	Irritant to Skin and Eyes	Non-Irritant Non-Toxic
Carcinogenicity	Non Carcinogenic	Carcinogenic	Non Carcinogenic
Dilution Percentage	1%	2%	20%

As soon as the reagents are mixed, a violet effervescence takes placeandformaldehydeissetfree. (Ananthanarayan *et al.,* 2013)

e) Paraformmethod

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.ofspace. (Ananthanarayan *et al.,* 2013)

f) Virkon method

A Chemical compound - VIRKONis gaining importance as non-Aldehyde compound. Virkon is proved to be a safe virucidal, bactericidal, fungicidal, mycobactericidalis 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) enumeratesvarious chemicals used for fogging. (Shwetha *et al.,* 2012; StafinTuski *et al.,* 2009)

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.

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