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# STERILIZATION AND DISINFECTION IN HOSPITALS: A BRIEF OVERVIEW

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## ABSTRACT

Improper decontamination results in nosocomial infections. So, sterilizing medical equipments and other surfaces is a critical part of a health care center's day-to-day activity. In sterilization process, all forms of life and other biological agents are eliminated to the extent that they are no longer detectable by standard culture media.This article will discuss briefly various methods of sterilization such as moist heat sterilization, dry heat sterilization, radiation, ethylene oxide gas, hydrogen peroxide, and other sterilization methods.

**KEYWORDS:** Sterilization, medical equipment, dry heat sterilization, bacterial spores.

## INTRODUCTION

Sterilization and disinfection are two basic components of infection control activities of hospital. Every day, a number of surgical procedures are performed in hospitals including invasive type of procedures. During these procedures, surgical or medical instruments come in contact with sterile body tissue or mucous membrane of patient which increases the chance of pathogen entrance in patient's body causing infection. Also, there is risk of transmission of infection from patient to patient, patient to doctor, or vice versa and also from environment to patient due to inappropriate sterilized area and instruments.[1] It was reported that a number of outbreaks and infections occurred in hospital setup due to improper sterilization of devices.[2] Therefore proper sterilization is necessary for medical and surgical equipments in all health care centres.[1]

*Sterilization* is the complete elimination or destruction of all forms of microbial life and is accomplished in health care facilities by different methods either physical or chemical process. Sterilization refers to absolute removal, not a relative one. Some chemicals are used for the destruction of all forms of microbiologic life, including fungal and bacterial spores, they are called as chemical sterilants. These germicides when used for shorter exposure time periods may also be part of the disinfection process that is high level disinfection.[3] Commonly used sterilizing agents in hospitals are: Steam under pressure, dry heat, ethylene oxide (ETO) gas, hydrogen peroxide gas plasma, vaporized hydrogen peroxide, and liquid chemicals.[3]

Disinfection is a process of complete elimination of vegetative forms of microorganisms except the bacterial spores from inanimate objects. Technically, there is reduction of $\geq 10^3$ log CFU of microorganisms by this method without spores.[1] Disinfection is usually done by using liquid chemicals. The disinfectant chemical efficacy depends on various factors. The factors that affect both sterilization and disinfection processes are: prior cleaning of the object, presence of the organic and inorganic load, type and level of microbial contamination, the concentration and exposure time duration to disinfectant used, the nature of the object, the presence of biofilms, the temperature, pH of the disinfection process, and, the relative humidity of the sterilization process.[3]

According to definition disinfection differs from sterilization by lacking sporicidal property. But a few disinfectants can kill spores also with long exposure time and these are called as chemical sterilants. When same concentration disinfectant used for short duration of time, they will kill all microorganisms but leaving large number of spores and these are called as high level disinfectants. Low-level disinfectants may kill most of vegetative bacteria, some fungi, and some viruses in a practical period of time (≤10 minutes), whereas intermediate-level disinfectants may kill mycobacteria, vegetative bacteria, most viruses, and most fungi but do not necessarily kill bacterial spores.[3]

"No-touch" decontamination technologies are introduced, these include aerosol and vaporized hydrogen peroxide, mobile devices that emit continuous ultraviolet (UV-C) light, a pulsed-xenon UV light system, and use of high-intensity narrow-spectrum (405 nm) light. These new methods have been shown to decrease bacterial contamination of surfaces. A micro-condensation hydrogen peroxide system has been associated in multiple studies with reductions in healthcare-associated colonization or infection, while there is more limited evidence of infection reduction by the pulsed-xenon system.[4]

### Classification of medical equipments

#### Critical items

These have high risk of infection when contaminated with any microorganism and bacterial spores. These items enter sterile tissues or vascular system of patient. These include surgical devices, cardiac and urinary catheters, implants, laparoscopes and ultrasound probes. These should be either purchased in sterile form or should be steam sterilized, but if heat sensitive, these may be sterilized by ETO, hydrogen peroxide gas plasma, hydrogen peroxide vapor or chemical sterilants. Some of these sterilants are:2.4% or more glutaraldehyde-based formulations, hypochlorous acid/hypochlorite 650 to 675 ppm free chlorine, 1.12% glutaraldehyde with 1.93% phenol/phenate, 3.4% glutaraldehyde with 26% isopropanol, 7.5% stabilized hydrogen peroxide, 2.0% hydrogen peroxide, 8.3% hydrogen peroxide with 7.0% peracetic acid, 0.2% peracetic acid, 0.55% or greater ortho-phthalaldehyde, and 0.08% peracetic acid with 1.0% hydrogen peroxide.[3,5,6]

**Semicritical items:** These are objects those come in contact with mucous membrane or non intact skin. These items include respiratory therapy equipments, some endoscopes, esophageal manometry probes, prostrate biopsy probes, coagulation devices, diaphragm fitting rings and cystoscopes. These items require minimally high level disinfection. After disinfecting with high level disinfectants, these should be rinsed with sterile water to prevent their contamination with other microorganisms that may be present in normal tap water. If the sterile water is not available, tap water or filtered water can be used followed by an alcohol rinse and forced air drying. This force air drying decreases bacterial contamination, by eliminating wet environment which is favorable for bacterial growth. Glutaraldehyde, hydrogen peroxide, ortho-phthalaldehyde, peracetic acid, and peracetic acid with hydrogen peroxide are cleared by the U.S. Food and Drug Administration (FDA) for disinfecting semicritical items.[3,7-9]

Some semicritical items which touch the nonintact skin for a short time are usually considered as noncritical devices. Low or intermediate level disinfectants are used for disinfecting these items.[3]

**Noncritical items:** These items come in contact with intact skin but not mucous membranes. Intact skin provides barrier against most of microorganisms. These noncritical items include bedpans, blood pressure cuffs, bed rails, bedside tables, floors and patient furniture. Most of these items are reusable and these can be disinfected at their location and need not to be transported to a central processing area. In literature, there is no documented risk of transmission of infection via these noncritical items. But these items could potentially contribute to secondary transmission of infection by contaminating hands of health care staff or by contacting medical equipments which will further come in contact with patients. Low level disinfectants are used for disinfecting these items.[3]

### Recommendation for the Cleaning and Decontamination of Environmental Surfaces in hospitals

- There should be demarcation and separation of space for cleaning and other work areas by walls.
- The staff members of hospital should be properly trained regarding the cleaning and decontamination procedures of hospital surfaces.
- The staff of hospitals should wear personal prophylactic equipment (PPE) that includes gowns, gloves, masks, and boots. There must be separate area for removing all these personal prophylactic equipment.
- Detergents or disinfectants should be freshly prepared every day and used with the proper dilution as per the manufacturer guidelines.
- Wet mopping of floors should be encouraged over dry mopping as dry mopping produces dust aerosols.
- Mopping of the hospital surfaces should be done using detergent. Table tops and counters should also be cleaned regularly by detergent only.
- Mopping of high-risk infectious areas including the intensive care units, burn wards, transplant units, isolation wards, operation theaters (OTs), and dialysis machines should be done using HLD instead of detergent. In these areas cleaning by vacuum pump is preferred and high-efficiency particulate air (HEPA) filters are used for the exhaust in these places.[10]

### Guidelines for blood spill on the surface

- Cleaning and decontamination of the hospital surfaces which have spills of blood is done as per the guidelines of Occupational Safety and Health Administration/World Health Organization/CDC.
- Disinfectants with tuberculocidal activity should be used for cleaning of blood spill in the hospital surfaces.
- Surfaces with small amount of blood spills (<10 mL) can be decontaminated by using, sodium hypochlorite solution with a dilution of 1:100. For blood spill of size >10 mL, sodium hypochlorite with 1:10 dilution is used for the first application. Then the organic matter should be cleaned with absorbent material, and finally disinfection can be done with sodium hypochlorite solution with 1:100 dilution.[11-16]

### Guidelines for cleaning and disinfection of medical equipments

- The cleaning and disinfection of medical equipment used in hospitals depends on various factors such as physical nature, type of the material it is made up of, lumen size of equipment, etc. Thorough cleaning of these medical equipments is preferred before the use of the disinfectants so that cleaning removes majority of the microbes from the equipment effectively before disinfection.
- Staff members of hospital should be properly educated and trained regarding the cleaning procedure, physical and chemical nature of the equipments used in hospitals, nature of disinfectants, etc.
- It is difficult to remove dry organic materials from the equipment. Hence, drying of instruments should be avoided by immersing them in the detergent or disinfectant solution prior to their cleaning. The soaked matter from the surface of instrument can be cleaned by manual scrubbing and rubbing with brush or an automated scrubber and washed thoroughly with water under pressure. Soaking for prolonged time or overnight soaking of the instrument should be avoided.
- The time of exposure to disinfectant or detergent, and concentration of the detergent or disinfectant, should be properly maintained as described in the literature. Too low concentration of disinfectant may not work effectively to eliminate the organic materials or microorganisms from the instruments.
- Disinfectant pH should be properly obtained as per the manufacturer's instruction. Neutral pH. should be used for delicate items.
- Enzymes like proteases may be added to the solution to increase the cleaning action. Enzymatic cleaners with neutral pH are preferred to avoid the damage of the articles like in case of flexible endoscope, neutral pH detergent with enzymatic action is preferred.[17-24]

### Commonly used Methods of sterilization

### Moist heat sterilization

In this method, steam is used to kill microorganisms present on the surfaces which are exposed to steam. This high temperature steam eliminates the proteins of microorganisms. Autoclave is used for moist heat sterilization. The steam in the autoclave is under pressure, makes autoclave to kill more microorganisms in less time and in low temperature. This increases efficiency of autoclave as it needs thermal energy to be effective. Total time taken by autoclave depends on items to be sterilized and autoclave performance. Different parts and instruments used to achieve and control the sterilization process in autoclave, include the following:

- Temperature sensor
- Pressure sensor
- Data logger which records the values of temperature and process variables.
- Vacuum pump
- Human machine interface for parameter setting and readouts.

The procedure of autoclave is to heat at 1.1 kilograms/ square steam pressure, which produces a temperature of 121C degree. At this temperature sterilization is achieved in 15-20 minutes depending on the volume of load. For successful sterilization one should ensure:

- Evacuate the air to fill the chamber with steam.
- Objects in autoclave should be placed so that steam can penetrate them.

### Types of autoclaves

1. Gravity displacement type autoclave: Most common type used in laboratories and it is available in different sizes:
   - *Vertical type* with small capacity
   - *Horizontal type* with large capacity.
2. Positive pressure displacement type autoclave
3. Negative pressure displacement autoclave.[25]

### Dry heat sterilization

This method requires longer time duration and high temperature as compared to moist heat sterilization. Dry heat methods include: Hot air over, incineration and flaming.

This method is used for items which can be damaged by moist heat sterilization or resistant to penetration of moist heat.

### Types of dry heat sterilizer

- Static-air type
- Forced-air type

**Static-air type:** It is an oven-type sterilizer consisting of heating coils in the bottom which cause the hot air to rise inside the chamber through a gravity connection. This type of sterilizer needs a longer time to achieve the sterilization temperature, it is slower in heating, and it has less uniform temperature control throughout the chamber.

**Forced-air type**: It is also known as mechanical convection sterilizer which has a motor-driven blower that circulates heated air at a high velocity throughout the chamber. This allows a rapid transfer of energy from the air to the instruments to be sterilized. This type of sterilizer is preferred as it delivers the heat load to the object with better homogeneity.[26,27]

### Principle of Hot air oven

Sterilization in this is completed by conduction. Heat gets absorbed in outer surface of objects, and then passes to the center of object layer by layer. Thus, the entire object will reach to that temperature needed for sterilization. Dry heat causes damage by oxidizing molecules. The essential cell components are destroyed resulting in killing of organism.

The most common time-temperature relationships used for sterilization are:

- 170°C (340°F) for 30 minutes
- 160°C (320°F) for 60 minutes, and
- 150°C (300°F) for 150 minutes or longer depending on the volume.

*Bacillus atrophaeus* spores should be used to monitor the sterilization process for dry heat because they are more resistant to dry heat than the spores of *Geobacillus stearothermophilus*.

**Objects which are sterilized in hot air oven**

- Glassware such as petri dishes, flasks, pipettes, and test tubes.
- Powders like starch, zinc oxide, and sulfadiazine.
- Materials containing oils
- Metal equipment such as scalpels, scissors, and blades.

**Advantages of dry heat sterilization**

- A dry heat cabinet is easy to install and with low cost.
- It penetrates materials.
- It is nontoxic and causes no harm to environment.
- It is noncorrosive for metal and sharp instruments.

**Disadvantages of dry heat sterilization**

- This method is time-consuming due to slow rate of heat penetration.
- High temperature is not suitable for most of materials such as plastic and rubber objects.
- The time and temperature needed is variable for different materials and overexposure may damage some substances.[28]

**Flaming**

Flame sterilization is a quick and simple method of killing microorganisms on an inoculating loop or needle. The loop or needle is held inside a flame for a few seconds to bring to redness and then cooled. On cooling, the loop or needle can be used for various culture manipulations. Care should be taken that area touching the culture is flamed to redness and should be cool down, which usually takes 15-30 seconds. While doing flame sterilization, instrument is dipped in alcohol or spirit before burning it in flame. This method does not ensure sterility.

**Incineration**

Incineration is the process of sterilization along with a significant reduction in the volume of the wastes. It is usually conducted during the final disposal of the hospital or other residues. The scraps are heated till they become ash which is then disposed of later. This process is conducted in a device called incinerator.[29]

**Radiation sterilization**

As some items are not heat resistant, so new methods for cold sterilization were developed. These are: Gas sterilization and radiation sterilization.

In middle 1940s, first gas method came into existence and this method is still frequently used method of sterilization.

Ability of ionizing radiation to kill bacteria had been recognized at the end of 19$^{th}$ century and use of radiation for sterilization started in 1957 in USA.

**Two types of radiation sources used are**

Radioactive gamma source and electrical sources based on accelerators that give electron beams. Radiation obtained from both of these sources is effective for sterilization and offers number of advantages.

- These radiations are suitable method for sterilization of many materials except for some plastics, glass and living cells. Sterilizing dose of radiation that is 25 kGy does not increase temperature significantly, so this method can be used for heat sensitive drugs and objects made from low melt transition plastics.
- Radiation reaches all parts of an item due to its high penetration ability. These objects can be prepacked in hermetically sealed, durable packages which are impermeable to microorganisms. The shelf life of these radiation sterilized and prepacked objects is indefinite. As the objects are packed and boxed prior to sterilization, it eliminates the requirement for aseptic areas and procedures.
- Chemical reactivity of ionizing radiation is low as compared to highly reactive gases used for sterilization. So, the chances of occurrence of chemical reaction that may produce undesirable alterations in the product are very low. Therefore, radiation sterilization gives more freedom in selection of objects to be sterilized.
- The effect of radiation is instant and simultaneous within the entire volume of product as there is no problem of convection of heat or diffusion of gas.
- Delivery of radiation can be stopped at a desired time and additional dose can be delivered if needed to achieve sterility level.
- Radiation sterilization can be easily adapted to continuous processing, but batch processing is used in case of gas sterilization. Continuous process needs less labor but presupposes large-scale production to make it practical and economically viable.
- Sterilization with radiation is most reliable method due to certainty of radiation energy and power. There is only time which is variable and need monitoring once the operation parameters have been established. In all other methods, there is need to control simultaneously many factors such as temperature, pressure, humidity etc.[30]

**Some commonly used disinfectants are**

**Alcohol:** These are water soluble chemical compounds with underrated germicidal features. These are ethyl alcohol and isopropyl alcohol. These are rapidly bactericidal rather than bacteriostatic against vegetative forms of bacteria. They are unable to destroy bacterial spores. When these are diluted below 50 percent concentration, the cidal activity decreases sharply. The appropriate bactericidal concentration is in the range of 60-90 percent solutions in water. These are effective for disinfection of oral and rectal thermometers, computers, hospital pagers, scissors, cardiopulmonary resuscitation manikins, tonometers, ventilators, and stethoscopes.These are not recommended for sterilizing medical and surgical instruments as they lack sporicidal property.[32,33]

**Chlorine and chlorine compounds:** Most commonly used chlorine disinfectants are hypochlorites. These are available in both liquid and solid forms. Aqueous solution of 5.25% to 6.15% sodium hypochlorite is mostly used in United States. These have broad spectrum antimicrobial activity. Advantages of these are: no toxic residue, no effect of water hardness, inexpensive and fast acting and eliminate dried organisms and biofilms from surfaces. But they may produce ocular irritation or oropharyngeal, esophageal, and gastric burns, corrosiveness to metals in high concentrations, inactivation by organic matter, discoloring of fabrics, and generate toxic chlorine gas when mixed with ammonia or acid.[34]

**Glutaraldehyde:** It is a saturated dialdehyde which is as accepted high-level disinfectant and chemical sterilant. Aqueous acidic solution of glutaraldehyde is not sporicidal, but when it is activated by using alkalinizing agents, it becomes sporicidal. After activation shelf life of solution is 14 days as polymerization of glutaraldehyde molecules occurs which blocks the active sites of glutaraldehyde molecules that are responsible for its cidal activity.

**Hydrogen peroxide:** Previous literature described good germicidal activity and attest to its bactericidal, virucidal, sporicidal and fungicidal properties. 3% hydrogen peroxide commercially available that is stable and effective disinfectant for inanimate surfaces. It was reported that it is effective in spot-disinfecting fabrics in patients' rooms. Hydrogen peroxide–soaked tonometer tip may cause corneal damage that was not properly rinsed.[31]

**Quaternary Ammonium Compounds:** These are widely used as surface disinfectants. These are nitrogenous organic compounds. Chemical structure consists of a nitrogen atom with four hydrogen atoms attached around it. To create quaternary ammonium compounds, each hydrogen atom is replaced with some combination of four other organic chains or rings. There are different versions of quaternary ammonium compounds are available in market and new ones are constantly in development. These compounds do not damage clothes and carpets. They are non-corrosive to metal pipes and other surfaces. In diluted form, these compounds can be used without extra precautions such as masks, googles and gloves etc. On mixing with organic matter, it lost its effectiveness. So, these compounds are ineffective in presence of blood, urine, fecal matter or soil. Therefore, these compounds are used for non-critical surfaces like floors and railings in hospitals. Effectiveness of these compounds decreases if clothes made of cotton or other organic matter are used to spread these disinfectants.[35]

**Hydrogen peroxide plasma:** It is a new low temperature sterilization method used for sterilization of temperature sensitive instrument. A recently cleared by FDA, the sterrad 50 which is smaller version of sterrad 100. The sterrad 50 consists a single shelf for placing equipments to be sterilized within a rectangular chamber but sterrad 100 has two shelves and a cylindrical chamber. The sterilization cycle for sterrad 50 is 45 minutes and for sterrad 100 is 72 minutes.[36]

**Attest Ethylene oxide (EO) rapid readout:** It is widely used low temperature sterilization method since 1950s and used for temperature and moisture sensitive medical instruments in U.S. Currently available and cleared by FDA consists of 100% EO and EO with variable stabilizing gases like carbon dioxide or hydrochlorofluorocarbon. New rapid readout EO biological indicator is used for rapid and reliable monitoring of EO sterilization processes which indicate failure of sterilization process by generating fluorescent change. This biological indicator detects the B. Subtilis presence by detecting an enzyme activity of B. subtilis.[37,38]

## CONCLUSION

There is need for using appropriate disinfection methods as various infections can spread from improperly disinfected patient care items in hospitals. Also, there is need to identify whether cleaning, disinfection or sterilization is needed on the basis of item's use. There are various methods of sterilization available including physical and chemical methods. The method is selected based on the type of object and its use. The different methods should be selected and applied according to recommendation and manufacturer's instructions. Various new sterilization methods are introduced with significant benefits over exiting sterilization technologies. Their effectiveness data presently available have primarily been provided by manufacturers and it need to be validated independently. Maintaining hand hygiene remains cornerstone of all the infection control activities performed in hospitals.

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