INFECTION CONTROL IN ISOLATION UNITS/HDUs/ICUs- A COMPARATIVE STUDY USING THREE DIFFERENT DISINFECTANTS WITH FOGGER FOR ENVIRONMENTAL DECONTAMINATION

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ABSTRACT

BACKGROUND

Intensive care units (ICUs), High dependency units (HDUs) and Isolation units or wards carry high risk of nosocomial infection, morbidity, mortality and health care cost. To limit the nosocomial infection, health care providers should adopt aggressive and effective infection control measures. The importance of disinfection is frequently acknowledged but previous data indicated little distinction between manual and automated area decontamination. WHO has updated guidelines on infection control from time to time.

MATERIALS AND METHODS

Various studies recommended automated fogging system for environmental decontamination and with this perspective we conducted our study using fogger with three different disinfectants namely 1) H₂O₂ silver solution; 2) Octyldecyldimethylammonium chloride, Dioctyldimethylammonium chloride, Didecyldimethylammonium chloride, Alkyldimethylbenzylammonium chloride; 3) N-Alkyldimethylbenzylammonium chloride, Didecyldimethylammonium chloride, Polymeric biguanide hydrochloride. During the study, rooms of isolation wards, high definition units and intensive care units were fogged separately with all the three disinfectants along with high end cleaning of all the surfaces. The swab samples were taken from various sites like wall, bed, floor and air.

RESULTS

The results of growth then obtained were compared and analysed. The causes of bacterial and fungal growth even after fogging were analysed and enumerated. The control measures were adopted to reduce bacterial and fungal growth to nil.

CONCLUSION

Infection control policy and guidelines were prepared and distributed to concerned departments for implementation and to check cross infection at various vulnerable points.

KEYWORDS

Intensive Care Unit, High Dependency Unit, Isolation Wards, Disinfectants, Hand Associated Infections.

HOW TO CITE THIS ARTICLE: Singh H, Kumar R, Singh K, et al. Infection control in isolation units/HDUs/ICUs- A comparative study using three different disinfectants with fogger for environmental decontamination. J. Evolution Med. Dent. Sci. 2017;6(38): 3091-3096, DOI: 10.14260/Jemds/2017/667

BACKGROUND

Infection control is an application of scientific and epidemiological principles for prevention and reduction of infection. Today as many as 1 in 20 or a total of 1.7 million hospitalised patients annually develop HAI in US hospitals with approximately 5% mortality. There are very less studies in India regarding epidemiology of infections in ICUs, HDUs and isolation surgical wards, medical wards and burn units. Environmental disinfection is one way to minimise the results of hospital-acquired infections. The vast majority of surface disinfection in hospitals over the past centuries has been attempted by using the process widely known as "spray

and wipe", which even on high touch surfaces will not reduce HAIs in significant way. Traditional manual cleaning and disinfection practices in hospitals are often suboptimal, this often imparts to a variety of personnel issues that environmental services department may encounter. Failure to follow manufacturer's recommendations for disinfectants use and lack of antimicrobial activity of some disinfectants against health care associated pathogens may also affect the efficacy of disinfectant practices.

Hand washing, aseptic techniques and environmental cleaning are the most important infection control measures. Infection control programs have become a requirement for hospital accreditation by the joint commission on accreditation of health care organisation.¹ The hospital should have infection control committee including an infection control practitioner (Physician), trained ICU epidemiologist and microbiologist with aim to develop infection control policies in hospital. Infection control practices are key components of all invasive medical procedures because undiagnosed infection is common.²

Studies by Ignaz Semmelweis in 1847 in Vienna and Oliver Wendell Holmes in 1843 in Boston established a link between the hands of health care workers and the spread of

Financial or Other, Competing Interest: None.

Submission 18-03-2017, Peer Review 01-05-2017,

Acceptance 06-05-2017, Published 11-05-2017.

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DOI: 10.14260/Jemds/2017/667

hospital-acquired disease.³ The US centres for disease control and prevention state that hand washing is most important measure for preventing spread of pathogens. In November 2008, a non-peer-reviewed study was presented to European tissue Symposium by the University of Westminster, London, comparing the bacterial levels present after the use of paper towels, warm air dryers and modern jet air and dryers.⁴ In the United States, OSHA⁵ standard recommended easy accessibility of hand washing facilities to all employees. In response to the realisation of the magnitude of the problem, various agencies including federal and state government, and professional societies both nationally and internationally, have recommended measures aimed at reducing the occurrence of nosocomial infections. Centre for Infection Control and Epidemiology guidelines for hand hygiene in health care settings had made recommendations for infection control practices.¹

The World Health Organization (WHO) together with CDC set prevention of nosocomial infections on priority by developing a practical guide (Manual) for the prevention of nosocomial infection globally. The manual described strategies like hand decontamination, personal hygiene, utilisation of masks and gloves and linen handling techniques where health care workers perform patient care activities. However, despite the development of policies and recommendations, the incidence of nosocomial infections and their impact on health care costs, morbidity and mortality remains unabated.⁶

In a developing country like India, there is little awareness among the health care workers about infection control practices. Purpose of this study was therefore to develop the disinfection and sterilisation policy in critical areas like ICU, HDU and isolation wards. In recent years, there is an increasing consensus that improved cleaning and disinfection of environmental surfaces are needed in health care facilities. Experts generally agree on a number of areas, including the fact that careful cleaning and/or disinfection of environmental surfaces daily and at the time of patient discharge are essential elements of effective infection prevention program. Moreover when disinfectants are used, they must be used appropriately to achieve the desired effects. The purpose of this study was to summarise the many factors that affect standard cleaning and disinfection practices and to discuss modern technologies that can supplement traditional cleaning and disinfection methods. There is no known accepted procedure for monitoring hospital areas or personnel for microbial contamination.⁷ Although there is no known method for demonstrating a causal relationship between the persistence of pathogens and infection of new patients or personnel, it is generally conceded by many hospital personnel that persistence of airborne organism may be an important means of spreading infection throughout hospitals and among hospital staff.⁸ Thus, it is felt by some that a decrease in detectable pathogens in a hospital environment should be a major goal for disinfection procedures. Use of effective air disinfection procedures also thought to be of value in protecting housekeeping personnel, who are exposed to airborne infections in rooms prior to and during the housekeeping procedure.⁹

Epidemiology of Nosocomial Infections in ICUs/HDUs/Isolation Wards

The most common transient bacteria in ICUs are the *Staphylococcus aureus*, *Escherichia coli*, Beta-haemolytic Streptococci, *Serratia marcescens*, *Klebsiella pneumoniae*, *Pseudomonas aeruginosa*, *Enterobacter* species, *Candida albicans* and *Clostridium difficile*. The sources of infection can be categorised as environmental source or patient related sources. Environmental sources are air, water, architecture and patient related sources are illness, immune status, age, duration of hospital stay, surgery, invasive procedures, surgical equipment and antibiotic resistance.¹⁰ The factors responsible for increasing HAI among ICU patients are high burden of pathogen population, vulnerability and compromised immunity of patients, poor hand hygiene, ineffective cleaning process, use of broad spectrum antibiotics, increasing variety of surgical procedures and invasive techniques, etc.¹¹ The major HAIs include catheter associated urinary tract infections (CAUTI 40%), Ventilator associated pneumonias (25%), Central line related blood stream infection (CRBSI, 10%) and Surgical site infection (SSI).

Transmission

Droplets and droplet nuclei of microorganisms transmitted in air, cause infection in patients by direct or indirect contact like contamination of equipment or devices.¹² Airborne transmission poses severe risk of HAIs by directly person-to-person or indirectly by environmental surfaces.¹³ A healthcare worker's hands play a key role in contact-spread transmission,¹⁴ and it is well established that hand washing and hygiene is the single most important measure to prevent the spread of pathogens in hospital.¹ The microorganisms transmitted by direct contact are mainly bacteria, such as MRSA, VRE, and *C. difficile*.

The emerging trends of Nosocomial Infections in ICUs/HDUs/Isolation Wards

The major factor involved in nosocomial infections is long-term antimicrobial use in ICUs. Widespread use of cephalosporins is often associated with Vancomycin-Resistant Enterococci (VRE) and Methicillin-resistant *S. aureus* (MRSA). Widespread empiric use of vancomycin in response to concerns about MRSA and for treatment of vascular catheter associated infection by resistant Coagulase-negative *Staphylococcus* is the major initial selective pressure for VRE. High use of antimicrobial drugs in long-term care facilities and hospitals have created a large reservoir of resistant strains in nursing homes.¹⁵

Predisposing Factors

Critically ill patients in the ICU are more likely to have invasive catheters/devices or undergo surgical treatment that disrupts the skin barrier.¹⁶ Burn victims also develop HAIs as a result of the physical barrier disruption. The ability to clear infections may further be reduced by underlying chronic diseases (i.e. diabetes mellitus, congestive heart failure, renal failure, liver failure, malnourishment, alcoholism, chronic obstructive pulmonary disease), thus increasing the risk of HAI.¹⁷ Other significant factors include urinary catheter >10 days, ICU confinement >3 days, presence of intracranial pressure monitors, arterial line,

central venous catheter and shock.¹⁸ Inadequate staff not only diminishes basic hygienic practices but also will be source of infection.

The battle against pathogenic infections includes the sterilisation of instruments, appropriate use of antibiotics and categorisation of hand sanitisers and environmental disinfectants. About 150 years ago, studies in Vienna by Dr. Ignaz Semmelweis and in Boston by Dr. Oliver Wendell Holmes established that hospital-acquired diseases were often transmitted via the hands of doctors and nurses. Since that time, much has been written and done to try the prevention of transmission of pathogens by staff to patients. New technologies were developed to disinfect the environment in US like use of UV rays, but effectiveness remains low of this technique due to low penetrations particularly overshadowed and covered areas.¹⁹ To date a number of studies have demonstrated the efficacy of hydrogen peroxide against a range of healthcare-associated pathogens including methicillin-resistant *S. aureus* (MRSA), *E. coli*, *P. aeruginosa*, *Clostridium difficile* and vancomycin-resistant enterococcus (VRE).²⁰ This is a relatively new and fully regulated technology available for ICU sterilisation by forming either H₂O₂ vapour or an aerosol fog with 99% kill rate.²¹

Other disinfectants include hydrogen peroxide and silver solution, quaternary ammonium compounds especially 5th generation with same killing rate. Hospitals in developing countries lack clear accountability and budget for reducing HAIs. Hence, there are legitimate challenges in using the new technologies. Most of the sterilisation technologies require long time of sterilisation which is not possible due to increase in number of patients in ICUs/HDUs/Isolation rooms.

Objectives of the Study

1. To evaluate three different disinfectants for disinfection of high risk areas in hospital by fogging system.
2. Isolation and identification of various organisms present in the environment of high risk areas.
3. To access the BCP (bacteria carrying particle) load by settle plate method in high risk areas.

MATERIALS AND METHODS

The study was conducted in three high risk areas, ICU, HDU and Isolation rooms of Guru Nanak Dev Hospital, Amritsar. The study was conducted in two parts. In the 1st part of the study, observations were noted without preliminary cleansing with detergent of various sites and in 2nd part observations were noted with preliminary cleansing.

Three different Disinfectants were chosen and their Composition was as follows:

1. Hydrogen peroxide-10%, Silver solution-0.01%. 10% solution was made by adding 100 mL of it in RO water to make total 1 litre solution for mopping and 20% solution was made by adding 200 mL to RO water to make total volume 1 litre for fogging.
2. Octyldimethylammonium-chloride- 6.510%,
Dioctyldimethylammonium-chloride- 2.604%,
Didecyldimethylammonium-chloride- 3.906%,
Alkyldimethylbenzylammonium-chloride- 8.680%.

Its 0.39% solution was made by adding 3.9 mL to tap water to make volume up to 1 litre.

3. N-alkyldimethylbenzylammonium chloride-13.6%, Didecyldimethylammonium chloride-13%, Polymeric biguanide hydrochloride-5%. 1% solution was prepared by adding 10 mL of this disinfectant to tap water to make it 1 litre.

Each disinfectant was used in ICU, then HDU followed by Isolation rooms on different days. Two containers/buckets were taken, one for disinfectant solution and 2nd for clean water. The health worker doing disinfection procedure used PPE (Personal protection equipment) like wearing gloves, gown, mask and eye protection. Before fogging and high end cleaning surface, three swab samples from wall, floor, bed, monitor, etc. were taken. Air sample was taken on blood agar plate for bacterial and fungal colonies.

A clean double folded cloth was soaked in disinfectant solution under study for wet mopping. Walls were cleaned from above downward. One surface of mop was used once and then other side of it was used. Similarly, the floor was cleaned with mop from one end to other end. After four surfaces of the mop were used, it was dipped in clean water and squeezed to remove dirt and water. Mop was again dipped in disinfectant solution and again used for cleaning various surfaces. Treated surfaces remained wet for 10 min. Another clean mop was taken, dipped into the disinfectant solution under study and squeezed to make it dry. This dry mop was then used for mopping of monitor and ventilator. Ventilator and monitor were covered with water proof drape after 10 min. of dry mopping. AC was switched on 10 min. before fogging. After that, fogging of the prepared room was done with one of the disinfectants planned for the room. One litre of prepared solution was filled in the fogger and the fogger was kept at the height of 2 ft. in one of the corners of the room and was switched on for 30 min. for 1000 cubic feet area. For 2000 cubic ft. area, 2 litre solution was fogged for 60 min. For area more than 2000 cubic ft., two foggers were used simultaneously.

Room was opened 1 hour after fogging. Terminal/High end cleaning of walls, floor and bed was done with the sponge soaked in the respective disinfectant and squeezed to dry the various surfaces. Three surface swab samples were taken from the wall, bed, floor, monitor, etc. Air samples were taken on blood agar plate on same, 1st and 2nd consecutive post-fogging days for bacterial and fungal colonies. All samples were sent to Microbiology Department of Government Medical College, Amritsar for processing. A total of 27 surface swab samples were taken before and same number after fogging.

In 2nd part of study, CDC guidelines were followed, more comprehensive and modified approach was adopted. Due to poor results with hydrogen peroxide with silver solution in 1st part of study, 2nd part of study was done by using detergent (Surf excel) for preliminary/pre-cleaning of heavily soiled areas. Scrubbing of wall, floor and bed was done with sponge soaked in detergent solution followed by washing with liberal amount of water. After that 3 different disinfectants were used for mopping, fogging and terminal cleaning in ICU, HDU and Isolation room on different days according to manufacturer's instructions for concentration.

Three surface swab samples and one air sample were taken before fogging and three surface swab samples and three air samples on three consecutive days were taken in post-fogging period with use of each disinfectant. The collected samples were sent to Microbiology Department for processing.

Observations of two parts of the study were compared to authenticate the results.

Statistical analysis

The statistical analysis was done to evaluate the association of disinfectants with infection control. A value of $p < 0.05$ was considered statistically significant. The Chi-square (χ^2) test was used to demonstrate the significant difference between the reduction in different organisms before fogging and after fogging. All the statistical values were calculated using SPSS Version 16 (SPSS Inc, Chicago, IL).

RESULTS

First part of study: With disinfectant No.1, Growth in pre-fogging swab samples was 100% and in post-fogging was 44.45%. With disinfectant No. 2 in pre-fogging swab samples, growth was 100% and in post-fogging samples growth was 33.34%. With disinfectant No. 3, Growth in pre-fogging samples was 100% and in post-fogging samples was 66.7%. The results are shown in figure 1.

Figure 1. Percentage of Growth in Swab Samples before and after Fogging

After fogging the reduction in growth of swab samples were found significant with p value of < 0.05 with 1st and 2nd disinfectants while with 3rd disinfectant result was non-significant with $p > 0.05$.

Figure 2. Percentage of Various Organisms before and after Fogging

Table 1 shows the reduction in percentage of Klebsiella 66.6% to 45.83%, E. coli from 16.6% to 4% and Pseudomonas from 16.6% to nil, respectively. Results were found significant with p value < 0.05 .

Dis-infectant	Klebsiella		E coli		Pseudomonas	
	Before Fogging	After Fogging	Before Fogging	After Fogging	Before Fogging	After Fogging
1	55.56	33.34	33.34	Nil	11.12	Nil
2	88.88	22.23	11.12	Nil	Nil	Nil
3	66.67	66.67	Nil	Nil	33.34	Nil

Table 1. Percentage of Various Organisms in Pre-fogging and Post-Fogging Swab Samples with Three Disinfectants

Disinfectant	Bacterial count				Fungal count			
	Before Fogging	After Fogging			Before Fogging	After Fogging		
		Days				Days		
		Same	1 st	2 nd		Same	1 st	2 nd
1	16	2	4	12	10	2	2	10
2	52	2	3	9	22	2	2	3
3	6	4	15	30	12	3	5	8
Table 2. Colonies Count (cfu) of Bacteria and Fungi before Fogging and after Fogging on Three Successive Days in Air Samples								

Disinfectant	Bacterial			Fungal		
	Before Fogging	After Fogging	% age Reduction	Before Fogging	After Fogging	% Age Reduction
1	30	Nil	100	2	Nil	100
2	50	Nil	100	3	Nil	100
3	40	2	95	4	2	50

Table 3. Reduction in Bacterial and Fungal cfu after Fogging and Pre-cleansing with Detergent

Disinfectant	Bacterial			Fungal		
	Before Fogging	After Fogging	% age Reduction	Before Fogging	After Fogging	% Age Reduction
1	16	2	87.5	10	2	80
2	52	2	96.15	22	2	90.9
3	6	4	33.34	12	3	75

Table 4. Reduction in Bacterial and Fungal cfu after Fogging without Pre-cleansing

Dis-infectant	Bacterial		Fungal	
	Fogging with pre-cleansing	Fogging without pre-cleansing	Fogging with pre-cleansing	Fogging without pre-cleansing
1	100	87.5	100	80
2	100	96.15	100	90.9
3	95	33.34	50	75

Table 5. Reduction in Bacterial and Fungal cfu after Fogging with and without Pre-cleansing with Detergent

Second Part of Study

We observed 100% reduction in bacterial and fungal count when fogging was done after proper pre-cleansing and scrubbing of various sites with detergent by using disinfectant no.1 and 2 while 95% reduction in bacterial cfu and 50% reduction in fungal cfu with pre-cleansing with disinfectant no.3. Number of samples for each disinfectant is 9, so total samples are 27.

Disinfectant	Number of Samples	Before Fogging		After Fogging	
		+ve	-ve	+ve	-ve
1	9	9	Nil	4	5
2	9	9	Nil	3	6
3	9	9	Nil	6	3

Table 6. Difference in the Number of Positive and Negative Samples before and after Fogging

DISCUSSION

1st part of our study showed that although disinfectant No. 1 was effective with efficacy of 55.55% in reducing bacterial load by fogging on same and 1st day, but it was ineffective in reducing fungal load. Disinfectant No. 2 had efficacy of 66.66% and reduced bacterial load on successive three days but was again ineffective in reducing fungal load. Disinfectant No. 3 was only 33.33 % effective in reducing bacterial growth and was ineffective in reducing fungal growth. Low efficacy of disinfectant No. 1 than disinfectant No. 2 may be due to its ineffectiveness in reducing organic load prior to fogging.

Our study also showed much reduction in bacterial and fungal count after fogging with pre-cleansing of various sites and this matches the studies¹⁸ of Barbut F et al and Chan-Myers H and Chang GA claiming 99.999% kill rate with hydrogen peroxide fog.¹⁰

We also found some pathogens in swab cultures and in air after fogging. The reasons which lead to poor efficacy of all the three disinfectants in our study were lack of pre-cleansing with detergent/hypochlorite solution/quats, daily high end cleaning, routine fumigation, less often use of HME (humidified moisture exchanger) filters, poor hand hygiene of the health workers and the attendants, dust contamination from outside construction work, reuse of suction catheters after washing with tap water, least cleaning of AC filters and improper sealing of room before fogging.

Bacterial contamination of operation theatre in hospital settings had contributed significantly to the high prevalence of nosocomial infection.²² It is very important to consider that the efficiency of disinfectants vary greatly depending on the nature of the surface being disinfected, number and nature of the organisms present, presence of organic soil, duration of exposure and temperature.²³ The level of bacterial contamination simply revealed the quality of air within the units. Primarily, the quality of indoor air depends on external and internal factors such as the type of ventilation system, cleaning procedures, surgical/medical team and degree of activity. In our study, reduction in prevalence of various organisms were observed after fogging of high risk areas of hospital. *Klebsiella* was reduced to 45.83%, *E. coli* 4% and *Pseudomonas* to nil. We have included quaternary ammonium compounds in our study for disinfection. Similar study was done by Herman Friedmann et al.²⁴ We found efficacy of disinfectant No.1 slightly less than No.2 in reducing

bacterial and fungal count in air. This may be because of organic load present prior to fogging. Similar observation was reported in other studies. We found a persistent high bacterial load after fogging on second successive day, indicated by the high bacterial and fungal count in Table 2, is in accordance with the findings of Singh²⁵ which also revealed high bacterial contamination in air.

2nd Part of Study

We plugged all the vulnerable points from where infection could enter ICU/HDU/Isolation ward. CDC guidelines were followed, a more comprehensive and modified approach was adopted using WHO, CDC guidelines and rectifying our own faulty techniques in disinfecting the environment. Rooms were cleaned/scrubbed with detergent prior to fogging and high end cleansing after fogging with three disinfectants in different rooms. With use of disinfectant 1 and 2 there was 100% reduction in bacterial and fungal cfu, while with disinfectant no.3 there was 95% reduction in bacterial cfu and 50% reduction in fungal cfu on the same post-fogging day. Our results match with study by Barbut F who used H₂O₂ fog and claimed 99.999% kill rate if all ideal preconditions were followed before fogging.

Based on our results obtained after adopting CDC guidelines we recommend the use of disinfectant No. 1 & 2 though the results of disinfectant No. 1 are more promising but it is very costly as compared to other two disinfectants, we must also see cost effectiveness in country like India. Disinfectant No. 2 and 3 also do not need any other cleansing agent (Detergent) prior to mopping and fogging while disinfectant no. 1 needs pre-cleansing of surfaces with detergent/QUATS.

CONCLUSION

In conclusion, manual cleaning and disinfection of environmental surfaces in health care facilities (daily and at patient discharge) are essential elements of infection control program. Many factors make it difficult to achieve high rates of effective disinfection on a routine and sustained basis. The results of present investigation indicate that spray fog disinfection with all the three disinfectants are readily accepted by housekeeping personnel and is a valuable adjunct for reducing the number of detectable microorganisms in ICU, HDU and Isolation wards. To achieve desired levels of surface disinfection, adoption of modern technologies like fogging with quaternary ammonium compounds in addition to high end cleaning with them is indicated to supplement traditional methods. Further research into the efficacy of new technologies is needed.

Recommendations/Suggestions

Based on our study, we recommend the use of disinfectant No. 2. Although the effectiveness of disinfectant No. 1 and 2 was found equally good but disinfectant No. 1 needs pre-cleaning with detergent/QUAT as it is corrosive to plastic and metal and was not economical. Also, disinfectant No. 2 and 3 (QUATS) do not require pre-cleaning but disinfectant No. 3 was found less effective in reducing bacterial and fungal count. Quaternary ammonium compounds act as cleanser as well as disinfectant. They should be used daily for high end cleaning and for fogging weekly in high risk areas. Quaternary ammonium compounds have advantages like high efficacy

against different microbes, are aldehyde free, corrosion free, biodegradable and economical.

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