The use of disinfectants in medical and health related Institutions: An Overview

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Abstract

The effective use of disinfectants in health institutions constitute a significant factor in the prevention of health care associated infections. In developing countries lack of appropriate physical resources contribute to the inability to apply effective control of these infections. Increasingly, disinfectants are being marketed both in developed and developing countries. Considering the limitations encountered during physical sterilization procedures in Nigeria, it is necessary for health care workers to have an in-depth knowledge of disinfectants. This overview summarizes the type of disinfectants commonly available, their antimicrobial activities, categories, mode of action, and their application in health care institutions.

Key words : Disinfectants, health care associated infections, antimicrobial activity.

Introduction

Disinfectants complement sterilization and both are indispensable in medical practice. Although sterilization is the ultimate in the attempt to control health care associated infections yet disinfection has proved to be the saving grace in many situations where sterilization has not been practical. The effective use of disinfectants constitute a significant factor in the prevention of health care associated infections[1], especially those which would otherwise be transmitted through direct and indirect contacts with working surfaces[1]. Studies have demonstrated that hepatitis B virus (HBV) can survive in the dry environment on inanimate surfaces for ten days[1]. In some other studies, some laboratory surfaces, dental surgery surfaces, heamodialysis units and others, where there is frequent contamination with blood, tissue fluid or tissue, demonstrated the presence of hepatitis B surface antigen (HBAG), even in the absence of visible blood or chemically detectable blood[2]. This explains instances of disease transmission in the absence of overt percutaneous or mucous membrane exposures[3]. Hence disinfection of surfaces, equipment and materials in contact with patients either directly or indirectly is imperative in clinical practice.

With the evolution of medical practice, various equipment and instruments, for example endoscopes, some dental hand pieces, have been manufactured, which are increasingly complicated and expensive and some of them are not compatible with various sterilization procedures[4]. The minimum treatment recommended for such instruments for which sterilization procedures are not feasible is high level disinfection[4].

In developing countries, lack of appropriate physical resources and human resource constraints contribute greatly to the inability to apply effective cross-infection control procedures[5]. In Nigeria in particular, lack of constant supply of electricity means that procedures involving the application of moist heat and dry heat are hampered. The cost of appropriate and efficient sterilizing equipment is another set back in the fight against health care associated infections in this country. In addition the lack of running water has serious implications for the control of infection in the health care institutions. Seemingly, few hospitals in this environment are built with specifications for disposal of liquid and solid medical waste. Thus infection of people, who are not directly involved in medical care of patients, and who may come in contact with these waste products is imminent.

Among health care associated infections, Hepatitis B as well as Human Immunodeficiency Virus (HIV) infections have attracted much attention. With the new trend of HIV infection in Nigeria, with prevalence variation of 2% in Ekiti and Oyo states in the South West zone, and 10% in Benue state in North Central zone as well as the prevalence of hepatitis B as high as 10% to 20 % in Sub-Sahara Africa, it is imperative that control of health care associated infections be taken seriously in all health care institutions. This paper is presented to provide an overview of disinfectants for health care institution workers and how they can be used to full advantage in such challenging situations as we have in our environment.

Definition

A disinfectant is defined by the Oxford Dictionary as a substance which cleans by destroying bacteria that causes disease. In the light of prevention of health care associated infections, a disinfectant is better defined as a substance used for procedures that destroy all recognised pathogenic micro-organisms but not necessarily all microbial forms

(e.g. Bacteria spores) on inanimate objects[8].

Types of disinfectant

Disinfectants are grouped into physical and chemical disinfectants[9]. Table 1 illustrates different types of disinfectants commonly available in Nigeria.

Physical disinfectants

Several physical processes such as moist heat, dry heat and ionizing radiation generally can be depended upon to kill all types of microorganisms including bacterial spores and will therefore effect sterilization[9]. However moist heat below or equal to 100°c at ambient pressure can not destroy bacterial spores and some viruses such as hepatitis B virus and rather has a disinfecting action[9]. Ultraviolet (UV) radiation can kill spores but can not penetrate. It is therefore regarded as a surface sterilizer only and thus effects disinfection rather than sterilization[9].

Chemical disinfectants

Chemical disinfectants, like other germicides commonly used in medical and health related institutions, are either derivatives or compounds of chlorine, iodine, bromine, aldehydes, peroxygen, alcohol, phenol, quarternary ammonium compounds, chlorhexidine and a few others[9] (Table 1).

Antimicrobial activity of disinfectants and factors that affect this activity.

Chlorine Products

Chlorine products include commonly used disinfectants such as Alcide, Chlorosol, Milton and others. They are broad spectrum disinfectants; often used in concentrations of 500ppm-5000ppm and are active at ambient temperature[10]. They are not inactivated by the presence of organic material such as blood, tissue, tissue fluids, nor saliva[10]. They are most active at acidic pH. Halogens potentiate their antimicrobial activity. They are considered as intermediate-level disinfectants for specific site disinfection and their effectiveness is due to the release of free chlorine which acts on the microorganism[10]. They are fungicidal, tuberculocidal, virucidal, could be sporicidal depending on the concentration[10] and they have the disadvantage of being corrosive and irritant[10].

Iodine Products

Iodophors, Povidone iodine, lugal solution, to mention a few in this group, are broad spectrum disinfectants which are active within a concentration of 2.5-524ppm, at 25°C and an increase in temperature increases their antimicrobial effect[11]. Their antimicrobial activity depends on the amount of free iodine released[11]. They are not active against *Pseudomonas aeruginosa* and they are not inactivated by organic material and they are active within the pH range of 3-9. Iodine ions potentiate their antimicrobial activity[11]. They have a residual effect, depending on their concentration and are grouped under low-level or intermediate level disinfectants. They are non-corrosive.

Aldehyde Products

Glutaraldehyde and Cidex are a few of the commonly used disinfectants which fall into this group. They are broad spectrum disinfectants and are commonly used in concentration of 2% [12]. They are not inactivated by organic materials such as tissue fluid, blood, saliva and tissues. They are most active in alkaline pH [12]. They are therefore not stable and have a shelf life of 14days after mixing. Aldehyde products, more particularly gluteraldehyde have been classified as high-level disinfectants, capable of producing sterility if the exposure time is long enough [12]. They are highly volatile and toxic and some clinics have recorded hazardous effect on clinic staff when used in very high concentrations[12]. Gluteraldehyde does not have a deleterious effect on lensed instruments and it is highly recommended for disinfection of endoscopes.

Chlorhexidine Products

They are broad spectrum disinfectants, active mainly against vegetative gram positive and gram negative bacteria [13]. They are cationic bisbiguanide products, active within a concentration range of 100-500 ppm, at ambient temperature and an increase in temperature beyond a certain range precipitates them[13]. They are inactivated by organic materials such as blood, saliva, tissue fluid and tissues [13]. They are pH dependent and inorganic anionic compounds such as detergents inactivate them[13]. They have a shelf life of one year and they have residual effect. Chlorhexidine has limited sporicidal activity[14]. However, they are effective on viruses with an outer envelope e.g. herpes, cytomegalovirus and 0.05% chlorhexidine was 100% effective against H.I.V type I in one minute [15]. They are often used for non-critical and certain types of semi-critical instruments and these items must be totally submerged in the disinfectant [14]. They are detrimental to rubber and plastic materials and are irritant to the skin and mucus membrane[14].

Alcohol Products

They are intermediate level disinfectants and excellent mycobacteriocidal agents [16]. They are most active within a concentration range of 50% - 95% and at a temperature of 25°C [16]. They are not sporicidal and their activity against viruses is limited to lipid containing viruses[16]. Their antimicrobial activity is reduced by organic material. The germicidal effect of alcohol is potentiated when other agents such as Iodine, Formaldehyde and Chlorhexidine are added[16]. Cleaning of bronchoscopes with 70% alcohol and periodic ethylene gas sterilization was found to be inadequate and responsible for an outbreak of pulmonary infection due to *Serratia marcesceus* [17]. Alcohols are damaging to some rubber and plastic materials and cannot be used for lensed instruments containing shellac mountings[16].

Phenol Products

They are considered to be intermediate to low level disinfectants and they are used principally for disinfecting a variety of environmental surfaces such as glassware, linens, wash bowls, toilets, furniture and floor and for non-critical instruments or devices. They are tuberculocidal and are more effective against gram positive bacteria than on gram negative bacteria [16]. They are active within a concentration range of 400-1,300ppm, a wide range of pH and are not inactivated by soap or organic compounds. Their activity is potentiated by halogens and they are toxic

and detrimental to rubber and plastic products [16].

Quaternary Ammonium Compounds

Cetylpyridinium chloride is a commonly used example of this group. They are classed as low-level disinfectants [18]. They are broad spectrum and are most active against gram(positive) organisms [18]. They are not tuberculocidal when used alone and are in fact used in the laboratory to isolate tubercle bacilli from clinical materials [19]. They are poorly active against viruses [18]. They are active within the concentration range of 1ppm to 10ppm aqueous solution, at ambient temperature. An increase in temperature increases their activity and they are not pH dependent [18]. They are inactivated by organic materials such as blood, tissue fluid, tissue and saliva and also detergents reduce their anti-microbial activity.

Peroxygen Compounds

Peracetic acid and hydrogen peroxide are examples of peroxygen compounds commonly used in this environment. They are broad spectrum disinfectants and are highly active against anaerobic organisms[20]. They are sporicidal, bactericidal and virucidal. They are active within an aqueous concentration range of 3%-90% at ambient temperature. An increase in temperature increases their activity, although beyond a certain range of temperature, peroxygen compounds are destroyed[20]. They are not pH dependent, however they are more active in acidic medium[18]. Peroxygen compounds are generally unstable and to maintain stability, they are kept free of dust and other contaminants, in special containers[18]. They are not inactivated by organic materials such as blood and tissue fluid[18]. Iron, Copper, chromium, alcohol, manganese and cobalt salts potentiate their antimicrobial activity [19]. Some products such as peracetic acid in high concentrations could cause rusting[20].

Mode of action of disinfectants

Having discussed the effectiveness of disinfectants, it is appropriate that we should know their mode of action. Just like other antimicrobial agents, their destructive action is directed at various components of the cell [21] (Table 2).

Table 1: Commonly marketed chemical disinfectants

Chlorine Products	Chloryte, Darkins Solution, Liquid bleach, Chlorax, Chlorinated T.S.P (Trisodium Phosphate)
Aldehyde Products	Glutaraldehyde, Cidex, Gigasept Formaldehyde.
Chlohexidine Products	Hibitane, Savlon, Hexachlorphane, Parachlorometaxylanol
Iodine Products	Iodophors, Povidone-Iodine, Biocide Betadine, Lugal Solution, Iodine Topical Solution, Strong Iodine Tincture.
Alcohol Products	Isopropyl alcohol, methanol, Phenylethyl alcohol, benzylalcohol
Peroxygen Compound Products	Hydrogen peroxide, vapour phase hydrogen peroxide, paracetic acid, permanganate
Phenol Products	Triclosan, Irgasan, Detol, Santophen, Stericol Jeyes fluid
Quaternary Ammonium Compound Products	Cetavlon, Centrimide, Roccal, Savlon, Cepacol, Benzalkonium chloride

Table 2 Mode of action of disinfectants

Target	Mode of Action
Cell Wall :	- Inhibition of cell wall synthesis, attack peptidoglycan (B1-4 links) - Librate N. terminal glycine and alanine - Lysis
Outer Membrane :	- Chelation of cations e.g. Mg++ and Ca++ - Release of 50% of lipopoly saccharide of outer membrane - Iron binding proteins - Displace cations
Cytoplasmic Membrane:	- Leakage of low molecular weight materials - Binding to sterols
Protein Synthesis :	- Affects protein synthesis in various ways
Nucleic Acid :	- Binding of agents to nucleic acid
Enzymes Or Proteins :	- Combine with DNA or RNA - Sulphydryl groups of enzymes which may be membrane associated.

Categorization of disinfectants

Spaulding categorised disinfectants into high level, intermediate level and low level, based on the resistance of certain selected micro-organisms to them. Selected micro-organisms used according to descending order of resistance are Bacterial spores (*Bacillus subtilis* and *clostridium sporegenes, mycobacterium tuberculosis var bovis*). Nonlipid or small viruses (Poliovirus, Coxsackie virus, rhinovirus), fungi (*Trichophyton spp, Cryptoccoccus spp, Candida spp*), vegetative bacteria (e.g. *Pseudomonas aeruginosa, Staphylococcus aureus, Salmonella choleraesuis*), lipid or medium sized viruses (e.g *Hepatitis B Virus, Human Immunodeficiency Virus, Cytomegalovirus, Herpes Simplex Virus, Respiratory Syncytial Virus*)[22].

Disinfectants classified as having high level action exhibit a killing action on spores, bacterial tubercle bacillus, vegetative cells, fungi, non-lipid and small size virus and lipid and medium size virus[22].

Disinfectants classified as having intermediate level action exhibit a killing effect on all the stated types of microorganisms except spores although a few like hypochlorites exhibit some sporicidal activity[22].

Low-level disinfectants although effective against some fungi, vegetative cells and some viruses, they are not tuberculocidal nor sporicidal[22].

The effect of disinfectants on the above micro-organisms constitutes the test for potency of many disinfectants, before their approval by United States Environmental Protection Agency (EPA) and Food and Drug Administration Agency (FDA), and their introduction into the market[22]. The test often used is the tuberculocidal test[22].

Medical and health related application of disinfectants.

Successful use of disinfectants depends on a number of factors which should be considered before making a

Table 3 Categories of medical and surgical material

Material	Properties
Category 1	
Critical Instrument :	- Introduced directly into human body or contact - blood stream - High risk of transmitting infection. Examples: cardiac catheter, forceps, blades
Category 2	
Semi Critical Instruments :	- Contact with mucus membrane, do not penetrate body Surfaces. Examples: Flexible fiber optic endoscopes, endotracheal tubes, aspirator tubes.
Category 3	
Noncritical Instruments :	- Contact unbroken skin, examples Face masks, blood pressure cuffs, neuralgic or cardiac diagnostic Electrodes.

selection from disinfection procedures[2]. These include, the degree of microbial killing required, the nature of the item or surface to be treated, amount of organic soil present, time item is in contact with disinfectant, temperature of exposure, pH, hardness of water, cost, safety and ease of use[2].

Based on the risk of transferring infection, Spaulding E.H. categorized medical and surgical materials/instruments into critical, semi-critical, non-critical instruments[12] and environmental surfaces[22]. Table 3.

Disinfection procedures recommended for each category of medical and surgical materials and instruments.

All critical instruments must be sterilized using any of the sterilization procedures[22]. Semi-critical instruments or materials, although sterilization is desirable, it is not obsolutely essential. They should be meticulously cleaned, and an appropriate high-level disinfection procedure can be used. Non-critical instruments can be washed with detergents and warm water and in addition, it is recommended that they are disinfected with an intermediate level disinfectants. Environmental surfaces such as medical equipment surfaces could be cleaned with detergent and warm water followed by disinfection with an intermediate level disinfectant. House keeping surfaces can be maintained at an adequate safety level by just using Hospital grade disinfectant detergent. In areas of spillage such as surgeries and theatres intermediate level chemical disinfectants such as chlorine products should in addition be used[22]

Contact time of disinfectants

Disinfection of instruments and surfaces should be more than 15minutes. And up to 60minutes[23]. Longtime disinfection disinfectants used, contain mostly aldehydes, oxygen releasing agents, halogen containing compounds, phenolic derivatives. Germicides for short time disinfection contain mostly alcohol and organic iodine compounds[23]. If sterilization is the objective of a treatment then contact time of 6 to 10 hours is required. Flexible fiber optic endoscope can not be subjected routinely to long contact time in liquid germicide without risking the degradation of the lenses[22]. The effectiveness of a chemical disinfectant in relation to its contact time depends on its concentration[23]. There is a minimum threshold concentration of a chemical disinfectant which may have no killing effect on a microbial population, no matter how long the contact time[23].

Re-use or in use life of disinfectants

Another vital information is the reuse life of a disinfectant after dilution to the required concentration. Some disinfectants such as the chlorine dioxide products can not be reused, whilst others such as some glutaraldehyde products list an inuse life of 14-30 days depending on the product and whether it is diluted or not[23]. Definitely with each reuse the potency of a disinfectant reduces, and the contact time then increases. Also depending on which organism is being treated, a fresh solution of the disinfectant may be needed. For example, for tuberculocidal effect, gluteraldehyde will need to be freshly mixed[23].

Conclusions

It is clear that the actual effectiveness of a chemical disinfectant is influenced not only by the nature of the active agent but also by the way it is used in the hospital setting. In view of the economic situation in many developing countries such as African countries, the lack of basic amenities, coupled with the rising prevalence of HIV and Hepatitis B infections, disinfectants hold much promise for health institutions in the fight against health care associated infections.

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