ORIGINAL ARTICLE

EFFICACY OF HYDROGEN PEROXIDE FUMIGATION IN IMPROVING DISINFECTION OF HOSPITAL ROOMS AND REDUCING THE NUMBER OF MICROORGANISMS

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Background: The hospital acquired infections are very common in any health care setting due to certain bacteria, viruses and fungi. In order to find out a solution to this problem, this preliminary study was designed to find out the efficiency of hydrogen peroxide fumigation in reducing the number of microorganisms and improving the disinfection of hospital rooms. It was a prospective cross over study, conducted in Arar Central Hospital, North region, Arar, Kingdom of Saudi Arabia, for the period of one year, from March 2015 to February 2016. Objective of the study was to determine the efficacy of hydrogen peroxide fumigation in the improvement of disinfection of hospital rooms. **Methods:** A total of 10 environmental samples were taken immediately after the patient was discharged (R1), 10 after terminal cleaning (R2), and 10 after the Bioxeco hydrogen peroxide fumigation (R3) in 20 different rooms of the hospital including ICU, general medical wards and operating rooms. (T=600) Results: Almost 95% rooms cultured (environmental surfaces) after patient was discharged (R1) revealed microorganism growth, 80% after terminal cleaning (R2) and 2% after Bioxeco Hydrogen Peroxide fumigation revealed growths of microorganisms like bacteria and fungi on the culture plates (R3). The highest rate of room contamination was found in the rooms where the patients had stayed for a longer period of time. **Conclusions:** Hydrogen peroxide fumigation has been proved to be an efficient disinfectant in a health care setting.

Keywords: Decontamination; Disinfection; Health care setting; Fumigation; Vaporized hydrogen peroxide

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INTRODUCTION

Hospital acquired infections are widespread and include device associated infections e.g. CLABSI (Catheter associated blood stream infection, CAUTI (Foley's catheter associated urinary tract infection), VAP (Ventilator associated Pneumonia), procedure associated SSI (Surgical site infections) and non-device associated infections (Blood stream infection, Urinary tract infection and Pneumonia). They are very important contributors of morbidity, mortality, increased cost and lengthy hospital stay in a health care setting. They are becoming more important as a public health problem because of overcrowding of people, impaired immunity (e.g. due to extreme age, any secondary illness, and additional treatments), discovery of new microorganisms, increased bacterial resistance to antibiotics, infrastructure of hospitals, low compliance of hand hygiene, understaffing, overcrowding, heavy workload, misuse of personal protective equipment, late establishment of infection control programs are major problems in limited-resourced and developing countries. Methicillin Resistant *Staphylococcus aureus*, *Pseudomonas aeruginosa, Staphylococcus aureus, Clostridium difficile* and Multi Drug Resistant Organism like *Acinetobacter baumanni* and Vancomycin resistant *Enterococci* account for majority of these Hospital Acquired infections.[1] They are usually transmitted by colonized and infected patients to the environment, one patient to another, patient to health care workers and then again to another patient and the cycle goes on.

Multiple studies have shown that patients are the major source of microorganisms and environmental surfaces near them are full of contamination they spread through highly touched areas like bed side rails, door knobs, curtains, sinks, equipment, gloves, gowns, files of the patients and sometimes on the skin and body of the patient. Their contamination is at a peak during the patient stay as compared to other less frequently touched or non-touched areas. In addition, inappropriate environmental cleaning and disinfection may play a significant role in amplifying these health care associated infections. Cleaning frequency should be

increased at times for potentially risk environmental areas and equipment.

A wide range of liquid-based detergents and disinfectants is currently being used for environmental cleaning, including Clorox (sodium hypochlorite), quaternary ammonium compound and phenol-based products. They vary significantly in their antimicrobial activity and are generally bactericidal, virucidal, sporicidal and fungicidal, but many have limited to no activity against more resistant microorganisms, including *Mycobacterium* species and bacterial spores. Although sodium hypochlorite has been used since decades, it has been proved that it does not always removes or kills bacteria. Vaporized hydrogen peroxide has been used effectively in decontamination of health care facilities. Hydrogen peroxide vaporized systems use chemical reactions which produce a vapours of hydrogen peroxide that is then dispersed throughout the area to be disinfected.[2] It is operated usually by an independent automated system. The oxygen in the hydrogen peroxide vapor reacts with the cell walls of microorganisms, causing cell lysis and death. HPV systems have been used as instrument sterilizers for some time. The basic concept is to fill the room with a mist (depending on the formulation) containing a certain percentage of hydrogen peroxide that coats the surfaces in the room. Vaporized hydrogen peroxide is a broad spectrum, dry, rapid antimicrobial and effective disinfectant. It has been used for disinfection of environment, surfaces, ducts, mechanical, electrical equipment, pharmaceutical facilities and animal holding rooms. In the 1960s, the use of chemical fumigation for control of microbial contamination in hospitals was thought to be an efficient way to environmental cleaning of hospital isolation rooms and other critical areas.[3]

Anthrax contamination incidents in the US in 2001 and problems with *Clostridium difficile* in UK hospitals have urged to think over it again and again. Certain fumigants in the vapor phase (formaldehyde, chlorine dioxide, hydrogen peroxide) were used to eliminate anthrax from buildings. Following the 2001 anthrax bioterrorism attack, there was reawakened interest in using fumigants for microbial decontamination.[4] Even more recently; researchers have proposed using chlorine dioxide or hydrogen peroxide vapours for terminal disinfection of hospitals contaminated with mold and bacteria after the discharge of the infected patients and routine terminal cleaning.

Unlike earlier fogging techniques using relatively large droplets, the newer techniques deliver the fumigant as a gas dispersed throughout the enclosed space. Vaporized hydrogen peroxide and chlorine dioxide gas are used for the purpose of decontamination of health care facility. Since fumigants can be dispersed very easily, this vaporized hydrogen peroxide has been used for decontamination of certain enclosed areas like incubators, medicine trolleys, laboratory cabinets, rooms and pharmaceutical areas.

Vaporized hydrogen peroxide has been more effective than chlorine dioxide and it is very effective against bacteria, viruses, parasites, fungus and spores. It is effective against *MRSA, VRE, Clostridium difficile*, *Pseudomonas aeruginosa*, *Acinetobacter* species, *Klebsiella, Norovirus, Candida* species, *Mycobacterium tuberculosis* and *Aspergillus.*[5,6] Concentration of hydrogen peroxide as surface wiping disinfectant is 2–3%.

In this study, a programmed automated device (Bioxeco) that provides a dry aerosol of hydrogen peroxide (H_2O_2) disinfectant was tested for surface decontamination of rooms and different types of medical devices and equipment, in a secondary health care setting.

MATERIAL AND METHODS

This prospective cross-over study was performed during a one-year period (March 2015 to February 2016) in seven medical and surgical ICUs rooms, five operating rooms and eight medical rooms; total twenty rooms, located in the Arar Central Hospital, (350 bed Secondary care Hospital) in North region, Arar, Kingdom of Saudi Arabia. These areas include operation room, adult, neonatal and paediatric intensive care units, and male medical and surgical wards, female medical and surgical wards. The ICU units included two 4-bed, one 5-bed, and four 3-bed units. The operation theatres included one 4-bed and four two-bed units. The medical rooms included two 4-bed, one 5-bed, and five 2-bed units.

The primary objective was to determine the efficiency of H_2O_2, used after terminal cleaning, in reducing the number and percentage of rooms contaminated with microorganisms.

Routine terminal cleaning was performed after patient discharge and was followed by H_2O_2 disinfection.

Routine cleaning is done usually thrice a day with 1:10 chlorox (Hypochlorite) solution. For our research purpose ordinary/ routine cleaning was done in the vacant rooms. Terminal cleaning was done in the rooms of infected patients when they were discharged. A procedure required to ensure that an area has been cleaned/decontaminated following discharge of a patient with an infection (i.e., alert organism or communicable disease) in order to ensure a safe environment for the next patient. These infected patients included the patients with *Vancomycin Resistant Enterococcus*, *Methicillin*

Resistant Staphylococcus aureus, Carbapenemase Producing *Klebsiella pneumoniae,* Multi Drug Resistant *Acinetobacter baumannii* and *Clostridium difficile* endospores.[7] We opened all the closets, cupboards, window curtains and bed curtains so that the product can reach every open spot.

Roam Chemie products, Bioxeco 3D F machine (made by HUWA-SAN TECHNOLOGY, Belgium), based on silver stabilized hydrogen peroxide (12.5%) was used for disinfection of certain care areas of the hospital. Hydrogen peroxide in the vapor phase was used. Actually, it is a compact ambulatory system that produces VHP and yields it into a closed system which is developed by connecting the hydrogen peroxide vapours into the inlets and outlets of the air conditioning system supplying the required room. All the wet spots and areas were cleaned and the visible contaminations were removed. Hydrogen peroxide concentration was kept minimum 100 ppm in order to achieve the successful disinfection. Once the disinfection process was finished, we allowed it to drop to 25ppm. We entered the room using the surgical face masks and eye protection and windows were opened for extra ventilation. The disinfected room was released when the measured concentration was lower than 1ppm, as it was depicted on the screen. On the completion of the cycle, levels of VHP were monitored for safe re-entry (less than 1ppm) into the room.

The disinfection process produces particles that circulate freely in the air as an aerosol disinfectant that has access to all the surfaces. The system consists of an automatic machine together with the laptop that can be pre-programmed to release the required concentration of vaporized hydrogen peroxide needed for the disinfection. The time required for the disinfection depends on the area of the room and also on the number of equipment present in the room. All the doors and windows were closed, ventilation areas were sealed with tape to avoid the escape of hydrogen peroxide vapours and appropriate PPE were worn to avoid any irritation of eyes, nose or skin or damage to the clothes.[8]

Routine environmental samples are usually not appreciated in a health care setting unless there is an outbreak. Thirty microbiological samples were collected per room (30/room) at three same time points (10 samples before cleaning, 10 after terminal cleaning and 10 after hydrogen peroxide disinfection):

- just after patient discharge (R1),
- after terminal cleaning (R2) and
- after H_2O_2 disinfection(R3).

Remoistened swabs were used to sample certain environmental surfaces: In ICU units the sites were 1) Mattress, 2) Telephone, 3) Bed, 4) Bed rail, 5) B.P monitor, 6) Over bed table, 7) Crash cart, 8) Suction machine, 9) sink and 10) Bedside table.

In operation theatres, the sites were 1) Drip stand, 2) Stethoscope, 3) Bed, 4) Bed rail, 5) B.P monitor, 6) Monitor, 7) Ventilator, 8) Suction machine, 9) Head light, 10) Instrument Trolley.

In medical wards, the sites were 1) Mattress, 2) Door, 3) Bed, 4) Bed rail, 5) B.P monitor, 6) Over bed table, 7) Sink, 8) Door knob, 9) Curtain, 10) Bedside table.

Highly touched surfaces like doorknobs, light switches, walls around toilets, privacy curtains, bedrails and electronics, call buttons, low touch like table surfaces, floors and even surfaces that are usually difficult to reach were disinfected environmental surfaces were sampled by the use of moistened swabs, before starting the disinfection. Such areas are difficult to be disinfected by the conventional cleaning methods. Each swab was plated on Columbia blood agar. The plates were incubated at 37 °C for 24–48 hrs. After disinfection a few hours later the fumes of vaporized hydrogen peroxide settled down and the rooms were apparently free of microorganisms and were ready to use again for the new patients. Samples were collected before fumigation and after disinfection by vaporized hydrogen peroxide at three times: after the patient was discharged R1, after terminal cleaning R2, after Hydrogen Peroxide fumigation R3. In each room, almost 10 environmental surface areas and equipment were sampled using swabs remoistened in distilled water together with the controls. (T=600)

RESULTS

At least 20 unoccupied hospital rooms and 600 samples (10 environmental surfaces were used, from each surface 3 samples were taken at 3 different times) were evaluated in our study as shown in figure-1.

That environmental surfaces routinely touched by patients, visitors and health care workers may play a role in the spread of these microorganisms. The cultures were taken from the rooms before doing Bioxeco hydrogen peroxide fumigation and after disinfection. Cultures were taken from different places of the rooms like beds, incubators, instruments, crash cart, tables, telephones, doors, around and from air conditioners, blood pressure monitors, medicine cabinets, bed railings, television, weight machine, table of operation rooms, suction machines and food tables of the patients. Controls were also placed at the same time from all the rooms. Most of the areas cultured after the patient was discharged (R1), before bioxeco fumigation revealed growths of microorganisms like bacteria and fungi (R2). But after bioxeco hydrogen peroxide fogging

there was almost no growth on the most of the culture plates (R3) as depicted in table-1. This study revealed that the bioxeco hydrogen peroxide disinfection is very effective one. Other than exposure time and concentration of fumigants, the nature of the contaminated material and the type of microorganisms were also associated with the effectiveness of VHP decontamination process. However, the bacteria were not identified to genus or specie level. This could be our future plan to identify if the microorganisms are virus, bacteria or fungi. Only the presence of microorganisms was assessed.

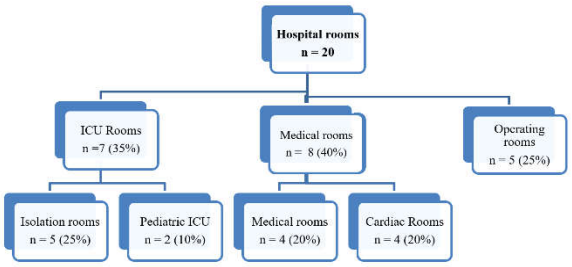

Figure-1: Distribution of hospital rooms.

Table-1: Efficiency of terminal cleaning and H_2O_2 disinfection

	R1 Number of rooms=20	R2 Number of rooms = 20	Δ R1-R2	*p*- value	R3 Number of rooms = 20	Δ R2-R3	*p*- value
Rooms contaminated with at least one or more bacteria	19/20 (95%)	16/20 (80%)	19-16=3 3/20 15%	<0.001	2/20 (10%)	16-2=14 (70%) are clean/ free of bacteria	<0.001

R1= Immediately after the patient is discharged from the room. R2= Before disinfection with Hydrogen Peroxide.
R3=After disinfection with Hydrogen Peroxide

DISCUSSION

Vaporized hydrogen peroxide has been used for decades for the disinfection of operating rooms, isolation rooms, intensive care units and general medical wards. It's obvious from our results that the terminal cleaning followed by hydrogen peroxide fumigation is much more effective as compared to routine terminal cleaning alone for disinfection of microorganisms in general medical wards as well as ICUs. Hydrogen peroxide (H_2O_2) acts as an oxidizing agent and disinfectant by producing reactive oxygen species (hydroxyl radicals and superoxide anions), which attack essential cell components such as DNA, lipids and proteins as described by Linely E. *at el* 2012.[3] Hydrogen peroxide is a more effective antimicrobial agent in the gaseous form in comparison with the liquid form. The use of vaporized hydrogen peroxide is an efficient method of decontamination or certain closed areas like isolation rooms, clean and dirty rooms, medical equipment and devices.[8–11] Regarding the advantages of hydrogen peroxide: it is safe to use, environmentally friendly and is extensively used in food industry, less toxic as its broad spectrum activity eventually converts to water and oxygen and it can be used with false ceilings and no residues are found at the end usually[1]. And some of the disadvantages are: rooms require to be vacated and pre cleaning is important to remove the visible dirt, it is expensive, vapours must be moved around as it is irritating to eyes, mucous membrane and skin may cause lung irritation if inhaled, problems can occur with new patient, time consuming, and disinfected room cannot be occupied by the patient immediately due to these reasons and it should be operated by the trained personnel. [12,13,14] A study by Quan JH. *et al* in 2012 has revealed that HEPA filters can be bio decontaminated with VHP by extending the fumigation time efficiently.[13] It is also obvious from certain previous studies that room terminal cleaning hydrogen peroxide has been a very efficient disinfectant for especially multidrug resistant microorganisms.[15,16] Hydrogen peroxide efficiency has been observed against certain bacteria, viruses and fungi. But the mechanism still needs to be understood. Another study by Finnegan *et al* revealed that hydrogen peroxide is a very effective biocide at 2% concentration.[4]

It has been found as an alternative to formaldehyde fumigation for disinfection of animal rooms in Tuberculosis research lab as hydrogen peroxide is decomposed to water and oxygen, it possesses almost no environmental risks associated with formaldehyde.[5,7,9]

Jennifer L. *et al* in 2015 has revealed that hydrogen peroxide spray for contaminating soft surfaces in hospitals and a significant reduction in bacterial contamination on the soft surfaces is found.[16]

SPSS software (version 18.0) was used for data analysis. Results are presented as frequency (percentage) for quantitative variables. The normality of distribution was tested by a Shapiro Wilk test. All P values were calculated. The statistical significance was defined as $p<0.05$.

CONCLUSIONS

It has been concluded from the above-mentioned study that hydrogen peroxide fumigation is one of the best disinfectants in a health care setting these days

and it could be a very effective bactericidal agent. Some of the limitations of hydrogen peroxide fumigation are its irritating to eyes and nose if the concentration is not controlled, the machine is to be operated by the well-trained technical staff and after the HP fumigation, the room cannot be used immediately for the admission of new patients.

In future we intend to do more studies addressing these above-mentioned issues. It is also associated with increased cost. And our study was conducted only in one health care facility, therefore our results may not be comparable with other institutions with different practice of infection control.

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AUTHORS' CONTRIBUTION

TH: Literature search, data collection, data interpretation, write up. AQ: Conceptualization of study design, Data analysis. SFA: Data collection. JC: Data analysis and interpretation. FH: Data analysis, Write up, Proof reading.

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