CHAPTER 7

INFECTION CONTROL METHODS

Abstract

Infection control involves good housekeeping (sanitation and dust control), hand washing, using personal protective equipment (PPE) such as gloves, and using natural, physical, or chemical methods to make the environmental conditions detrimental for pathogens. The type of likely pathogens should be considered while choosing the type of disinfection. Nearly all the chemical disinfectants are toxic or harmful to the eyes, skin, and lungs. Sterilisation is recommended for *critical items* that are directly introduced into the blood stream or into the normally sterile areas of the body. *Semi-critical items* come in contact with mucous membranes, do not ordinarily penetrate body surfaces, and require high level chemical disinfection. *Non-critical items* that do not come in contact with the patients or touch their intact skin only, require general housekeeping measures like washing with detergents and water. The basic principle of *universal biosafety precautions* is that blood and body fluids from all patients ought to be considered as potentially infected, irrespective of their serological status. These precautions should be followed during patient care and handling of dead bodies in health care settings.

Key Words

Antisepsis, Barrier nursing, Biomedical waste management, Cohort nursing, D value, Decontamination of spills, Disinfection, Hand washing, Handling dead bodies, Infection control, Needle stick injuries, Personal protective equipment, Sterilisation, Survivor curve, Task nursing, Universal biosafety precautions

7.1 – DEFINITIONS

1. Sterilisation (Latin: *sterilis* = barren): This is a "process by which, an article, surface, or medium is freed of all living entities (including vegetative microorganisms and spores)". An article may be regarded as *sterile* if it can be demonstrated that the probability of viable microorganisms on it is less than one in a million as per pharmacopoeia definition (Simpson & Slack, 2006).
2. Antisepsis (Greek: *anti* = against; *sèpsis* = putrefaction): This is a "process by which, *living tissues* are freed of pathogens". This is usually done by destruction of pathogens or by growth inhibition.
3. Disinfection (Latin: *dis* = reversal of): It is defined as a "process by which, *inanimate* objects, or surfaces are freed of all pathogens". Usually, disinfection does

not affect spores. A disinfectant in higher dilution can act as an antiseptic. But, the reverse is not always true. *Prophylactic disinfection* is defined as "measures applied *before* the onset of disease" and includes chlorination of drinking water, pasteurisation of milk, and washing of hands before clinical procedures. *Concurrent disinfection* refers to "measures applied *during* illness, to prevent further spread of the disease" and includes disinfection of patient's excretions, secretions, linen, and materials used in treating the patient. *Terminal disinfection* is defined as "measures applied *after* the patient has ceased to be a source of infection after cure, discharge, or death". This technique is obsolete. Terminal disinfection is now replaced by terminal cleaning of rooms, including ventilation. Rarely, bedding is fumigated (Ananthanarayan & Paniker, 2000; Collins & Grange, 1990; Sathe & Sathe, 1991).

4. Incineration (Latin: *cineris* = ashes): Incineration is "total combustion of all living and organic matter, by dry heat at not less than 800°C"
5. Decontamination (Latin: *dis-* or *de-* = reversal of; *contamunätum* = pollutant): This is a general term that indicates procedures put into practice to make equipment safe to handle. The word "contamination" may refer to chemical, microbiological or radioactive contamination (Simpson & Slack, 2006).
6. Sanitation (Latin: *sanitas* = health): This refers to reduction in the number of pathogens (Ananthanarayan & Paniker, 2000). Sanitation includes cleaning, wet mopping, dust control, environmental hygiene, and safe disposal of waste.

7.2 – KINETICS OF STERILISATION AND DISINFECTION

7.2.1 – Survivor Curve

When microorganisms are subjected to a lethal process, the number of viable survivors decreases exponentially in relation to the extent of exposure to the lethal process. If a logarithm (to the base 10) of the number of surviving organisms is plotted against the lethal dose received such as duration of exposure to a particular temperature, the resulting curve is called the "survivor curve". This survivor curve is independent of the original population of microorganisms. Ideally, the survival curve should be linear. Extrapolation on the survivor curve helps in determining the lethal dose required to give 10^{-6} survivors to meet the pharmacopoeia definition of "sterile" (Simpson & Slack, 2006).

7.2.2 – D Value

While manufacturing sterile products, a figure known as "D value" is used. It is the abbreviation for "death rate value" (Collins & Grange, 1990) and is also called "decimal reduction value" (Simpson & Slack, 2006). The "D value" is the time and dose of exposure, as determined in the laboratory, to reduce the viable count by one log, i.e. one order of magnitude = 1/10 (Collins & Grange, 1990). "D value" is the time and dose of exposure required to inactivate 90 per cent of

organisms in the initial population (Simpson & Slack, 2006). The D value remains constant over the full range of the survivor curve. This means that the time and dose required to reduce the population of organisms from 10^6 to 10^5 is the same as that required to reduce the population of organisms from 10^5 to 10^4 (Simpson & Slack, 2006). In order to ensure effectiveness of sterilisation, the magnitude of exposures used is many times more than the "D value", which is calculated according to the known "bio-burden" (Collins & Grange, 1990).

7.2.3 – Components of Infection Control

Infection control involves: (a) good housekeeping (cleaning, wet mopping, and dust control), (b) using PPE (gloves, masks, etc.), and (c) using physical or chemical methods to make the environmental conditions detrimental for pathogens. Many physical methods act by chemical mechanisms. For example, heat kills the pathogens by denaturing cellular proteins (Sathe & Sathe, 1991). The process of disinfection should be technically correct. Many commonly used methods of disinfection are mentioned below, but the type of likely pathogens should be considered while choosing the type of disinfection.

7.2.4 – Classification of Medical Equipment

Medical equipment or items can be divided into three categories (Chitnis, 1997; Simpson & Slack, 2006).

1. Critical Items: All equipment or items that are directly introduced into the blood stream or into the normally sterile areas of the body, e.g. surgical instruments, cardiac catheters, needles, arthroscopes, parenteral fluids, and implants. These articles have to be *sterile* at the time of use.
2. Semi-Critical Items: Articles that come in contact with mucous membranes and do not ordinarily penetrate body surfaces, e.g. non-invasive flexible and rigid fibrooptic endoscopes, endobronchial tubes and ventilation equipment, cystoscopes, aspirators, and gastroscopes. *High-level chemical disinfection* is sufficient for items belonging to this category.
3. Non-Critical Items: Items that do not touch the patients or touch the intact skin only, e.g. blood pressure cuffs, crutches, bed pans, urine pots, and furniture. *General housekeeping measures* like washing with detergents and water are adequate.

7.2.5 – Prior Cleansing

Before subjecting any article or equipment to sterilisation or disinfection, it is essential that the lowest possible bioburden is present at the start of the process. Any used article or instrument is to be soaked in a chemical disinfectant, cleaned with a detergent, followed by thorough rinsing (Mitchell *et al.*, 1997). This is necessary before subjecting the material or equipment to the sterilising

process. Cleaning, per se, is also a valuable method of low-level disinfection. Ultrasonic baths are useful in removing dried debris on instruments that are ordinarily difficult to clean. This partially reduces the bioburden. Detergents have surface tension reducing property – they wash away many organisms. The dilution effect of thorough rinsing further reduces the burden and thus increases the probability of successful sterilisation (Simpson & Slack, 2006). Lipid membrane envelope of HIV is highly susceptible to surface tension reducing action of detergents. Hence clothes and utensils may be decontaminated by washing with detergents.

7.2.6 – Factors Affecting Sterilisation and Disinfection

1. Species or Strain of Microorganism: In general, vegetative organisms are more vulnerable, while spores are resistant to action of sterilising and disinfecting agents. There is an interspecies variation in the D value at 60°C – *Escherichia coli* (few minutes) to *Salmonella enterica* subtype Senftenberg (one hour); D value at 70°C – *Staph aureus* (less than 1 minute) and *Staph epidermidis* (3 minutes). Prions (organisms that cause scrapie, bovine spongiform encephalopathy, and Creutzfeldt-Jakob disease) are killed at 134°C for 18 minutes. Hence it is desirable to use gamma-sterilised disposable instruments for operating on nervous tissue including retina because risk of exposure to prions is high (Simpson & Slack, 2006).
2. Growth Conditions: Organisms that grow under nutrient-rich conditions are more resistant to sterilising and disinfecting agents. Resistance usually increases through the late logarithmic phase of microbial growth and declines erratically during the stationary phase.
3. Spore Formation: Bacterial spores are more resistant, as compared to fungal spores. In general, disinfection processes have little or no action against bacterial spores.
4. Micro-Environment: The presence of organic matter (blood, body fluids, pus, faeces, urine) reduces the effectiveness of chlorine-releasing agents (Simpson & Slack, 2006). Presence of salt reduces effectiveness of ethylene oxide (Simpson & Slack, 2006). Chemical disinfectants will inactivate at least 10^5 viruses within few minutes. With the exception of phenols, many chemical disinfectants are inactivated in the presence of organic matter. Hence thorough cleaning is necessary before disinfection (Simpson & Slack, 2006).
5. Bioburden: Higher the initial bioburden (number of microorganisms) the lethal process must be more stringent and extensive to achieve high quality of sterility.
6. Time Factor: All microorganisms do not get killed instantly when exposed to physical agents or to chemical disinfectants because in any population of microorganisms, some will be more resistant than others (Collins & Grange, 1990). Higher the bioburden, longer will be the time taken to destroy all of them (Simpson & Slack, 2006).

7.2.7 – Factors Affecting Action of Chemical Disinfectants

1. Concentration, stability of disinfectant, temperature, and pH during use. "In-use concentration" is the optimal concentration required to produce a standardised disinfecting effect (Simpson & Slack, 2006).
2. Number, type, and accessibility of the microorganisms – Gram-positive bacteria are more sensitive, as compared to Gram-negative bacteria, mycobacteria, and bacterial spores; lipophilic and enveloped viruses are more sensitive, as compared to hydrophilic viruses, e.g. poliovirus. Hepatitis B virus (HBV) is also relatively resistant to action of disinfectants.
3. Presence of inactivators of disinfectants – organic (especially protein) substances, hard water, cork, plastics, organic matter, soaps, detergents, or another disinfectant. Users should refer instructions of manufacturers regarding such inactivators (Simpson & Slack, 2006).

7.3 – PHYSICAL METHODS

7.3.1 – Dehydration

Dehydration (also called "dessication") is lethal to most pathogens, since the organisms lose moisture. Drying can be achieved by exposing the object or article to strong sunlight, or by keeping the object/article in desiccators (Ananthanarayan & Paniker, 2000). *Vacuum drying* is used to preserve the potency of vaccines and the nutritive value of foods. *Adequate ventilation* acts by drying and diluting the number of suspended organisms in the air. Delicate organisms such as meningococci are vulnerable to drying by air (Sathe & Sathe, 1991). Dehydration is unreliable because many viruses and spores are not destroyed. Drying reduces the infectivity of the HIV. Hence, dried serum and blood are not highly infectious. Like other enveloped viruses, HIV must remain in *moist state* (or in solution) in order to be infectious. It is also susceptible to inactivation by physical and chemical agents in the *moist* state (Cunningham, 1997).

7.3.2 – Dry Heat

Dry heat acts by denaturing proteins of the microorganism.
Flaming: Exposure of scalpels or necks of flasks to a flame for a few seconds is of uncertain efficiency. Inoculating loops and needles are sometimes immersed in methylated spirit or alcohol and burnt off. But, this method does not produce sufficiently high temperature. In addition, there is the flammable risk of alcohol. The following items can be sterilised using the blue (oxidising) flame of a Bunsen burner – spatulas, inoculating loops, glass slides. Use disposable inoculating loops when dealing with highly pathogenic organisms. This is because flaming may cause "spluttering" of unburnt material, which is dangerous (Simpson & Slack, 2006).

Incineration: Unfortunately, many incinerators are inefficient for burning hospital waste. The waste may be merely scorched and the infected waste may escape with the smoke and pollute the atmosphere. The basic requirements in design of incinerators for hospital waste include: (a) easy attainability of high temperatures (at least 800°C) with the "load", and (b) presence of an "afterburner", i.e. a chamber, where smoke and other gaseous effluents are heated to similar or even higher temperatures (Collins & Grange, 1990). It is essential to train incinerator operators on what type of materials can (or cannot) be burned and how to mix loads in order to ensure adequate combustion, with the minimum of toxic effluent. Even an intrinsically efficient incinerator may fail if it is improperly used (Collins & Grange, 1990). During the process of incineration, the pathogens are destroyed along with the contaminated article/object. This method is recommended for disposal of low-value non-reusable articles like soiled dressings, swabs, dry waste, etc., and for incinerating animal carcasses and biomedical waste (Collins & Grange, 1990; Sathe & Sathe, 1991).

Hot Air Oven: The articles are wrapped in heat-resistant paper before they are placed in the hot air oven. The recommended temperature and duration is 160°C for 1 hour. This method is used for sterilising sharp instruments, glassware (syringes), dusting powders (French chalk, antibiotic powders), vaseline, and paraffin.

7.3.3 – Methods using Moist Heat

Moist heat is more lethal than dry heat. The cell wall of the microorganisms encloses protein particles in colloidal suspension. Heat coagulates cellular protein, which results in death of microorganisms. Coagulation of protein is instantly lethal and takes place at a lower temperature in the *presence of moisture*. Hence, moist heat is more lethal than dry heat. The vegetative forms contain more moisture and therefore, their cellular proteins coagulate faster. Spores contain less moisture and are consequently more resistant to action of heat (Sathe & Sathe, 1991).

Pasteurisation: Rapid heating, followed by sudden cooling destroys or inactivates most of the pathogenic organisms. Pasteurisation is chiefly used for milk and milk products. The methods of pasteurisation are:

(a) *Holder method* – Milk is heated to 63°C for half an hour and is rapidly cooled
(b) *Flash process* – Also known as "high temperature, short time (HTST) method". Milk is rapidly heated to 72°C within 15 seconds and is quickly cooled
(c) *Ultra-high temperature (UHT) method* – Milk is superheated to 125°C in 15 seconds and is rapidly cooled. Milk and milk products pasteurised by UHT method have a longer shelf life.

Water Baths: Used for disinfecting sera and other products that are destroyed or denatured at high temperatures. The recommended temperature and duration is 60°C for 1 hour (Ananthanarayan & Paniker, 2000).

Boiling: Boiling destroys all vegetative organisms within 5 minutes. But, spores may remain viable (Ananthanarayan & Paniker, 2000). Moist heat is not suitable for woolens and may cause shrinkage. Boiling is useful for disinfecting linen, crockery, utensils, bottles, and glassware. The articles should be thoroughly washed with soap or detergent before they are boiled. A bundle of clothes should be boiled at least for half an hour so that the moist heat can penetrate the bulky mass. Sputum, collected in a metal container, should be boiled for 1 minute after adding some water (Sathe & Sathe, 1991). HIV in solution is inactivated by heat at 56°C within 10–20 minutes. In lyophilised protein preparations, such as Factor VIII, HIV is killed at 68°C within 2 hours.

7.3.4 – Steaming at Atmospheric Pressure

Types of Steam: *Dry steam* does not contain suspended droplets of water. *Wet steam* contains suspended droplets of water at the same temperature and is less efficient as a sterilising agent. *Saturated steam* holds all the water it can, in the form of transparent vapour. For effective sterilisation, steam should be both *dry* and *saturated* (Simpson & Slack, 2006). *Superheated steam* is at a higher temperature than the corresponding pressure would allow. This type of steam behaves in a manner similar to hot air and is less penetrative. Mixture of steam at low temperature and formaldehyde gas combines the thermal effect of steam generated at subatmospheric pressure and chemical effect of formaldehyde gas to give effective sporicidal action. This method is useful for reprocessing heat-sensitive instruments. However, safety requirements make the process unsuitable for routine hospital use (Simpson & Slack, 2006).

7.3.5 – Autoclaving

The autoclave (Greek: *auto* = self; *clavis* = key) is essentially a pressure cooker. The autoclave has a cylindrical body made of strong alloy. The lid, made of gunmetal, can be sealed with "butterfly screws". The autoclave has an outlet for steam, a safety valve, and a pressure gauge. In modern autoclaves, the process, temperature, and time are controlled automatically. Articles to be sterilised are kept on a perforated stage inside the autoclave cylinder. The water level is to be checked every time the autoclave is used and should be below this perforated stage. Gas burner or electricity may be used for heating. Autoclaving is a reliable method of sterilisation, which destroys all living entities (pathogenic as well as non-pathogenic microorganisms). Vegetative organisms are killed instantly and most spores within 2 minutes. Trained personnel are required for handling and maintenance. Articles are moist soon after they are removed from the autoclave. Sharp instruments lose their sharpness and hence cannot be autoclaved (Collins & Grange, 1990; Sathe & Sathe, 1991).

The autoclave is used in laboratories for sterilising all biochemical and bacteriological media, except those containing heat labile substances like blood,

serum, or eggs (Sathe & Sathe, 1991). In health care settings, autoclaves are used for sterilising linen, gloves, gowns, and surgical instruments (other than sharps). Needles and syringes may also be autoclaved in certain situations though use of disposable, gamma-sterilised needles and syringes is recommended (Collins & Grange, 1990; Sathe & Sathe, 1991).

7.3.6 – Working Principles

Charles' Law: The higher the pressure, the higher is the temperature, when the volume is constant. At normal atmospheric pressure (at sea level), water boils at 100°C. A pressure of 15 pounds per square inch (PSI) is equivalent to *one atmosphere* pressure. Metric (SI) units are not used in autoclaving. When water is subjected to a pressure of 15 PSI above the atmospheric pressure, water will boil at a temperature of 121°C if air is completely expelled from the closed container. If air is not expelled, water will boil at a lower temperature. Pressure, *per se*, does not ensure effective sterilisation since microorganisms can withstand high pressures. Pressure acts by raising the temperature at which water boils, and increasing penetration of steam. The raised temperature is instrumental in ensuring sterilisation (Collins & Grange, 1990).

Latent Heat of Steam: For converting water into steam at the same temperature, an additional heat of 540 calories per gram has to be supplied. Conversely, when 1 g of steam condenses back to form water at the same temperature, this heat is instantly released without any change in temperature. Hence, this is called "latent heat" (latent = hidden). The latent heat is instantly delivered to the article on which the steam condenses resulting in instantaneous death of the microorganisms that may be present (Collins & Grange, 1990).

Sudden Reduction in Volume During Condensation: About 1,700 mL of steam at 100°C condenses on a relatively cooler surface to form 1 mL of water at 100°C and releases latent heat. Condensation causes a local drop in pressure, which draws in more steam. This movement of steam continues till the article reaches temperature equilibrium (Collins & Grange, 1990).

Action of Moist Heat: Once the surface layer of the article/object has reached temperature equilibrium the steam does not condense on the surface layer since the temperature is the same. The steam penetrates into the next cooler layer and condenses. Thus, moist heat under pressure is more penetrative. This action continues till the entire article or object is penetrated by steam (Collins & Grange, 1990).

7.3.7 – Prior Cleansing

Before subjecting any article or instrument to autoclaving, it is essential that the lowest possible bioburden is present at the start of the process. Any used article or instrument is to be soaked in a chemical disinfectant, cleaned with a detergent, followed by thorough rinsing. Cleaning, per se, is also a valuable method of

low-level disinfection. Ultrasonic baths are useful in removing dried debris on instruments that are ordinarily difficult to clean. This partially reduces the bioburden. Detergents have surface tension reducing property and wash away many organisms. The dilution effect of thorough rinsing further reduces the burden and thus increases the probability of successful sterilisation (Simpson & Slack, 2006).

7.3.8 – Elimination of Air

Since air is a bad conductor of heat, its presence inside the autoclave chamber reduces the maximum temperature that can be achieved, and thus diminishes the penetrating power of steam. Steam under a pressure of 15 PSI reaches a temperature of 121°C only when the air is completely removed. Air can be removed from the autoclave chamber by a vacuum pump. Alternatively, air can be removed by downward displacement. Since cooler air (being heavier) tends to settle at the bottom of the chamber, steam is let in from the top to displace air downwards. When steam starts coming out of the discharge outlet, it indicates that the air is completely removed from the chamber. The steam outlet valve is then closed and the pressure inside the chamber is allowed to rise (Collins & Grange, 1990).

7.3.9 – Sterilisation Time

Sterilisation time has the following components:

(a) *Heating or penetration time*: Time taken to increase the temperature of the article to that of steam.
(b) *Holding time*: Time during which the contents of the chamber are maintained at the selected temperature (usually 121°C at 15 PSI). *Prions*, the causative agents of scrapie, bovine spongiform encephalopathy, and Creutzfeldt-Jakob disease, are killed at 134°C for 18 minutes (Simpson & Slack, 2006). Hence, to ensure *absolute sterility*, a temperature of 135°C is to be attained. The holding time is determined by the *thermal death point* of heat-resistant bacterial spores.
(c) *Safety period*: This is usually 50 per cent of the holding time for dressing drums and is equal to the holding time for fabric bundles. It is essential to follow the instructions mentioned in the autoclave manufacturer's operating manual (Collins & Grange, 1990).

7.3.10 – Tests to Ensure Completeness of Sterilisation

Commonly, the pressure gauge is relied upon to check for the completeness of sterilisation. However, it is essential to have a thermometer fitted and to record the actual temperature attained, and the duration for which the temperature was maintained. Equipment with vacuum-assisted air removal cycle are fitted with air detectors. Temperature-sensitive probes (thermocouples) may be inserted

into standard test packs (Simpson & Slack, 2006). The *Bowie-Dick test* monitors the penetration of steam by a bubble of residual air in the pack (Simpson & Slack, 2006). In the original test, an adhesive indicator tape is pasted on the surface of the articles or objects to be sterilised, before they are placed in the autoclave chamber. This indicator tape, usually green in colour, changes to black if the article has been exposed to the recommended temperature (Collins & Grange, 1990; Sathe & Sathe, 1991). The change in colour should be uniform along the entire length of the indicator tape (Simpson & Slack, 2006).

Biological indicators comprise dried spore suspensions of a reference heat-resistant thermophilic spore-bearing bacterium such as *Bacillus stearothermophilus, Bacillus thuringensis*, or *Bacillus subtilis*. Spores of one of these organisms are kept in a sealed glass ampoule and placed inside the autoclave chamber. After the process of autoclaving, the ampoule is sent to the laboratory where the spores are incubated to check for bacterial growth. Presence of growth indicates that the spores have remained viable. This procedure requires laboratory support, is expensive, and the results of the laboratory tests are not available immediately (Collins & Grange, 1990; Sathe & Sathe, 1991). These biological indicators are no longer considered for routine testing. Spore indicators are essential in low-temperature gaseous processes like ethylene oxide, in which physical measurements are not reliable (Simpson & Slack, 2006).

7.3.11 – Tips for Successful Autoclaving

The manufacturer's operating manual should be carefully followed and autoclave operators should be trained. Materials such as talcum powder cannot be penetrated by steam and should not be autoclaved. Before using the autoclave, water should be maintained at a level recommended by the manufacturer. Steam outlet and safety valve should be checked and cleaned if necessary. All articles should be wrapped in kraft paper or cloth and then placed in individual trays. The barrel and plunger of the syringes should be disassembled and wrapped in cloth or kraft paper. Linen should be wrapped in loose flat bundles since larger bundles would need longer time for sterilisation. The *thermo-chemical indicator tape* is stuck on the cloth covering each tray. It is important to ensure that all the air is expelled, since a mixture of air and steam will not have the same penetrative effect as saturated steam alone. The steam outlet is closed only after all the air in the cylinder is expelled and excess steam starts coming out from the steam outlet. The temperature, pressure, and the sterilisation time are recorded. The "holding time" is counted after the steam outlet is closed. It is safer to rely on the temperature attained and the time period for which this temperature is maintained. To ensure absolute sterility, a temperature of 135°C is to be attained. The autoclave should cool on its own. Autoclaved articles should be prevented from contamination during drying, transportation, and storage. For sterilising small quantities, a domestic pressure cooker may be used. The "holding time" is counted after the first "whistle" (expulsion of steam) from the steam outlet of the pressure cooker (Collins & Grange, 1990; Sathe & Sathe, 1991).

7.3.12 – Radiation

Ionising Radiation: The articles/objects exposed to ionising radiation do not get heated. Hence, this method, also called "cold sterilisation", is the most cost-effective and safe method of sterilisation. Sterilisation is achieved by using high-speed electrons (beta-rays) from a linear accelerator or gamma-rays from an isotope such as Cobalt-60. A dose of 255 kilo Gray is adequate for large-scale sterilisation (Simpson & Slack, 2006). The articles travel through the facility on a conveyor belt. Ionising radiation is used for large-scale sterilisation of pre-packed single-use syringes, needles, catheters, antibiotics, ophthalmic medicines, microbiological media, heat-sensitive plastics, and other heat-sensitive instruments (Ananthanarayan & Paniker, 2000).

Non-Ionising Radiation: Substances exposed to non-ionising radiation get heated. *Short wave* radiation (such as ultraviolet rays) is more bactericidal than *long wave* radiation (such as infrared rays). Infrared radiation is used for sterilising glassware. Ultraviolet (UV) radiation is a low-energy, non-ionising type of radiation, with poor penetrating power. Ultraviolet rays are lethal to microorganisms under optimal conditions. UV lamps produce effective UV radiation with wavelength of 240–280 nm. The UV rays with shortest wavelength that reach the earth's surface have a wavelength of 290 nm. UV lamps are used for sterilising closed areas, such as operation theatres, wards, neonatal intensive care units, and laboratory safety cabinets (Simpson & Slack, 2006). Commercially available household water purifiers use UV radiation for sterilising small quantities of water for laboratory or household use. Its disinfecting action on water is impaired if water is turbid. UV light is also used for therapeutic purpose, to accelerate the conjugation of bilirubin in neonates with jaundice. It should be noted that eye protection is essential because exposure to UV light may lead to premature cataract.

7.4 – CHEMICAL METHODS

Lipophilic viruses such as HIV, HBV, and cytomegalovirus are *highly sensitive* to chemical disinfectants (Gangakhedkar, 1999). Disinfectants rapidly inactivate HIV in suspension but are less effective against HIV in dried body fluids (Cunningham *et al*., 1997). HIV is inactivated by 70 per cent isopropanol (3–5 minutes), 70 per cent ethanol (3–5 minutes), 2 per cent povidone iodine (15 minutes), 4 per cent formalin (30 minutes), 2 per cent glutaraldehyde (30 minutes), household bleach (diluted) containing 1 per cent available chlorine (30 minutes), and 6 per cent hydrogen peroxide (30 minutes). For decontaminating used medical equipment, 2 per cent glutaraldehyde may be used.

Criteria For Selecting Disinfectants:

(a) Area of health care facility, where the disinfectant will be used
(b) Spectrum of action – bacteria, lipophilic and hydrophilic viruses, mycobacteria, fungi, and spores

(c) Rapidity of action and residual effect – antimicrobial action is to be sustained for prolonged periods
(d) Should not cause allergy or irritate the skin or mucous membrane
(e) Microorganisms should not develop resistance on repeated use
(f) Odour and colour should be acceptable
(g) Should not stain skin or clothing

Factors Affecting Disinfection: Before disinfection, the articles or surfaces must first be thoroughly cleaned with detergent and thoroughly rinsed with water. Effective chemical disinfection depends on multiple variables such as concentration of the disinfectant, temperature and pH, presence of organic substances, and contact period (period of exposure to the disinfectant). Since it is difficult to consider all the variables that can affect chemical disinfection, it would be easier to follow the manufacturer's guidelines. A minimum "contact period" of 30 minutes is recommended.

7.4.1 – Standard Operating Procedures

The hospital infection control committee (HICC) should agree on a sterilisation and disinfection policy and procedures involved. Once the policy is finalised, all concerned staff members should be made aware of the policy and trained in the Standard Operating Procedure (SOP). The sterilisation and disinfection policy should mention choice of sterilising or disinfecting process is required for equipment, instrument, skin, mucous membrane, furniture, floors, and biomedical waste. The available choices or options are to be restricted to avoid unnecessary costs, confusion, and chemical hazards. The processes are categorised and the SOPs for items in the hospital that are to be disinfected or sterilised are described. Copies of the SOP should be circulated to all concerned staff members. The policy and SOPs may be updated periodically by the HICC (Simpson & Slack, 2006).

7.4.1.1 – Components of standard operating procedure

1. Details of methodology
2. Site where the procedure is to be done
3. Time schedule for the procedure
4. Persons responsible for carrying out the various steps in the entire procedure
5. Safety precautions and type of protective equipment to be worn during each procedure
6. Supervision of entire procedure including safety considerations

7.4.2 – Limitations of Disinfectants

Under ideal conditions, chemical disinfectants destroy most of the vegetative microorganisms. Few kill bacterial spores, fungi, and viruses that have lipid capsids (Collins & Grange, 1990). Presence of organic materials, protein, hard water, rubber, and plastics may impair the action of some disinfectants. The recommendations of the manufacturer are to be followed for correct dilution,

storage after dilution, and use. Nearly all the chemical disinfectants are toxic or harmful to the eyes, skin, and lungs. Therefore, they should be cautiously selected and used. Disinfectants are not a substitute for efficient cleaning with detergent and water. If pre-diluted to working concentrations, chemical disinfectants may rapidly lose their strength on storage. In health care settings, sterilisation by autoclaving is the most reliable method. When neither autoclaving, nor boiling is possible, chemical disinfectants are to be used.

7.4.3 – Quality Control of Disinfectants

Unfortunately, chemical disinfectants are overused and abused, and then they are most inefficient and may give a false sense of security. Disinfectants that are used in health care settings should be monitored regularly (Chitnis, 1997). A wide range of testing methods has been developed for medical and veterinary use. In Europe, standardisation of test methods include: (a) simple screening tests of rate of kill, (b) laboratory tests simulating in-use conditions (skin antisepsis and inanimate surface disinfection tests), and (c) in-use tests on equipment and samples of disinfectants (in "in-use dilutions"). These tests determine survival and multiplication of contaminating pathogens. In-use tests are used for monitoring effectiveness of the disinfectant or antiseptic and monitoring method of use. The *Rideal Walker coefficient* (RWC), also known as carbolic coefficient or phenol coefficient, compares the bactericidal power of a given disinfectant with that of phenol. A major limitation of this test is that it compares disinfectants, without the presence of organic matter such as pus, faecal matter, blood, or body fluids (Chitnis, 1997). *Chick Martin test* compares the disinfecting action of two disinfectants in the *presence* of organic matter (Chitnis, 1997). *Capacity test of Kelsey and Sykes* gives guidelines for the dilution of the disinfectant to be used (Kelsey & Sykes, 1969). After a particular disinfectant is selected at the desired dilution using the capacity test of Kelsey and Sykes, routine monitoring should be done using the *"in use" test of Maurer* (Maurer, 1969).

7.4.4 – Coal-Tar Derivatives

Phenols are relatively cheap, stable, and not readily inactivated by organic matter with the exception of chlorxylenol. Adding ethylene diamine tetraacetic acid (EDTA), as a chelating agent, can improve the activity against Gram-negative organisms. *Black* and *white* phenols (insoluble in water) leave stains on surfaces and *clear soluble* phenols are replacing these. *Corrosive phenols* are used for disinfection of floors, in discarding jars in laboratories, disinfection of excreta, etc. *Non-corrosive phenols*, such as chlorxylenol are less irritant and are used for topical antisepsis (Chitnis, 1997). With the exception of Chlorhexidine, phenols are incompatible with cationic detergents. Contact with rubber and plastic is to be avoided since they may get absorbed. Due to slow release of phenol fumes in closed environments and corrosive action on skin, phenols are being replaced in hospitals by detergents for cleaning, and by hypochlorites for disinfection (Simpson & Slack, 2006).

Carbolic Acid: Joseph Lister first used carbolic acid (pure phenol) for antisepsis. Crystals of carbolic acid are colourless, but when exposed to air, they turn pinkish and then dark red. Pure phenol is not a good disinfectant. It is toxic to tissues and can penetrate intact (unbroken) skin. Carbolic acid is used as a standard to compare the disinfecting power of disinfectants. For phenol, Rideal Walker coefficient is one. It is added to fuchsin dye to prepare carbol fuchsin, which is used for staining acid-fast bacilli. Formerly, carbolic acid was used as 0.5 per cent solution in glycerine as mouthwash, ear drops, and topical antipruritic; as analgesic in dentistry; and as 5 per cent solution in almond oil for sclerosing haemorrhoids.

Crude Phenol (Household Phenyl): This is a mixture of phenol and cresol and is available as a dark, oily liquid, used as general-purpose household disinfectant in a concentration of 1–2 per cent. Phenyl is effective, even in the presence of organic matter, against most Gram-positive and Gram-negative bacteria. However, it is an irritant to living tissues and is *not* effective against spores and acid-fast bacilli.

Cresol: This is a mixture of ortho-, meta-, and para-isomers of methyl phenol. It is effective against both Gram-positive and Gram-negative bacteria and is safer than pure phenol. But, it is an irritant to living tissues and only mildly effective against acid fast bacilli. It is used as an all-purpose disinfectant in the following concentrations: for faeces or sputum (10 per cent); for floors in wards and operation theatres (5 per cent).

Saponified Cresols: Lysol, izal, and cyllin are emulsions of cresol, prepared by mixing with surface-active agents. These are very powerful disinfectants. Being irritants to living tissues, they are used as all-purpose disinfectants for faeces, sputum, and floors in wards and operation theatres, and for the sterilisation of sharp instruments like scalpels.

Chlorhexidine (Hibitane): It is a chlorinated phenol containing cationic biguanide (Chitnis, 1997). It is effective against *vegetative forms* of Gram-positive, Gram-negative bacteria and fungi, and has moderate action on *Mycobacterium tuberculosis*. It is fast acting and has residual action for 5–6 hours. Hibitane is effective over a wide range of pH (5–8) and can be safely used on living tissues (skin and mucous membrane). However, this disinfectant is not effective against spores and is inactivated by soap (anionic detergents), organic matter, hard water, and natural materials like cork liners of bottle closures. It is combined with compatible (cationic) detergent and used for hand wash or combined with 70–90 per cent alcohol for use as "hand rub". Hibitane is a component of Savlon (Cetrimide + Hibitane) and is used as a skin antiseptic for wounds and burns. Hibitane is also available as lotion or cream (Ananthnarayan & Paniker, 2000; Sathe & Sathe, 1991).

Hexachlorophane: It is a chlorinated diphenyl (bis-phenol) and has a restricted role as a disinfectant due to its limitations (Chitnis, 1997). It is very effective against Gram-positive organisms and is compatible with soap, i.e. anionic detergents

(Ananthnarayan & Paniker, 2000; Sathe & Sathe, 1991). In infants, hexachlorophane may get absorbed through the skin and cause neurotoxicity. Hence, a concentration of more than 3 per cent should not be used in neonatal units. Triclosan is used for controlling outbreaks of methicillin-resistant *Staphylococcus aureus* (MRSA) in nurseries (Simpson & Slack, 2006). It is poorly effective against Gram-negative organisms, mycobacteria, fungi, and viruses. Hexachlorophane is used in germicidal soaps and in deodorants to prevent bacterial decomposition of apocrine sweat. As a topical ointment, it is employed in the treatment of seborrhoeic dermatitis and impetigo (Ananthanarayan & Paniker, 2000; Chitnis, 1997).

Chloroxylenol: This is chlorinated derivative of phenol is available as concentrated solution, liquid soap, and soap cake under the brand name Dettol. Being relatively safe, it is used as a household skin antiseptic and for disinfecting plastic equipment. It requires a minimum contact period of 15 minutes for action on Gram-positive bacteria and more time is required in case of Gram-negative bacteria (Ananthanarayan & Paniker, 2000; Chitnis, 1997) Chloroxylenol is easily inactivated by organic matter and hard water and is not recommended for hospital use (Simpson & Slack, 2006).

Triclosan: It is chemically phenyl ether and is highly effective against Gram-positive bacteria. It has moderate activity against Gram-negative bacteria, fungi, and viruses (Chitnis, 1997). Triclosan is used for controlling outbreaks of MRSA in nurseries (Simpson & Slack, 2006).

7.4.5 – Alcohols

Ethyl, isopropyl, and methyl alcohols have rapid and high levels of initial activity, but no residual activity. Optimal disinfecting activity is at 70–90 per cent concentration; antimicrobial activity decreases at both higher (more than 90 per cent), and lower (less than 70 per cent) concentrations (Chitnis, 1997; Simpson & Slack, 2006). Alcohols have good action on viruses, limited action on mycobacteria, and no action on spores, with reduced activity in presence of organic matter. Alcohol-based formulations of chlorhexidine, Savlon, and povidone iodine are used for hand-washing (Simpson & Slack, 2006).

Ethanol (synonym: ethyl alcohol): 100 per cent ethyl alcohol (called "absolute alcohol") has poor antiseptic and disinfectant properties, while 60–70 per cent ethyl alcohol is a good general purpose skin antiseptic and can also be used to dilute other antiseptics, such as tincture iodine, chlorhexidine, and Savlon. It inactivates vegetative bacteria in a few seconds. Being a fat solvent, it can dissolve sebaceous secretions on the skin. However, its action on spores, viruses, and fungi is not reliable. It is volatile in warm climates. Methyl alcohol is added to ethyl alcohol to prepare *methylated spirit* to prevent consumption.

Isopropanol (synonym: isopropyl alcohol): It is more bactericidal, more of a fat solvent, and less volatile than ethanol. However, it is more toxic than ethanol,

and its action on spores, viruses, and fungi is *not* reliable. Isopropanol is used at 70 per cent for skin antisepsis and for disinfecting clinical thermometers, incubators, and cabinets.

Methylated Spirit (synonyms: rectified spirit, denatured spirit): Methyl alcohol is added to ethyl alcohol to prepare methylated spirit to prevent consumption. A 70 per cent solution has bactericidal, fungicidal, and virucidal action. However, it is a volatile compound. It is used for decontaminating surfaces, such as metals and table tops, where use of household bleach and hypochlorites is contraindicated. A mixture of 70 per cent methyl alcohol and 1 per cent glycerine is used as a hand-washing antiseptic (called "alcohol hand wash"), in all clinical settings. Glycerine is used in a concentration of 1 per cent as emollient to counter the drying effect of alcohol on the skin (Simpson & Slack, 2006).

7.4.6 – Aldehydes

Most aldehyde disinfectants are based on formulations of glutaraldehyde or formaldehyde, alone or in combination. Since they are an irritant to the eyes, skin, and respiratory mucosa, health and safety authorities in many countries control their use. Aldehydes are to be used only with adequate protection (protective clothing, safety hoods) of staff and ventilation of the working environment (air scavenging equipment). The treated equipment is to be thoroughly rinsed with sterile water to remove toxic residues. All chlorine-releasing agents should be removed from areas where formaldehyde fumigation is to be done, in order to prevent release of carcinogenic products (Simpson & Slack, 2006).

Glutaraldehyde: When buffered with sodium bicarbonate to pH 7.5–8.5, this has potent bactericidal, mycobactericidal, sporicidal, fungicidal, and virucidal action. The buffered solutions should be used within 2 weeks of preparation (Chitnis, 1997). Alkaline-buffered solution of glutaraldehyde is claimed to have a residual effect for several days but this will depend on the amount of contaminating organic material (Simpson & Slack, 2006). After disinfection with glutaraldehyde, the equipment should be thoroughly washed with sterile water. It is available under the brand name Cidex. A 2 per cent solution provides a high level of disinfection, which approximates sterilisation. It is the only disinfectant that can be reused. It is less toxic than formaldehyde and does not damage optical lenses and cementing material of endoscopes. However, glutaraldehyde has a strong odour and is expensive, as compared to formaldehyde. At alkaline pH (more than 8.5), glutaraldehyde gets polymerised, resulting in loss of antimicrobial activity. It is used for disinfecting sharp instruments, surfaces/instruments (which are destroyed by household bleach and sodium hypochlorite), face masks, catheters, endoscopes, endotracheal tubes, and respirators. An aqueous solution of 2 per cent is used topically for treatment of idiopathic hyperhidrosis of the palms and soles. Flexible endoscopes are to be disinfected by special closed washer–disinfector systems. These systems use oxidising agents, such as peracetic acid, chlorine dioxide, and super-oxidised water (Simpson & Slack, 2006).

Formaldehyde: Commercially available formaldehyde (formalin) contains 35–40 per cent formaldehyde. The vapours are toxic and irritant. A solution used in 1:10 dilution (containing 3.5–4 per cent formaldehyde) inactivates vegetative forms of bacteria, viruses, and fungi in less than 30 minutes. Any equipment that is disinfected with formaldeyde should be thoroughly rinsed with sterile distilled water before reuse (Chitnis, 1997). It is a cheap disinfectant, which kills all vegetative bacteria, most viruses, and fungal spores, while mycobacteria and bacterial spores are killed slowly. It does not damage metals or fabric, but is an irritant to the eyes and respiratory tract. It can damage optical lenses and cementing material used in endoscopes. Formaldehyde tablets (used for disinfection of equipment and nursery incubators) are not reliable and need to be subjected to quality control after use (Chitnis, 1997). As *aqueous solution* (formalin), it is used for preserving biological specimens and cadavers, and for destroying anthrax spores in animal hair and woollen products. Woollen products are soaked in a 2 per cent solution of formalin at 40°C temperature for 2 minutes. Hair and bristles are soaked in a 2 per cent solution at 60°C temperature for 6 hours. This process is called "duckering". A mixture containing one part formalin + one part glycerine + 20 parts water is used as a liquid spray for disinfecting walls and furniture in operation theatres, prior to fumigation. A 3 per cent solution may be used for removal of warts on palms and soles. Formalin in a concentration of 4 per cent is recommended for decontamination of spills of blood and body fluids. Formaldehyde vapour is used for fumigating operation theatres, wards, beds, books, and mattresses. Formaldehyde vapour is generated in special fumigators or by pouring 280 mL of 40 per cent formalin on 45 g of potassium permanganate ($KMnO_4$) crystals per 1,000 cubic feet of space. The exposure period for fumigation is 36–48 hours (Chitnis, 1997). The excess gas is neutralised using ammonia vapour.

7.4.7 – Halogens

Halogens (compounds of chlorine and iodine) are relatively inexpensive and have a broad spectrum of action. Hence, they are commonly used for decontamination of surfaces (Chitnis, 1997). However, they are required in higher concentrations in the presence of organic substances such as blood, body fluids, excretions, or secretions.

Compounds of chlorine kill vegetative organisms and inactivate most viruses by strong oxidising effect of nascent chlorine. The disinfecting power of all chlorine compounds is expressed as "percentage of available chlorine" for solid compounds and as "percentage" or "parts per million" (PPM) for solutions. All chlorine-releasing agents should be removed from areas where formaldehyde fumigation is to be done, in order to prevent release of carcinogenic products (Simpson & Slack, 2006). Chlorine-releasing agents are corrosive and most compounds deteriorate rapidly (Ananthanarayan & Paniker, 2000; Chitnis, 1997).

Sodium Hypochlorite: This compound is available as solution containing 5 per cent available chlorine, powder containing 60 per cent available chlorine, or tablets containing 1.5 g of available chlorine per tablet. The solution is available under various brand names such as Milton's solution, Saaf, Chlorwat, Kloroklin. It is bactericidal, virucidal, cheap, and more effective than bleaching powder ($CaOCl_2$) solution. However, it deteriorates rapidly, corrodes nickel and chromium plating of metallic instruments, and has an offensive odour. Sodium hypochlorite is most commonly used for bleaching and disinfecting linen and clothing: decontaminating spills of blood and body fluids; sterilising infant feeding bottles; and emergency disinfection of drinking water, fruits, and raw vegetables during epidemics.

Household Bleach: Also commercially available as fabric stain remover under various brand names, the solution contains 5 per cent available chlorine. It is bactericidal, virucidal, relatively cheap, and more effective than the solution of bleaching powder (calcium hypochlorite). For disinfecting materials and surfaces contaminated by blood or body fluids, household bleach should be made available in plastic recyclable bottles in hospitals and clinics. Household bleach deteriorates rapidly, corrodes galvanised buckets, nickel and chromium plating of metallic instruments, and has an offensive odour. The bleaching action may affect fabric and carpets while disinfecting spillage of blood or body fluids (Simpson & Slack, 2006).

Bleaching Powder: Chemically, this is calcium hypochlorite (CaOCl), also called "chlorinated lime". Bleaching powder is an unstable compound and should contain 33 per cent of available chlorine. When stabilised by mixing with lime (calcium oxide) it is called "stabilised bleach" or "tropicalised chloride of lime" (TCL). Bleaching powder is used in powder form or as a *freshly* prepared solution. A 1 per cent solution of bleaching powder can be prepared by mixing one-fourth teaspoonful (1 g) of bleaching powder in 1 L of water. This gives a chlorine concentration of 1,000 PPM. The minimum contact period is half an hour. The OCl^- ion is responsible for disinfection. *Uses of bleaching powder*: (a) decontaminating spills of blood and body fluids, (b) as a deodorant and disinfectant for toilets and bathrooms, (c) chlorination of water in wells (2.5 g of bleaching powder per 1,000 L of well water; contact period = 1 hour), (d) disinfection of faeces and urine (400 g of bleaching powder per litre; contact period = one hour), and (e) preparing Eusol, which was formerly used in dressing wounds.

Povidone Iodine: An "iodophor" is a loose complex of elemental iodine or triiodide with an anionic detergent, which increases solubility of iodine and functions as sustained-release iodine reservoir. "Povidone iodine" is a water-soluble complex of iodine and polyvinyl pyrrolidone (Simpson & Slack, 2006). Povidone iodine, which is available under various brand names, such as Betadine and Microshield, is an intermediate level disinfectant with bactericidal, fungicidal, and virucidal action. It does not stain or irritate the skin and is water miscible. However,

it has poor residual effect. A *freshly* prepared dilution of povidone iodine is to be used everyday. It is relatively expensive and should not be used on copper and aluminium (Chitnis, 1997). It is used as a 0.75–1 per cent solution for hand wash; for disinfecting instrument trays, head-rests, and equipment; and for decontaminating spills of blood and body fluids. Aqueous or alcohol-based povidone iodine is used for skin antisepsis (preoperative preparation), peritoneal wash, and treating superficial mycoses, such as *Tinea circinata* (ringworm) and oral/vaginal moniliasis. One per cent solution used as gargles for pharyngitis. Due to its virucidal action, it is used for local treatment of wound in case of dog bite.

Sodium Dichloroisocyanurate (NaDCC): Also known as "Troclosene", this compound is available as white powder, granules, and tablets. NaDCC powder containing 60 per cent available chlorine is recommended for decontamination of blood spills. The chemical is readily soluble in water. In solution, combined forms of chlorine (di- and mono-chloroisocyanurate) exist in a 50:50 equilibrium with hypochlorous acid (HOCl) and nascent chlorine (Cl) – combined forms of chlorine. As the chlorine is used up, the free chlorine is released from combined forms so as to maintain the 50:50 equilibrium. The process continues till all the combined chlorine is depleted. NaDCC is used for disinfection of drinking water, decontamination of floors, blood spills, laboratory glassware, bedpans, and urine bottles. NaDCC kills bacteria, mycobacteria, fungi, viruses, and spores. Its disinfecting action is not generally affected by presence of organic matter such as faeces, algae, blood, pus, and serum. It has a long shelf life (up to 2 years) and is effective over a wide pH range of 4–9. It is relatively less corrosive to metals and relatively safe. The antidote for accidental ingestion is drinking plenty of milk.

7.4.8 – Surface-Active Agents

Anionic Detergents: Common soap is an anionic detergent. Hard soap contains saturated fatty acids and hydroxide of sodium, or potassium; while soft soap contains unsaturated fatty acids and hydroxide of sodium, or potassium. Anionic detergents reduce surface tension and wash away microorganisms, sebaceous secretions from the skin, and dirt. Soaps are moderately bacteriostatic against Gram-positive bacteria. They are used for washing hands and body parts, and for soap water enema (evacuation enema). However, soaps are incompatible with cationic detergents and are precipitated by hard water.

Cationic Detergents: These quaternary ammonium compounds are water-soluble and act mainly on Gram-positive vegetative bacteria. They reduce surface tension and wash away microorganisms, sebaceous secretions from the skin, and dirt. These compounds are heat-stable, even on autoclaving and are most active at neutral pH and slightly alkaline pH. However, they have no effect on most Gram-negative organisms and mycobacteria, and are inactivated by anionic detergents (common soap) and acidic pH. Cationic detergents combine with protein in organic matter such as pus, sputum, blood, and body fluids, and

thus get inactivated. They are adsorbed by cotton, rubber, and porous material and potentially hazardous to neural tissue. Cationic detergents are used as general-purpose skin antiseptics in 1:1,000 dilution. For burns and wounds, 1:2,000 dilution is recommended. They are also used as disinfectants in 1:2,000 dilution for nylon (*not* rubber) tubings and catheters; and in 1:20,000 dilution for irrigation of bladder and urethra in catheterised patients. For preventing nappy rash, nappies may be washed in 1:8,000 dilution. A 5 per cent w/v (weight by volume) solution is recommended for topical use for treatment of dandruff (*Pityriasis capitis*). *Benzalkonium chloride* is a quaternary ammonium compound with strong action against Gram-positive bacteria. When EDTA is added as a chelating agent, it acts on Gram-negative organisms also (Chitnis, 1997).

Savlon: This is a combination of cetavlon (or Cetrimide, a cationic detergent) and chlorhexidine (Hibitane). Though it is inactivated by anionic detergents (common soap) and acidic pH, its advantages are its solubility in water and alcohol. When diluted with alcohol, it is a better disinfectant than when diluted with water. It reduces surface tension and washes away microorganisms and dirt. It is effective against Gram-positive, Gram-negative bacteria, and fungi. It is heat stable even on autoclaving and acts through a wide pH range of 5–8, but most effective at neutral and slightly alkaline pH. Savlon is effective even in the presence of organic matter. It is chiefly used as a skin antiseptic for general use. A 1 per cent solution of Savlon is used for disinfecting plastic appliances, clinical thermometers, and Cheatle's forceps. The solution is to be changed daily.

7.4.9 – Miscellaneous Agents

7.4.9.1 – Hydrogen peroxide (H_2O_2)

Hydrogen peroxide (H_2O_2) is an unstable compound. A solution containing 6 per cent w/v (weight by volume) releases 20 times its volume of nascent oxygen (O). Such a solution is called 20 volumes H_2O_2. It releases nascent oxygen (O), when applied to tissues. Nascent oxygen (O) prevents multiplication of anaerobic bacteria and inactivates HIV in 30 minutes. Effervescence mechanically removes tissue debris from inaccessible regions. It has good microbicidal and deodorant action (Simpson & Slack, 2006). However, presence of proteinaceous organic matter reduces its activity (Chitnis, 1997). Release of nascent oxygen (O) and effervescence are of short duration. H_2O_2 should not be used in closed cavities, such as urinary bladder, due to its effervescence. It is to be stored in amber colour bottles and kept in a cold place. Being highly reactive and corrosive to skin and metals, it should not be used on copper, aluminium, brass, or zinc (Simpson & Slack, 2006). H_2O_2 is used for irrigating wounds, abscesses, and septic pockets to remove anaerobic conditions. In 1:8 dilution it is used as a deodorant gargle and mouthwash. It is also used for removing earwax and for disinfecting ventilators (Chitnis, 1997).

7.4.9.2 – Other oxidising agents

Peracetic acid, chlorine dioxide, and superoxidised water are used as oxidising agents for disinfecting flexible endoscopes in special closed washer-disinfector systems (Simpson & Slack, 2006). Endoscopes are immersed in 0.35 per cent peracetic acid or 1100 PPM chlorine dioxide (ClO_2) for 5 minutes. This alternative method is used since personnel handling glutaraldehyde may develop adverse reactions (Gangakhedkar, 1999).

7.4.9.3 – Ethylene oxide gas

Ethylene oxide is a highly penetrative, non-corrosive, and microbicidal gas. It is used in industry for sterilising heat-sensitive medical devices, such as prosthetic heart valves and plastic catheters. The devices to be sterilised are exposed to ethylene oxide gas at a concentration of 700–1,000 mg per litre for about 2 hours. When using ethylene oxide gas, the process of disinfection is complex, and requires appropriate temperature (45–60° Celsius) and high relative humidity (more than 70 per cent) for action, followed by post-treatment aeration (Simpson & Slack, 2006). *Before sterilisation* the devices to be sterilised should be cleaned thoroughly and wrapped in a material that allows the gas to permeate (Chitnis, 1997). Presence of salt reduces effectiveness of ethylene oxide (Simpson & Slack, 2006). *During sterilisation* adequate precautions should be taken because the gas is inflammable and is potentially explosive. It is also toxic to personnel. *After sterilisation* the product is aerated to remove residual gas (Simpson & Slack, 2006).

7.4.10 – Recommended Chemical Disinfection

For preventing transmission of blood-borne pathogens including HIV and HBV, the recommended concentrations of disinfectants are given below. "Clean" condition indicates that the item or surface has been already cleaned and is free from organic contamination. "Dirty" condition refers to contamination of item, article, or surface with organic substances such as blood, body fluids, and excretions.

Chlorine Releasing Compounds

1. Household bleach containing 5 per cent available chlorine: for "clean" condition – 1:50 dilution (20 mL/litre), and for "dirty" condition – 1:5 dilution (200 mL/litre)
2. Sodium hypochlorite solution containing 5 per cent available chlorine (0.1 per cent = 1,000 PPM = 1 g/L; 1.0 per cent = 10,000 PPM = 10 g/L): for "clean" condition – 0.1 per cent or 1:50 dilution (20 mL/litre), and for "dirty" condition 1.0 per cent or 1:5 dilution (200 mL/litre)
3. Calcium hypochlorite (bleaching powder) containing 70 per cent available chlorine: for "clean" condition – 1.4 g per litre, and for "dirty" condition -14 g per litre
4. Sodium dichloroisocyanurate (NaDCC) powder containing 60 per cent available chlorine: for "clean" condition – 1.7 g per litre, and for "dirty" condition –17 g per litre.

5. Sodium hypochlorite-based tablets containing 1.5 g of available chlorine per tablet: for "clean condition – 1 tablet per litre, and for "dirty" condition – 4 tablets per litre.
6. Chloramine containing 25 per cent available chlorine: for "clean" condition – 20 g per litre, and for "dirty" condition – 20 or 40 g per litre. Chloramine releases chlorine slowly. The solution is *freshly* prepared every day, in non-metallic containers. Acids should not be used concomitantly since they displace chlorine gas.

Iodine Compounds

1. Tincture of Iodine (iodine 0.5 per cent + alcohol 70 per cent): for both "clean" and "dirty" conditions – 2.5 per cent.
2. Povidone iodine usually 10 per cent solution containing 1 per cent available iodine: for both "clean" and "dirty" conditions – 2.5 per cent. *Freshly* prepared dilution is to be used everyday. Povidone iodine should not be used on copper and aluminium.

Aldehydes

1. Glutaraldehyde (buffered): for both "clean" and "dirty" conditions – 2.0 per cent.
2. Formalin (40 per cent formaldehyde + 10 per cent methanol in water): for both "clean" and "dirty" conditions – 2.5 per cent.

Alcohols

1. Ethyl alcohol (ethanol): for both "clean" and "dirty" conditions – 70 per cent.
2. Isopropyl alcohol (isopropanol): for both "clean" and "dirty" conditions – 70 per cent.
3. Methylated spirit (also known as denatured or rectified spirit): for both "clean" and "dirty" conditions – 70 per cent.

Phenol Derivatives

1. Cresol: for "clean" conditions – 2.5 per cent, and for "dirty" conditions – 5.0 per cent.
2. Lysol (a saponified cresol): for both "clean" and "dirty" conditions – 2.5 per cent.
3. Chloroxylenols (4.8 per cent w/v is marketed as "Dettol"): for "clean" conditions – 4.0 per cent, and for "dirty" conditions – 10 per cent.
4. Chloroxylenols (4.8 per cent w/v) + EDTA: for "clean"conditions – 3.0 per cent, and for "dirty" conditions – 6.0 per cent.

Miscellaneous Disinfectants

1. Savlon (Cetrimide + Hibitane): for "clean" conditions – 5.0 per cent, and for "dirty" conditions – 10 per cent.
2. Ethylene oxide gas: 450–800 mg per litre is used for "clean" conditions. This compound is not recommended for use under "dirty" conditions.
3. Hydrogen peroxide (30 per cent stabilised solution): 6 per cent weight by volume (w/v) *freshly* prepared solution is used for "clean" conditions. This compound is not recommended for use under "dirty" conditions. H_2O_2 is stored in amber colour bottles in a cold place. It should not be used on copper, aluminium, brass, or zinc.

7.5 – BARRIER NURSING

Barrier nursing refers to use of physical or chemical barriers by all categories of hospital personnel and is not restricted to nursing staff. The objective of barrier nursing is to prevent the spread of pathogens through the intermediary of hospital staff. Health care providers with cuts, injuries, or infectious diseases should not be involved in patient care. While imparting mouth-to-mouth resuscitation, the risk of transmission of HIV is low. However, it is *safer* to use a barrier. Placing at least a gauze piece on the patient's mouth is to be advocated (Gangakhedkar, 1999).

Pre-requisites for barrier nursing are:

1. Induction and periodic in-service training to all staff in asepsis
2. Disinfection and periodic health check-up of personnel to rule out carrier state
3. Fully functional and efficient Central Sterile Supplies Department (CSSD)
4. Availability of stand-by autoclave
5. Availability of separate isolation ward or special infectious disease hospital. During epidemics, makeshift arrangement may be made in school buildings and community centres, or home isolations can be organised

The procedures for effective barrier nursing include: (a) repeated hand washing after attending to each patient, (b) concurrent and terminal disinfection, (c) using PPE, (d) establishing multidisciplinary HICC, (e) periodic supervision of disinfection, and (f) microbiological surveillance.

Barrier nursing is indicated in high-risk areas such as infectious disease wards and hospitals, neonatal wards, premature baby units, intensive care units, post-operative wards, and burns wards.

There are three types of barrier nursing techniques. In *cubicle nursing*, patients suffering from the same type of disease are kept in a cubicle and a separate set of PPE is kept for each cubicle. *Cohort nursing* is practised in premature baby and neonatal units. A group of babies born on the same day are cared for by a nurse. In *task nursing*, each nurse performs a given task such as giving tablets or making beds, and washes her hands after attending to each patient.

7.6 – UNIVERSAL BIOSAFETY PRECAUTIONS

Synonym: Universal work precautions. The basic principle is that blood and body fluids from *all patients* ought to be considered *potentially infected*, irrespective of their serological status. In health care facilities, hepatitis B is much more transmissible than HIV, while hepatitis C is considered to be of intermediate risk. However, HIV/AIDS has caused fear in the minds of lay persons and also health care personnel due to its: (a) association with sexual minorities, socially marginalised groups, and heterosexual promiscuity, (b) lack of preventive vaccine or curative therapy, and (c) fear of impending death if infected with HIV (Gangakhedkar, 1999).

The rapidly increasing prevalence rates of HIV infection in the general population increases the likelihood of occupational exposure to HIV. Transmission of HIV may be direct (contact with blood or body fluids) or through infected instruments. The major risk of transmission is through percutaneous exposure to infected blood or body fluids. Though infective doses of HIV are present in CSF, semen, blood, and cervico-vaginal secretions, HIV is present in different concentrations in almost all *body fluids* – amniotic, synovial, pleural, peritoneal, pericardial, sweat, faeces, nasal secretions, sputum, tears, urine, and breast milk of infected persons. Though CSF has the highest concentration of HIV, the likelihood of accidental occupational exposure to CSF is extremely low (CDC, 1988). The risk of transmission of HIV through exchange of fluids (other than sexual fluids and blood) tends to be extremely low or insignificant unless there is visible contamination with blood (Gandakhedkar, 1999). Lipophilic viruses such as HIV, HBV, and cytomegalovirus are *highly sensitive* to chemical disinfectants. In comparison, *Mycobacteria, Pseudomonas, Staphy-lococci*, spore-forming bacteria, fungi (*Candida, Cryptococci*), and hydrophilic viruses (polio virus, rhino virus) are not very susceptible to chemical disinfectants (Gangakhedkar, 1999).

7.6.1 – Controversies about Universal Precautions

It has been argued that universal precautions are too costly and time-consuming to be applied in case of *every* patient in *every* health care facility. The *suggested alternative* is to screen all patients for HIV antibodies before routine invasive procedures or surgery so that specific extra safety precautions can be taken. Extra safety precautions include selection of trained and experienced staff, restricting staff in the operating room to a bare minimum, and use of "surgical armour" for HIV-positive patients (2–3 pairs of gloves, impervious head gear, full-length waterproof apron, goggles, and rubber boots). Some surgeons are uncomfortable in such gear and feel their dexterity is compromised.

The pros and cons (Mitchell *et al*., 1997; Gangakhedkar, 1999) are given below.

Argument 1: Mandatory HIV screening will uncover previously undiagnosed HIV infection and special protective gear can be used for HIV-infected patients. From the community point of view, routine screening along with suitable counselling may limit HIV transmission by detecting more HIV-positive persons who would have otherwise remained undetected. Initiation of ARV therapy and follow up may prolong survival (Rhame & Mahi, 1988).

Counterpoint 1: Mandatory screening will not identify HIV-infected individuals during *window period* when there is *high viraemia*. A non-reactive HIV test during the window period may lead to complacency among staff and it is possible that procedures may be undertaken without adequate precautions. On the other hand, false positive results may lead to unnecessary panic among staff. It is possible that HIV-infected patients may be refused health care causing mental agony for the patient. Often, patients may require emergency surgery before

HIV test result becomes available. Mandatory screening for HIV will not protect against hepatitis B/C and other unknown blood-borne pathogens. Mandatory screening cannot replace universal precautions since most cases of accidental occupational transmission have occurred from patients with *known* HIV infection. A study of 1,307 consecutive surgical procedures at San Francisco General Hospital found that knowledge of patient's HIV sero-status did not decrease the risk of occupational exposure (Gerberding *et al.*, 1990).

Argument 2: Use of protective gear and disposables is expensive.
Counterpoint 2: Mandatory screening for all patients before surgery is more expensive than the cost of universal precautions. Universal precautions are meant to protect against exposure to a range of blood-borne pathogens, besides HIV.

Argument 3: Mandatory screening of patients before surgery is similar to mandatory screening of donated blood, organs, and tissues.
Counterpoint 3: Before HIV testing, it is obligatory to counsel the patient and obtain informed consent. In case some patients refuse HIV testing their treatment cannot be compromised. Mandatory screening of donated blood, organs, and tissues does not require the donor's consent. Mandatory screening of patients raises issues regarding human rights and confidentiality and may hamper doctor–patient relationship. These issues do not arise while screening donated blood, organs, and tissues. Screening cannot prevent patient-to-patient cross infection. Hence, universal precautions are necessary.

Argument 4: Using universal precautions in all procedures is time-consuming and will delay emergency procedures.
Counterpoint 4: In most countries including India, it is mandatory to impart pre-test counselling and obtain informed consent before blood is collected for HIV testing. These procedures are also time-consuming and will delay emergency procedures. Moreover, result of the HIV test is also not available immediately, or may be inconclusive. Practising universal precautions is less time-consuming than waiting for result of HIV test.

7.6.2 – Components of Universal Precautions

1. Hand washing
2. Careful handling and disposal of sharps
3. Safe decontamination of spills of blood and body fluids
4. Safe techniques and safe method of transporting biological material
5. Using single-use injection vials.
6. Decontaminating, pre-cleaning and sterilising or disinfecting all multiuse equipment before reuse
7. Disposal of disposable and reusable items/materials as appropriate
8. Compliance with hospital protocol and norms on sterilisation and disinfection
9. Using PPE and provision for their regular and adequate supplies
10. Covering wounds and weeping skin lesions with waterproof dressing

11. Immunising health care providers with hepatitis B vaccine
12. Segregation and safe disposal of biomedical waste
13. Periodic training of personnel to prevent occupational exposure
14. Establishing *needle-stick audit* and *spills audit* to prevent recurrence

7.6.3 – Organisms on Skin

Organisms present on the skin are categorised as:

(a) Resident Organisms: These survive and multiply in the superficial layers of the skin and include coagulase-negative *Staphylococci*, diphtheroids, and *Candida*;

(b) Transient Organisms: These pathogens are acquired from infected or colonised patients or from the hospital environment. They survive for a limited time period on the skin of health care providers. Examples include *Escherichia coli* and *Staphylococcus aureus*.

7.6.4 – Hand Washing

The transfer of microorganisms through the hands of health care providers is the most important mode of transmission of hospital-associated infections (Sathe & Sathe, 1991). Hand washing is the most important measure to prevent the spread of infections. There are *three* types of hand washing as described below.

Social Hand Washing: This involves the use of *plain soap* and *water*. Most of the transient organisms are removed from moderately soiled hands. This type of hand washing is indicated whenever hands are soiled, before handling food, before eating or feeding patients, after using the toilet, and *before* and *after* nursing procedures, such as bed-making. Surfaces of both hands are to be cleaned using plain soap and water. The cleaning of hands should be carried out for at least 10–15 seconds. Hands should be rinsed under a stream of running water and dried with a disposable paper towel. *In the absence of running water*, stored water from an elevated drum with a spout or tap may be used as running water. Alternatively, a clean bowl containing *pathogen-free wate*r may be used. The bowl is to be cleaned and water changed after each use. *In the absence of paper towel*, a clean cloth may be used for drying hands and this cloth is to be discarded in a laundry bag after each use.

Hygienic Hand Washing: In this method, hands are washed using *antiseptics*. Four per cent Chlorhexidine (Hibitane) or povidone-iodine containing 0.75 per cent available iodine diluted in water is used. Alternatively, 0.5 per cent Chlorhexidine (Hibitane) or povidone-iodine containing 0.75 per cent available iodine in 70 per cent isopropanol or 70 per cent ethanol is used. Other antiseptics are diluted as per manufacturer's guidelines. Hygienic hand washing is indicated in any situation where microbial contamination or contact with blood or body fluids of patients is likely to occur; *before* handling immunocompromised patients; and *before* and *after* using gloves. Hands are to be washed thoroughly

with the antiseptic, at least for 10–15 seconds. Subsequently, hands are rinsed and dried, as mentioned above. Alternatively, *alcohol hand wash* or *alcohol rub* is used, wherein the hands get automatically dry. Rinsing and drying of hands is not required. *Alcohol hand wash* solution contains 70 per cent methyl alcohol with 1 per cent glycerine (used as an emollient to prevent the skin-drying effect of alcohol).

Surgical Hand Washing: In this method, antiseptics are used for destroying transient organisms and decreasing the resident organisms. This method is indicated while carrying out invasive procedures to prevent wound contamination, when there is a risk of possible damage to gloves. During the washing procedure, it is *mandatory* to scrub hands, fingernails, and forearms (up to the elbows) at least *twice*. While washing, the hands are kept in an upright position with forearms flexed at the elbow. This ensures that water from the unwashed areas does *not* drip down to the washed (disinfected) areas. After washing, the tap is closed using the elbow. Alternatively, a foot-operated tap may be provided. The washed area is dried using a sterile towel or a disposable sterile paper towel. After drying, surgical gown and gloves are worn.

7.6.5 – Immunization against Hepatitis B

If the exposed person has not been previously vaccinated against hepatitis B, hepatitis B immunoglobulin in a dose of 0.06 mL per kg body weight is given intramuscularly. Additionally, complete primary course of hepatitis B vaccine is given. If the exposed person has previously received a complete course of hepatitis B vaccine, booster dose of the vaccine is given (NACO, Training Manual for Doctors).

7.6.6 – Preventing Needle Stick Injuries

Double gloves are to be worn (outer pair should be half size larger) during surgical procedures or where prolonged contact with blood or body fluids is likely. This prevents perforation of both the gloves at the same site and reduces risk of contact with blood or body fluids. Generally, needle stick injuries occur on the index finger and thumb of the non-dominant hand during procedures such as suturing. Injuries are usually caused by rash approach or lack of caution due to fatigue at the end of a surgical procedure. Exercising caution reduces risk of needle stick injury. Sharp instruments should *never* be handed over during a surgical procedure but should be placed on a tray so that the surgeon picks up the instrument by its blunt end. Needles should not be recapped after use. Used sharps (needles and other sharp instruments) are disposed off in a puncture-resistant container filled with freshly prepared 1 per cent hypochlorite solution. The needles should remain in the solution for at least half an hour. Used syringes are disposed of after heat-sealing their nozzles to prevent their reuse. Alternatively, used syringes are sent for incineration. Workers involved in disposal of sharps or infectious hospital waste must wear thick India rubber gloves that are reusable (Gangakhedkar, 1999).

7.6.7 – Transporting Biological Material

All body fluids and tissues from each and every patient should be considered potentially infectious, irrespective of the patient's HIV status. Body fluids and tissues should be sealed in a tightly closed inner container, which should be placed in a leak-proof transparent bag with a clearly visible "biohazard" label.

7.6.8 – Safe Decontamination of Spills of Blood and Body Fluids

All spills of blood or body fluids are potentially infectious. Health care personnel should adhere to the following procedure: (a) wear heavy duty India rubber gloves throughout the procedure, (b) cover the spill with absorbent material (paper napkin, thick blotting material, old newspaper), (c) pour *freshly prepared* hypochlorite solution containing 1 per cent available chlorine (10 gm per litre or 10,000 PPM) around the spill and over the absorbent material, (d) cover with absorbent material and place it in a waste container for contaminated waste, (e) wipe the surface again with disinfectant, (f) sweep the broken glass or fractured plastic containers, collect in a plastic scoop and dispose of in contaminated waste container, and (g) report all spills to hospital authorities. Hospital authorities should maintain a written record of all such incidents. After critical analysis they should issue recommendations to prevent recurrences.

7.6.9 – Handling Dead Bodies

Universal biosafety precautions are to be strictly followed while handling and cleaning the dead body and the trolley. HIV-positive cadaver is to be labelled on the right arm with a red patch, which is *suggestive* of HIV seropositivity, but maintains confidentiality. In order to maintain confidentiality, HIV status of the deceased should not be mentioned in the "Cause of Death" certificate. The secondary or opportunistic infection is to be mentioned as the cause of death. The details of the deceased are to be mentioned in a routine mortuary register. All natural orifices are plugged with cotton wool soaked in 1 per cent sodium hypochlorite, 2 per cent glutaraldehyde, or 10 per cent formalin to prevent spillage or seepage of body fluids from the cadaver. The body should be double-bagged in heavy plastic, irrespective of the HIV status of the deceased (Gangakhedkar, 1999).

If the deceased was known to be HIV-positive, the seropositive status of the deceased should be confided to the next of kin before handing over the body so that the relatives can take due precautions. The next of kin are to be advised that the body should be *preferably* be cremated. However, religious sentiments should be respected. After handing over the dead body to the next of kin, the following decontamination procedure must be adhered to, irrespective of the HIV status of the deceased: (a) first clean the trolley with soap and water, (b) *repeat* the cleaning process using 1 per cent sodium hypochlorite, 2 per cent glutaraldehyde, or 10 per cent formalin, (c) leave some of the disinfectant solu-

tion on the trolley for 1 hour, (d) subsequently, clean again with soap and water. Where possible, all materials that have been used in the diagnosis, nursing care, or treatment of the deceased should be incinerated.

Post-Mortem Examination: The number of persons in the autopsy room should be kept to a *minimum*. All persons should wear PPE (gown, impermeable apron, head cover, mask, gloves, and boots). All collected specimens (*except* specimens for culture or where fresh specimens are required) must be placed in 10 per cent formalin. After autopsy, the body should be double-bagged in heavy plastic, irrespective of the HIV status of the deceased. While handing over the body to relatives, they should be instructed not to disturb the plastic double bag before disposing of the body. If the deceased was known to be HIV-positive, the next of kin should be advised as mentioned above. After handing over the dead body to the next of kin, the decontamination procedure mentioned above is to be followed, irrespective of the HIV status of the deceased (Gangakhedkar, 1999).

Embalming: Strict adherence to universal precautions is essential while embalming. Body fluids and faecal matter are decontaminated using 0.5 per cent hypochlorite solution (Gangakhedkar, 1999).

Cadavers For Anatomical Dissection: All cadavers are injected intra-arterially with 10 per cent formalin before they are provided for anatomical dissection. HIV does not survive under these conditions. Experimentally, it has been shown that HIV gets inactivated within 48 hours even with one-tenth of this concentration of formalin (Gangakhedkar, 1999).

7.7 – PERSONAL PROTECTIVE EQUIPMENT (PPE)

PPE for blood-borne pathogens include – disposable solid front gowns (tied at the back) with cuffed sleeves, impermeable (waterproof) aprons, impervious head gear or head cover ("bouffant") with face mask, disposable gloves (surgical gloves and latex examination gloves with cuff), alcohol ("waterless") hand wash solution, absorbent laboratory mat, disposable bags with "biohazard" labels, rubber boots or shoe (foot) covers, and non-fog goggles or UVEX glasses (CDC, 2003a).

Face Masks: Health care personnel should discard face masks after 4–6 hours of use. Before performing procedures or surgeries where splashing of blood or body fluids is likely, it is better to wear safety hoods. Surgical masks are not splash-proof (CDC, 2003b).

Goggles (Eye Wear): Protective eye wear is to be worn before performing invasive procedures. Alcohol-based solutions are used to disinfect goggles prior to reuse. UVEX goggles may be worn with glasses (CDC, 2003a).

Latex Gloves: Latex is the milky, viscous sap of certain rubber-yielding trees that coagulates on exposure to air. Being a natural product, the availability of latex gloves is limited. Indiscriminate use of latex gloves would be wasteful. Heavy-duty

India rubber gloves should be used by workers involved in disposal of hospital waste. They should not wear latex gloves. The indications for using latex gloves are: (a) major surgical and invasive procedures, (b) procedures involving contact with blood (collecting blood by venepuncture, starting and removing intravenous lines, (c) procedures involving contact with body fluids (internal body examinations: per vaginal, per rectal, oral, dental), and (d) examination of infectious lesions – STIs and contagious infections of skin and mucosa.

Gloves should not be regarded as a substitute for hand washing. Hand washing is mandatory before sterile gloves are worn and after removing gloves. Gloves are not complete impermeable barriers because there is a risk of puncture or tear during surgery. Gloves should be changed after a procedure on a patient and even between two procedures on the same patient. If the gloves are torn during a procedure resulting in splash of blood or body fluids on the skin, the method for decontamination is as follows: (a) remove the torn gloves under *running* tap water, (b) wash hands thoroughly with soap and water for 2 minutes, (c) dip hands for 15 seconds in undiluted Savlon, and (d) wear a fresh pair of gloves before resuming the procedure (Gangakhedkar, 1999).

Gloves are sterilised by gamma radiation or autoclaving. Gamma-radiation sterilised disposable items should be used where possible. Ideally, surgical and examination gloves are to be used only once. While dealing with highly infectious diseases, gloves should never be washed or reused (CDC, 2003a). However, in resource-poor settings, reuse of gloves may be considered if not used in highly infectious situations. In such cases, gloves are to be reprocessed using the following procedure: (a) rinse gloved hands thoroughly in hypochlorite solution; then rinse gloved hands thoroughly under running tap water to remove residues of hypochlorite, which may cause deterioration of gloves; (b) wash gloved hands with soap or detergent and water; then rinse gloved hands thoroughly under running tap water to remove residues of soap or detergent, since these agents may enhance penetration of liquids through undetected holes in the gloves; (c) remove gloves and hang them up by their cuffs to dry; (d) wash hands thoroughly again with soap and water, (e) before reusing gloves, test for holes in the gloves by filling each glove with 325 mL water and 25 mL air at room temperature; twist them through 360° and place them in a rack for 2 minutes; detect leakage by visual and tactile means; and (f) dust gloves with French chalk powder or talcum powder before sending them for autoclaving (Gangakhedkar, 1999).

7.7.1 – General Guidelines for using PPE

Arrange all necessary equipment, material before starting the procedure. Wear and remove PPE in the order mentioned below. Decontaminate all used PPE, seal them in disposal bags and send for incineration. Do not reuse PPE.

Procedure for Wearing PPE: Wear shoe covers or rubber boots with trousers tucked inside. Wear face mask, head cover, and goggles. Rubber boots are preferable where the floor is likely to be wet or heavily contaminated. After surgical hand

wash, wear impermeable (waterproof) apron. Wear gloves with gown-sleeve cuff tucked into the glove.

Procedure for Removing PPE: Wash gloved hands in hand-wash solution (containing more than 60 per cent alcohol) such as Sterillium. Using gloved hands, remove boots and place in receptacle containing 1 per cent bleach. Using gloved hands, remove the waterproof apron, gown, and shoe covers, without contaminating the clothing underneath. Touch only the outside of apron, gown, and shoe covers. Place the waterproof apron, gown, and shoe covers in a disposal bag with "biohazard" label. Remove outer gloves in such a way that fingers are under the cuff of the second glove. This will avoid contact between the skin and the outside of the inner glove. Wash hands in hand-wash solution (mentioned above). Remove goggles and place in receptacle for cleaning with alcohol-based disinfectant. The person cleaning the goggles should use the same PPE procedures. Remove head cover and mask. Place it in a disposal bag with "biohazard" label. Wash hands thoroughly up to elbow in hand-wash solution (mentioned above). Then, wash hands up to elbow, thoroughly with soapy water. Change into street clothing and wash hands once again in soapy water.

7.8 – MANAGEMENT OF BIOMEDICAL WASTE

In 1998, the Indian Government notified that all establishments (hospitals, nursing homes, animal houses, blood banks, research institutions) that generate biomedical waste should get registered and should install a suitable biomedical waste treatment or disposal facility in their premises, or set up a common facility. As per the government notification, biomedical waste is any waste, which is generated during the diagnosis, treatment, or immunisation of human beings or animals or in research activities pertaining thereto or in the production or testing of biological products, and other products mentioned in Schedule-I of the Biomedical Waste (Management and Handling) Rules, 1998 (MOEF, 1998).

7.8.1 – Salient Features of the Rules

Segregation of Waste: All waste must be segregated into the containers/bags at the point of generation itself and properly labelled as provided in the rules. The biomedical waste shall not be mixed with other waste.

Transportation of Waste: Requisite information such as "category of waste", sender's name and address, receiver's name and address, shall be provided while transporting the waste.

Storage and Disposal of Waste: The waste must be disposed of within a period of 48 hours and in case of storage beyond this period, specific permission of the prescribed authority shall be obtained. An annual report shall be submitted by 31 January every year to the prescribed authority in the prescribed format.

Record Keeping: Records shall be maintained pertaining to the generation, collection, reception, storage, transportation, treatment, disposal and/or any other form of handling of biomedical waste. The records should be kept ready for inspection any time. Any accident involving biomedical waste should be reported to the prescribed authority.

Local Authorities: Municipal Corporations and Councils have been made responsible for providing suitable site for common disposal or incineration in the area under their jurisdiction and taking an initiative for providing common waste treatment facility (CWTF) so that the biomedical waste generated in various institutions can be handled, treated, and disposed of in a scientific manner. Municipal Corporations and Councils must continue lifting non-biomedical waste, as well as treated biomedical waste for disposal in dumping grounds.

7.8.2 – Segregation at Point of Generation

Different types of waste are collected in category-specific colour-coded containers or bags at the site of generation of waste (Table 1). At this stage, wastes are segregated into different streams. Incorrect classification of wastes at this stage may create many problems later. If the infectious waste (which forms a small part of total hospital waste) is mixed with other non-infectious hospital waste, the entire waste will need to be treated as "infectious" waste (an expensive option). Otherwise, the entire hospital waste would have the potential to cause infection during handling and disposal. Segregation helps in reducing the bulk of waste, preventing the spread of infection to general waste, and reducing treatment cost and overall cost of waste handling and disposal in health care settings.

7.8.3 – Safe Storage and Transport

The category-specific colour codes for the containers or bags have been notified by the Government of India (Table 1). The bags are tied tightly after they are three-fourths full. Waste should *not* be stored at the place of generation for more than 2 days. Date of collection and other details of biomedical waste should be clearly mentioned on *red labels*.

The biomedical waste containers should be provided with a well fitting lid; protected from insects, birds, animals, and rain; and should *not* be accessible to rag pickers and scavengers. All waste should be transported *without spillage* in vehicles specifically authorised for this purpose.

7.9 – INFECTION CONTROL CHECKLIST

This checklist contains six indicators and may be used to assess the status of infection control measures in health care settings.

Table 1. Specifications for waste containers and disposal options (MOEF, 1998)

Container and colour code	Category of waste	Disposal options
Yellow plastic bags	Category 1: Human anatomical wastes (organs, tissues, blood, and body fluids) Category 2: Animal/slaughter house waste Category 3: Microbiology and biotechnology waste Category 6: Soiled wastes (linen, bedding, dressing contaminated with body fluids)	Incineration or deep burial
Red disinfected container or red plastic bag	Category 3: Microbiology and biotechnology waste Category 6: Soiled wastes (linen, bedding, dressing contaminated with body fluids) Category 7: Disposable items (other than sharps)	Autoclaving, microwaving, or chemical treatment
Blue or white transparent plastic bag or puncture-proof container	Category 4: Waste sharps (that can cause cuts and punctures) Category 7: Disposable items (other than sharps)	Autoclaving or microwaving or chemical treatment destruction and shredding
Black plastic bag	Category 5: Discarded and cytotoxic drugs Category 8: Incineration ash Category 9: Chemical wastes (solids)*	Chemical treatment followed by disposal in secured land fills

* For chemical wastes (liquids), chemical treatment is followed by discharge into drains.

Hand Washing:

- Soap, adequate quantity of clean water, and clean towels available (observed)
- Washing of hands and drying done every time after contact with body fluid, removal of gloves, or contact with patient (observed)
- Observe hand washing technique (whether correct?)

Use of PPE:

Disposable gloves, face masks, head gear, protective eye wear, plastic (water-proof) apron, foot or shoe covers or rubber boots (observed)

Waste Disposal:

- Evidence of segregation and safe storage of waste
- Correct colour coding of waste containers
- Whether waste treatment is done on premises or waste is sent to common waste treatment facility

Instruments:
- Whether steriliser is in working condition
- Whether instruments are cleaned thoroughly after use
- Whether clean instruments are stored in cupboards

Prevention of Accidental Occupational Injuries:
- Correct puncture-proof container for waste sharp
- Container less than three-quarters full at the time of observation
- Whether sharps are protruding from the container
- Observe recapping of needle and syringe
- Whether hospital staff members know whom to report incidents of accidental injuries

Infection Monitoring Mechanisms:

- Evidence of microbiological monitoring of operation theatres, wards, and labour room
- Whether disinfectants or antiseptics are periodically assessed for efficacy on locally existing organisms
- Whether written documentation of SOP exists for disinfecting or sterilising each item
- Whether all concerned staff are aware of such a document

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