Disinfection efficacy stuides on three diffrent disinfection methods in health care facilities by ATP method

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Abstract

Objectives: Nosocomial infection has always been a significant topic in the field of public health. The disinfection procedures involved in health care facilities are extremely important to prevent potential transmission of diseases. Therefore, this study was performed to compare the disinfection efficacy between three different disinfection methods (Accel wipes, Hubscrub industrial washer, and Steam vapor) on three pieces of non-critical medical equipment: wheelchairs, mattresses and bath chairs.

Methods: The method used to evaluate the disinfection efficacy compared the reduction of contaminants count in the relative light unit using ATP monitoring methods. 30 samples of each of the three types of medical equipment were swabbed pre-disinfection and post-disinfection using the three disinfection methods. The recorded reduction number was then converted using log transformation. Statistical analysis was conducted using NCSS to assess differences between the disinfection methods.

Results: The mean log-reduction of disinfection for Accel wipes, Hubscrub, and steam vapor were 1.067, 1.490, and 1.485 respectively. Steam vapor and Hubscrub displayed statistically significantly better disinfection efficacy compared to Accel wipes in terms of log reduction (overall p=0.000002).

Conclusion: Hubscrub and steam vapor are better disinfectants compared to Accel wipes in terms of mean log reduction values; however, all three disinfection methods demonstrated effectiveness when cleaning and disinfecting non-critical medical equipment. For critical medical equipment, steam vapor and Hubscrub industrial washing are effective while Accel wipes do not meet the standards of high-level disinfection. As a result, combination usages of all three disinfection methods are recommended at health care facilities based on the categories of the medical equipment.

Keywords: Disinfection efficacy; medical equipment; public health; mean-log reduction; ATP

Introduction

Health care services establishments are known to pose significant risks to public health due to the introduction of potential pathogens and congregation of susceptible populations in the setting. One of the most common modes of transmission of communicable diseases in health care facilities is by vehicle-borne transmission. It is defined as the indirect transmission of an

infectious agent when a contaminated object comes in contact with a person's body. According to Heymann (2008), the health care setting may act as an amplifier of infection and a contributor of outbreaks. Therefore, eliminating potential pathogens in health care settings is critical to protect the health of the public.

Infection control in health care facilities usually consists of two major components: good hand hygiene and good disinfection on health care equipment. The importance of hand washing can be traced back to 1800s when Ignaz Semmelweis discovered the importance of antiseptic procedures in health care settings (Reid, 1975). Nowadays, most health agencies have their own guidelines and policies on how to maintain good hand hygiene. The World Health Organization (2006) developed a detailed guideline and recommendations on hand hygiene to demonstrate the evidence on the effectiveness of reducing pathogen transmission. However, the disinfections and sterilization methods of the health care equipment are just as important as maintaining good hand hygiene on infection prevention because without proper disinfection of the health care equipment, cross-contamination may occur which neutralizes the effectiveness of good hand hygiene practices. As such, the author conducted a research project comparing the effectiveness of three different disinfection methods on non-critical medical equipment.

Nosocomial infection

A nosocomial infection is defined as an infection acquired from health care facilities by a patient who was admitted for a reason not related to that infection (WHO, 2002). The impact of a nosocomial infection not only creates physiological problems to the patient, but also exerts emotional stress to the patient (WHO, 2002). As a patient acquires a nosocomial infection at the hospital, the length of hospitalization and the cost of treatment increase. This may cause the patient to develop emotional stress because he acquires the pathogen at the place he seeks treatment. In addition to the emotional stress on the patient, it also gives a negative impact on the health care facilities as valuable resources are being spent on secondary infections that can be preventable.

According to Spelman (2002), 5% to 10% of patients visiting health care facilities had acquired infection from health care facilities. As well, the rate of nosocomial infection has been increasing over two decades [1980s and 1990s]. The most common nosocomial infections are urinary tract infections, respiratory tract infections and surgical wound infections.

The transmission pathways for nosocomial infection can be classified into two modes. One is direct contact with people who harbour the pathogens and the other is via direct contact with equipment and devices that are contaminated. This gives more incentive to research of the efficacy of disinfection methods on health care equipment because proper disinfection of equipment devices interferes with, or disrupts with the transmission pathways, therefore stopping the loop of cross-contamination of pathogens between people and equipment.

Public Health Significance

Pathogens associated with nosocomial infection

According to the Public Health Agency of Canada (2013), there are four major pathogens that are associated with nosocomial infection. They are Clostridium difficile, Methicillin- resistant Staphylococcus aureus (MRSA),

Vancomycin-resistant Enterococci (VRE) and Carbapenem Resistant Gram Negative Bacilli (CRGN).

Clostridium difficile is a gram-positive spore-forming bacterium that may cause diseases such as toxic megacolon and perforation of the colon. The symptoms associated with this bacterium are fever, watery diarrhea, nausea and loss of appetite (Centre for Disease Control and Prevention, 2013). MRSA is a type of staphylococcus aureus that is resistant to methicillin. Staphylococcus aureus can be typically found on human skin and does not cause infection. However, MRSA may cause skin, wound, blood infections and pneumonia. VRE can be found in human intestines and female genital tract without causing disease; however, urinary tract or bloodstream infections can arise after surgical procedures with contaminated equipment. CRGN are groups of gram negative bacteria such as *E.coli* and *Klebsiella.* They are part of the normal flora in the intestines of healthy humans. If these bacteria spread outside the gut, they may cause serious infections of the urinary tract, bloodstream, and meningitis (Centre for Disease Control and Prevention, 2013).

According to WHO (2002), the development of nosocomial infections are mainly influenced by the following four factors: the microbial agent, the patient susceptibility, the environmental factors and the bacterial resistance. Specifically, patient susceptibility and the bacterial resistance are unique factors in health care facilities.

There are a lot of different groups of people visiting health care services establishments including immunocompromised individuals, infants and the elderly. These groups of people generally have weaker immune systems and as a result, they are more susceptible to nosocomial infections due to the increased risk of being in contact with opportunistic pathogens. Opportunistic pathogens are present in healthy individuals and are not disease-inducing because they are part of normal flora for healthy people. Healthy individuals possess good immune systems that prevent infection from these microorganisms. However, for immunocompromised people, these opportunistic pathogens are dangerous. Moreover, patients visiting health care facilities may have injuries to their mucous membrane and skin so that pathogens may bypass the natural defence mechanisms. Therefore, the infection control strategies are extremely important in health care facilities.

Bacteria antibiotic resistances

In addition to susceptible populations, another important factor that contributes to nosocomial infection is antibiotic resistances of bacteria. Schaberg et al. (1991) performed a critical analysis on surveillance data of microbiology associated with nosocomial infection in 1980s. They found that the pathogens involved in nosocomial infection are shifted from easily treatable pathogens to resistant pathogens with fewer options to treat. Struelens (1998) stated that the antibiotics resistance not only increases the morbidity and mortality in patients because treatment is not effective, it also increases the cost of treatment by prolonged hospitalization and the demand for secondary antibiotics which are extremely expensive. This brings more challenge to developing countries as they do not have these secondary antibiotics in stock. Moreover, if the health care facilities do not pay attention to this issue, the bacteria would eventually develop resistance to the secondary antibiotics.

Two major reasons that antibiotic resistance is developed are excessive prescription of

antibiotics by physicians and cross-contamination of the microorganism between colonized patients and the hands of health care staff or health care equipment (Struelens, 1998). The overuses of antibiotics are being stressed by various agencies across the world. According to BCCDC (2010), the overall uses of antibiotics are being steadily reduced over time.

However, according to the annual summary report of 2013 from BCCDC (2013), the trends in antibiotics resistance are fluctuating for several organisms. Take *E.coli* as an example, the resistance to antibiotics is shown in Figure 1.

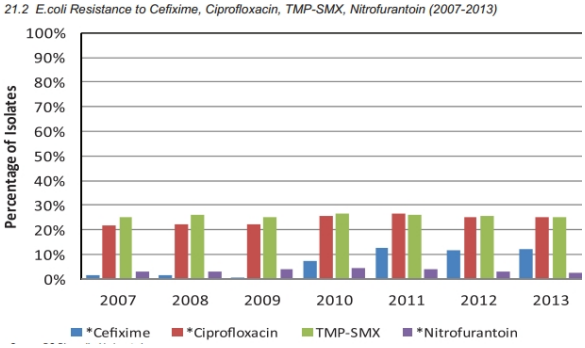

Figure 1 *E. coli* resistances to Cefixime, Ciprofloxacin, TMP-SMX, and Nitrofurantoin, 2007-2013 (BCCDC, 2013).

According to Figure 1, the antibiotics resistance of *E.coli* are steady for three antibiotics and one can see a significant increase in Cefixime from 2007 to 2013. This shows that the problem of antibiotic resistances cannot be solved solely by reducing administration of antibiotics. Development of specific disinfection methods and implementation of good management practices are also required to aid in prevention of antibiotic resistances of pathogens.

Disinfection methods

Hota (2004) found that specific microorganism such as *C.difficile* and VRE can predominate in the inanimate environmental surfaces even if these pathogens are endemic in the institution. But it is difficult to assess the role of disinfection in removing these pathogens as the level of hand hygiene and the degree and frequency of disinfectant uses are often not measured in health care facilities. Boyce (2007) stated that routine cleaning and disinfection of the environment surfaces can reduce the transmission of pathogens in nosocomial settings; however, some routine cleaning procedures on high-touch surfaces do not completely remove pathogens such as MRSA and VRE. This is due to the fact that these pathogens are capable of surviving for days to weeks on environmental surfaces. Dettenkofer and Spencer (2007) conducted a critical analysis on the importance of environmental decontamination for nosocomial infections. They found that there was no conclusive study on whether using disinfectants on environmental surfaces display more significant reduction compared to only using detergents. Wenzler et al. (2003) found that inanimate environment of health care facilities only contributes to a minor causative factor of complex nosocomial infection. Moreover, the extensive application of antiseptics can lead to the development of resistance in bacteria, especially when a low concentration of disinfectant is applied (Wenzler etal., 2003). All authors above addressed the need of studies on disinfection roles in health care settings as it is important in developing good environment disinfection procedures to prevent nosocomial infection.

According to Hota (2004), there are two major categories of cleaning in nosocomial settings, one is called sterilization and the other is called disinfection. Sterilization would kill all microbial life on an object or surface and is usually achieved by

combination of heat, pressure and chemicals. Disinfection eliminates most microbes and it is usually achieved by only chemicals. The level of disinfection can be classified into three different categories based on the concentration and chemical used. A high-level disinfection would eliminate all pathogens except large quantities of spores; an intermediate-level disinfection would eliminate all pathogens but spores; a low-level disinfection would not be able to kill mycobacteria or spores. This research project compared steam vapor, Accel wipes and Hubscrub at disinfecting hospital equipment to assess the efficacy of these three methods.

The Accel wipes that the author used for the research consisted of 0.5% hydrogen peroxide according to Virox (2012). These wipes are effective at removal of virus, bacteria and fungi in five minutes as described by Virox (2012). However, according to Presterl et al. (2007), 0.5% hydrogen peroxide solution is not effective against biofilm formed by *Staphycoccus epidermidis*. In order to achieve rapid eradication, a concentration of 3% to 5% of hydrogen peroxide is required (Presterl et al., 2007). The hubscrub method utilizes the same disinfectant as the Accel wipe method at a different concentration of 7% hydrogen peroxide as stated by Hubscrub Ltd (2015). In addition, Ba (2005) conducted an study on disinfection efficacy between Accel wipes and sani-cloths (germicide that utilizes alcohol as the active ingredient for disinfectant) and found out that Accel wipes were statistically significantly better at disinfection compared to sani-cloth as greater log reductions were seen with Accel wipes.

On the other hand, steam vapor was shown to be effective at removing all pathogens such as *E.coli*, MRSA, VRE and endospores of *clostridium difficile* (Tanner, 2008). The steam disinfection system rapidly kills all pathogenic microorganisms being tested within five seconds. Song et al. (2012) conducted a study on disinfection efficacy of steam vapor on biofilm developed by four different strains of bacteria. The result showed that steam vapor treatment reached over 99.95% efficiency on killing biofilm of all four bacteria.

According to several studies mentioned above, steam vapor was shown to have higher disinfection efficiency compared to chemical methods such as hydrogen peroxide solutions as steam vapor not only reaches high killing efficiency of bacteria, virus and fungi, but it is capable of destroying bacterial spores and biofilms, whereas hydrogen peroxide solutions display incompetency on removing bacteria biofilms. Therefore, the research study was warranted to confirm or refute the finding of previous studies.

Legislation and guidelines

There is no enforceable legislation with regards to disinfection and sanitation in health care facilities. However, detailed guidelines on disinfection and sanitation are being published in various agencies across multiple provinces in Canada.

The BC Ministry of Health (2007) published a detailed guideline on good practices of disinfection and sterilization of medical devices. In this guideline, the condition of environmental surfaces pre-disinfection is being emphasized as the efficacy of disinfection would be reduced if the environmental surfaces are not clean. The physical and chemical properties of the environment are being addressed as well. Factors such as water hardness, excessive humidity or the pH of disinfectant solution all contribute to the disinfection efficacy. 0.5% hydrogen peroxide solution is listed as

a low-level disinfection method and it is advised to use this method for non-critical medical devices which are defined as devices that touch only intact skin and not mucous membranes, or does not directly touch the patient. Steam vapor method is being listed as sterilization method and is applicable to critical medical devices which are defined as devices that enter sterile tissues, including vascular system. 7% hydrogen peroxide solution is listed as high-level disinfectant and it is advised to use this method for semi-critical devices which are defined as devices that come in contact with non-intact skin or mucous membranes but ordinarily do not penetrate them.

Similar to the BC Ministry of Health, the Ontario Agency for Health Protection and Promotion (2007) also developed a guideline on best practices of disinfection and sterilization of medical equipment. In this guideline, 0.5% hydrogen peroxide is classified as a low-level disinfection method as well and the low-level disinfection is being achieved after five minutes of contact at 20 degree Celsius. Steam vapor is being classified as a sterilization method and it is being achieved by increasing temperature to 121 degrees Celsius in a short period of time. 7% hydrogen peroxide is classified as a high-level disinfection method; however, in order to achieve high level disinfection, contact time of 20 minutes is required.

Both of these guidelines agreed with the previous studies and show that steam vapor has higher disinfection efficacy compared to hydrogen peroxide solutions. One role of environmental health officers is education for health service establishments on how to correctly apply disinfection methods to different health care facilities equipment based on these guidelines.

Purpose

The Canadian Red Cross (2014) has a program known as HELP (health equipment loan program). Different types of equipment are included in this program such as wheelchairs, bath seats and bed handles. Due to the high risk of cross-contamination between equipment and patients, a study was conducted to compare the efficacy of three different disinfection methods (Accel wipes, Steam Vapor and Hubscrub). The study focused on comparing the bacteria counts pre-disinfection and post-disinfection on selected equipment surfaces for both disinfection methods. Mean log reduction factor was calculated and can be used as an evaluation tool for the efficacy of the disinfection methods.

Materials

The three disinfectants being tested in this study were Accel wipes, steam vapor and Hubscrub industrial washer (model 20/70). Accel wipe is produced by Virox Technology Inc. It is commonly used in health care facilities as a disinfectant for medical equipment and environmental surfaces. According to Virox (2014), Accel wipe is made of polypropylene wipe material that can ensure even surface coverage to increase the efficiency of pathogen removal on environmental surfaces. The active ingredient is 0.5% hydrogen peroxide which can kill the pathogens by oxidation. There is no residue left on the equipment and environmental surfaces as Accel wipe will break down into water and oxygen molecules after use. Hubscrub utilizes 7% hydrogen peroxide as its active ingredient according to Hubscrub Ltd (2015). The mechanism of disinfection of Hubscrub washer is the same as the Accel wipes; however, the cleaning procedure is replaced by mechanical action instead of human manual cleaning in the Accel wipes method.

Steam vapor disinfection on environmental surfaces is achieved through commercial steam vapor cleaner. It utilizes heat and pressure to kill pathogens on medical equipment and environmental surfaces. According to Intersteam Technologies Inc. (2014), there are different types of steam vapor cleaner on the market in terms of their power. The most suitable one for health care facilities is 110V-120V steam cleaning equipment as it provides enough heat and moisture content to kill the pathogen on surfaces without generating excessive pressure to blow pathogens off and cross-contaminate other equipment or surfaces (Intersteam technologies Inc. 2014).

3M™ Clean-Trace™ ATP swabs were used in this experiment to sample the surfaces and equipment pre-disinfection and post-disinfection. After sample collection, the samples were put into 3M™ Clean-Trace™ NG Luminometer to produce relative light unit as a quantifiable measure of bacterial counts. The data were compiled and the mean log reduction of the relative light units measured pre-disinfection and post-disinfection of the environmental surfaces were calculated in Microsoft Excel. ANOVA and two sample t-tests were the statistical analyses carried out on NCSS9 software to compare the efficacy of disinfection for Accel wipes and steam vapor (NCSS statistical software. 2014).

Methods

30 samples of mattress/overlay, 30 samples of wheelchairs and 30 samples of bath chairs/toilet seats were were swabbed pre-disinfection and post-disinfection on the surfaces for three disinfection methods to measure the relative light units by the author. The staff members of the Canadian Red Cross conducted the cleaning and disinfecting procedures according to manufacturer's instructions between the swab samples. The surfaces disinfected were left to remain wet for one minute for the disinfectants to complete their jobs as advised by the BC Ministry of Health (2007). The detailed procedure of sampling is outlined in the following figures provided by the manufacture of the ATP hygiene monitoring products (3M Inc., 2014).

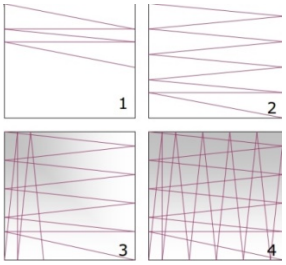

Figure 2. Swabbing Procedures

As one can see from Figure 2, the swabbing was conducted horizontally from one side to the other across the whole surface being tested followed by vertically swabbing across the whole surfaces from one side to the other. After the swabbing was completed, the swab will be put in the 3M™ Clean-Trace device as shown in Figure 3.

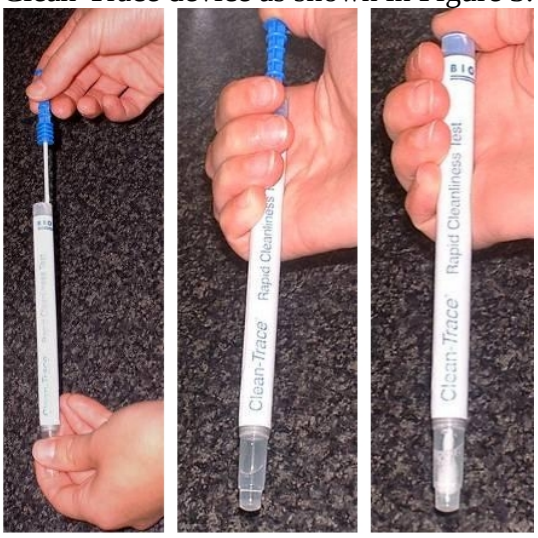

Figure 3. 3M™ Clean-Trace device

By pressing down the blue handle, the 3M™ Clean-Trace device was activated. After activation, one shook the swab in the device rapidly for a minimum of five seconds to mix the reagents and release ATP from the

swab. As shown in Figure 4, the swabs were placed into the luminometer to read the relative light units of the sample. The luminometer was turned on prior to measureing samples because setting a blank is necessary to accurately measure the ATP levels in the samples.

Figure 4. Luminometer and measurement of relative light units

After the data of relative light units for all samples were obtained, Excel and NCSS were used to perform mean-log reduction calculations and statistical analyses to evaluate three different disinfection methods tested.

Validity and Reliabilities of measure

According to Kyriakides and Patel (1991), adenosine triphosphate is found to be a sensitive indicator for presences of biological residues due to its universal presences in all living cells. Hence, it is an ideal marker for assessing the hygienic status of environmental surfaces. As demonstrated by Gould and Subramani (1988), it is very difficult to measure the concentration of ATP on surfaces directly. Therefore, indirect methods such as bioluminescent method are developed to assess the level of ATP on surfaces. Bioluminescent method utilizes the ATP bioluminescence system found in fireflies. The chemical equation for this light-generating reaction is:

$$\text{ATP} + \text{D-luciferin} + \text{O2} \xrightarrow[\text{Mg2+}]{\text{Luciferase}} \text{Oxyluciferin} + \text{AMP} + \text{PPi} + \text{CO2} + \text{light}$$

As one can see from this equation, ATP is being converted to light and the intensity of the light is being measured to assess the level of ATP. And the amount of ATP can be used to assess presences of organisms on surfaces. The relationships of these measurements are illustrated in Figure 5:

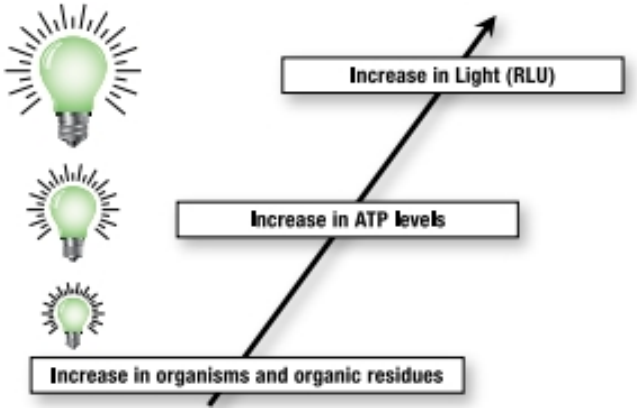

Figure 5. The relationship of number of organism, ATP and relative light unit

There have been different studies conducted on the ATP monitoring system to check the validity of this measurement. Chen and Godwin (2006) found that the ATP levels measured are closely correlated with bacterial colonies count using traditional methods and should be considered a valid measurement for determining the amount of bacteria present on surfaces. However, another group of scientists found that the correlation is not significant enough between ATP monitoring units and colony forming units and ATP monitoring is not substitute for quantification of microbial load (Elaine et al., 2003). A more recent study evaluated ATP based monitoring systems with respect to their validity of representing the microbial load on surfaces. They found that ATP system shows strong degree of linear correlation with the standard plate count method; however, it has limitation on detection of gram-negative bacteria due to incomplete cell lysis (Turner, et al., 2010). According to the Public Health Agency of Canada (2013), there are four major pathogens that are associated with

nosocomial infection. They are Clostridium difficile, Methicillin- Resistant Staphylococcus aureus (MRSA), Vancomycin-Resistant Enterococci (VRE) and Carbapenem Resistant Gram Negative Bacilli (CRGN). Three of four listed organisms are gram-positive bacteria; therefore, it is relatively valid to use ATP measurements to evaluate the quantification of bacteria in health care services facilities. The advantages of ATP measurements outweigh the limitation of ATP monitoring system.

The reliability of the ATP monitoring system is shown to be good since ATP meters demonstrate acceptable linearity and repeatability in their readings (Navid et al., 2014). However, they found that certain chemical disinfectants may interfere with the ATP levels. Therefore, it is important to carefully apply the chemical disinfectant on environmental surfaces and give enough time for it to evaporate to avoid interference with the ATP meters. In addition, careful calibration of the ATP luminometer was performed to ensure the reliability of the measurement apparatus. A positive control of a swab containing environmental contamination at 50 RLU and a negative control of a swab with no contamination were used to calibrate the luminometer.

Statistical analysis and Results

The data collected in the study are the relative light units (RLU) that were measured by the ATP hygiene monitoring products. They are numerical data and the inferential statistics being used is ANOVA test because one wants to compare differences in mean-log reduction between Accel wipes disinfection, steam vapor disinfection and Hubscrub disinfection. The raw data were compiled in Microsoft Excel and the statistical analysis was done on NCSS9. Table 1 contains the raw data for the study. The number measured is relative light units (RLU).

Table 2 was constructed in Excel by converting all the numerical raw data into log form for the purposes of conducting statistical analysis in NCSS9.

According to Table2, the mean log reduction and standard deviation of RLU for Accel wipes, steam vapor and hubscrub on 30 medical equipment are 1.067±0.367, 1.485±0.289 and 1.490±0.351 respectively.

There were four hypothesises that the author tested in this study:

1. $H_{0:}$ There is no difference between disinfection efficacies in terms of log-reduction for Accel wipes, steam vapor and hubscrub.
   H_a: There is a difference between disinfection efficacies in terms of log-reduction for Accel wipes, steam vapor and hubscrub.
2. $H_{0:}$ There is no difference between disinfection efficacies in terms of log-reduction for Accel wipes and steam vapor on Mattresses/overlays.
   H_a: There is a difference between disinfection efficacies in terms of log-reduction for Accel wipes and steam vapor on Mattresses/overlays.

c	Accel H2O2				Steam Vapor				Hubscrub		
Equipment	Pre	Post	Reduction	Equipment	Pre	Post	Reduction	Equipment	Pre	Post	Reduction
Matress/underlay	82	9	73	Matress/underlay	120	5	115	Wheelchair	124	6	118
Matress/underlay	59	17	42	Matress/underlay	121	5	116	Wheelchair	121	6	115
Matress/underlay	79	6	73	Matress/underlay	79	2	77	Wheelchair	130	2	128
Matress/underlay	69	27	42	Matress/underlay	157	5	152	Wheelchair	90	2	88
Matress/underlay	54	19	35	Matress/underlay	119	6	113	Wheelchair	160	6	154
Matress/underlay	130	5	125	Matress/underlay	130	3	127	Wheelchair	91	1	90
Matress/underlay	83	8	75	Matress/underlay	200	6	194	Wheelchair	95	0	95
Matress/underlay	79	5	74	Matress/underlay	95	8	87	Wheelchair	82	4	78
Matress/underlay	120	10	110	Matress/underlay	190	3	187	Wheelchair	94	0	94
Matress/underlay	138	10	128	Matress/underlay	120	2	118	Wheelchair	83	4	79
Matress/underlay	60	14	46	Matress/underlay	123	5	118	Wheelchair	80	5	75
Matress/underlay	134	6	128	Matress/underlay	59	4	55	Wheelchair	75	5	70
Matress/underlay	150	6	144	Matress/underlay	124	4	120	Wheelchair	90	4	86
Matress/underlay	120	21	99	Matress/underlay	77	1	76	Wheelchair	92	5	87
Matress/underlay	90	5	85	Matress/underlay	62	6	56	Wheelchair	81	15	66
Bathchair/toliet seat	140	4	136	Wheelchair	100	5	95	Bathchair/toliet seat	93	11	82
Bathchair/toliet seat	141	7	134	Wheelchair	120	7	113	Bathchair/toliet seat	120	2	118
Bathchair/toliet seat	100	3	97	Wheelchair	150	11	139	Bathchair/toliet seat	120	4	116
Bathchair/toliet seat	99	3	96	Wheelchair	160	9	151	Bathchair/toliet seat	103	0	103
Bathchair/toliet seat	130	16	114	Wheelchair	150	2	148	Bathchair/toliet seat	73	0	73
Bathchair/toliet seat	78	10	68	Wheelchair	101	0	101	Bathchair/toliet seat	91	0	91
Bathchair/toliet seat	87	1	86	Wheelchair	103	4	99	Bathchair/toliet seat	74	4	70
Bathchair/toliet seat	130	30	100	Wheelchair	89	2	87	Bathchair/toliet seat	72	5	67
Bathchair/toliet seat	118	18	100	Wheelchair	84	0	84	Bathchair/toliet seat	73	4	69
Bathchair/toliet seat	65	10	55	Wheelchair	72	0	72	Bathchair/toliet seat	67	5	62
Bathchair/toliet seat	121	7	114	Wheelchair	89	1	88	Bathchair/toliet seat	112	6	106
Bathchair/toliet seat	103	8	95	Wheelchair	90	4	86	Bathchair/toliet seat	93	4	89
Bathchair/toliet seat	134	9	125	Wheelchair	71	4	67	Bathchair/toliet seat	72	1	71
Bathchair/toliet seat	121	31	90	Wheelchair	90	5	85	Bathchair/toliet seat	86	0	86
Bathchair/toliet seat	76	4	72	Wheelchair	62	4	58	Bathchair/toliet seat	90	2	88
Means	103.0	11.0	92.0		110.2	4.1	106.1		94.2	3.8	90.5
Standard deviation	29.001	8.032	30.415		36.536	2.631	35.667		21.289	3.319	21.378

Table 1. Raw collected data on relative light unit pre-disinfection and post-disinfection for Accel wipes, steam vapor and Hubscrub.

	Accel H2O2				Steam Vapor				Hubscrub		
Equipment	Pre	Post	Reduction	Equipment	Pre	Post	Reduction	Equipment	Pre	Post	Reduction
Matress/underlay	1.914	0.954	0.960	Matress/underlay	2.079	0.699	1.380	Wheelchair	2.093	0.778	1.315
Matress/underlay	1.771	1.230	0.540	Matress/underlay	2.083	0.699	1.384	Wheelchair	2.083	0.778	1.305
Matress/underlay	1.898	0.778	1.119	Matress/underlay	1.898	0.301	1.597	Wheelchair	2.114	0.301	1.813
Matress/underlay	1.839	1.431	0.407	Matress/underlay	2.196	0.699	1.497	Wheelchair	1.954	0.301	1.653
Matress/underlay	1.732	1.279	0.454	Matress/underlay	2.076	0.778	1.297	Wheelchair	2.204	0.778	1.426
Matress/underlay	2.114	0.699	1.415	Matress/underlay	2.114	0.477	1.637	Wheelchair	1.959	0.000	1.959
Matress/underlay	1.919	0.903	1.016	Matress/underlay	2.301	0.778	1.523	Wheelchair	1.978	0.000	1.978
Matress/underlay	1.898	0.699	1.199	Matress/underlay	1.978	0.903	1.075	Wheelchair	1.914	0.602	1.312
Matress/underlay	2.079	1.000	1.079	Matress/underlay	2.279	0.477	1.802	Wheelchair	1.973	0.000	1.973
Matress/underlay	2.140	1.000	1.140	Matress/underlay	2.079	0.301	1.778	Wheelchair	1.919	0.602	1.317
Matress/underlay	1.778	1.146	0.632	Matress/underlay	2.090	0.699	1.391	Wheelchair	1.903	0.699	1.204
Matress/underlay	2.127	0.778	1.349	Matress/underlay	1.771	0.602	1.169	Wheelchair	1.875	0.699	1.176
Matress/underlay	2.176	0.778	1.398	Matress/underlay	2.093	0.602	1.491	Wheelchair	1.954	0.602	1.352
Matress/underlay	2.079	1.322	0.757	Matress/underlay	1.886	0.000	1.886	Wheelchair	1.964	0.699	1.265
Matress/underlay	1.954	0.699	1.255	Matress/underlay	1.792	0.778	1.014	Wheelchair	1.908	1.176	0.732
Bathchair/toliet seat	2.146	0.602	1.544	Wheelchair	2.000	0.699	1.301	Bathchair/toliet seat	1.968	1.041	0.927
Bathchair/toliet seat	2.149	0.845	1.304	Wheelchair	2.079	0.845	1.234	Bathchair/toliet seat	2.079	0.301	1.778
Bathchair/toliet seat	2.000	0.477	1.523	Wheelchair	2.176	1.041	1.135	Bathchair/toliet seat	2.079	0.602	1.477
Bathchair/toliet seat	1.996	0.477	1.519	Wheelchair	2.204	0.954	1.250	Bathchair/toliet seat	2.013	0.000	2.013
Bathchair/toliet seat	2.114	1.204	0.910	Wheelchair	2.176	0.301	1.875	Bathchair/toliet seat	1.863	0.000	1.863
Bathchair/toliet seat	1.892	1.000	0.892	Wheelchair	2.004	0.000	2.004	Bathchair/toliet seat	1.959	0.000	1.959
Bathchair/toliet seat	1.940	0.000	1.940	Wheelchair	2.013	0.602	1.411	Bathchair/toliet seat	1.869	0.602	1.267
Bathchair/toliet seat	2.114	1.477	0.637	Wheelchair	1.949	0.301	1.648	Bathchair/toliet seat	1.857	0.699	1.158
Bathchair/toliet seat	2.072	1.255	0.817	Wheelchair	1.924	0.000	1.924	Bathchair/toliet seat	1.863	0.602	1.261
Bathchair/toliet seat	1.813	1.000	0.813	Wheelchair	1.857	0.000	1.857	Bathchair/toliet seat	1.826	0.699	1.127
Bathchair/toliet seat	2.083	0.845	1.238	Wheelchair	1.949	0.000	1.949	Bathchair/toliet seat	2.049	0.778	1.271
Bathchair/toliet seat	2.013	0.903	1.110	Wheelchair	1.954	0.602	1.352	Bathchair/toliet seat	1.968	0.602	1.366
Bathchair/toliet seat	2.127	0.954	1.173	Wheelchair	1.851	0.602	1.249	Bathchair/toliet seat	1.857	0.000	1.857
Bathchair/toliet seat	2.083	1.491	0.591	Wheelchair	1.954	0.699	1.255	Bathchair/toliet seat	1.934	0.000	1.934
Bathchair/toliet seat	1.881	0.602	1.279	Wheelchair	1.792	0.602	1.190	Bathchair/toliet seat	1.954	0.301	1.653
Means	1.995	0.928	1.067		2.020	0.535	1.485		1.965	0.475	1.490
Standard deviation	0.131	0.333	0.367		0.141	0.304	0.289		0.091	0.346	0.351

Table 2. Relative light unit pre-disinfection and post-disinfection for Accel wipes, steam vapor and Hubscrub in log form.

3. H_0: There is no difference between disinfection efficacies in terms of log-reduction for Accel wipes and Hubscrub on bath chair/toilet seats.
   H_a: There is a difference between disinfection efficacies in terms of log-reduction for Accel wipes and Hubscrub on bath chair/toilet seats.
4. H_0: There is no difference between disinfection efficacies in terms of log-reduction for steam vapor and hubscrub on wheelchairs.
   H_a: There is a difference between disinfection efficacies in terms of log-reduction for steam vapor and Hubscrub on wheelchairs.

For the first hypothesis, statistical analysis was conducted in NCSS9 and the result is shown in the following figures:

Tests of Assumptions Section

Assumption	Test Value	Prob Level	Decision (0.05)
Skewness Normality of Residuals	0.4084	0.682985	Accept
Kurtosis Normality of Residuals	-1.6216	0.104879	Accept
Omnibus Normality of Residuals	2.7965	0.247027	Accept
Modified-Levene Equal-Variance Test	0.5967	0.552888	Accept

Figure 6. The test of assumptions

Analysis of Variance Table

Source Term	DF	Sum of Squares	Mean Square	F-Ratio	Prob Level	Power (Alpha=0.05)
A (...)	2	3.535592	1.767796	15.53	0.000002*	0.999221
S(A)	87	9.90219	0.1138183			
Total (Adjusted)	89	13.43778				
Total	90					

* Term significant at alpha = 0.05

Figure 7. Analysis of Variance Table for three methods tested

Scheffe's Multiple-Comparison Test

Response: Log_reduction_Hubscrub,Log_reduction_steam,Log_reduction_wipe
Term A:

Alpha=0.050 Error Term=S(A) DF=87 MSE=0.1138183 Critical Value=2.4905

Group	Count	Mean	Different From Groups
Log_reduction_Hubscrub	30	1.4897	Log_reduction_wipe
Log_reduction_steam	30	1.485167	Log_reduction_wipe
Log_reduction_wipe	30	1.067	Log_reduction_Hubscrub Log_reduction_steam

Figure 8. Scheffe's Multiple-Comparison Test for log reduction of three methods

According to Figure 6, the data is normally distributed since all four tests return "accept normality". Therefore, the inferential statistical analysis that the author looked at is the parametric test called "Analysis of Variance Table". According to Figure 7, the p-value is 0.000002. This shows that the differences between three disinfection methods were statistically significant. Therefore, one rejected the null hypothesis and concluded that there is a difference in disinfection efficacy between using Accel wipes, steam vapor and Hubscrub as the disinfection agents. According to Figure 8, Steam disinfection and Hubscrub disinfection showed a statistically significantly greater log reduction than Accel wipes. The mean log reduction for Steam disinfection, Hubscrub and Accel wipes were 1.485, 1.490 and 1.067 respectively. Therefore, steam vapor and Hubscrub machine are better disinfectants compared to Accel wipes.

The alpha error stands for the possible error that one rejects the null hypothesis when it is actually true. For the first hypothesis of this study, the p-value when a=0.05 is approximately zero; therefore, there is very little chance that alpha error was present.

Beta error stands for the error that one cannot reject the null hypothesis when the null hypothesis is actually false. In this study, the p-value is approximately zero. Hence, one concluded that there was no beta error for this study. The power of the study was approximated to be 0.999 as shown in Figure 7.

For the second hypothesis, statistical analysis was conducted in NCSS9 and the result is shown in the following figures:

Descriptive Statistics

Variable	Count	Mean	Standard Deviation	Standard Error	99.9% LCL of Mean	99.9% UCL of Mean
steam_on_mattresse_	15	1.4614	0.2579119	0.06659257	1.185677	1.737123
H2O2_on_Mattresse_	15	0.9813333	0.3432539	0.08862778	0.6143741	1.348293

Note: T* (steam_on_mattresse_) = 4.1405, T* (H2O2_on_Mattresse_) = 4.1405

Figure 9. Descriptive statistics for mean log reduction of two different methods on mattress/overlay

Tests of Assumptions

Assumption	Value	Prob Level	Decision (α = 0.050)
Skewness Normality (steam_on_mattresse_)	-0.1929	0.847066	Cannot reject normality
Kurtosis Normality (steam_on_mattresse_)	-0.4348	0.663674	Cannot reject normality
Omnibus Normality (steam_on_mattresse_)	0.2263	0.893022	Cannot reject normality
Skewness Normality (H2O2_on_Mattresse_)	-0.8579	0.390975	Cannot reject normality
Kurtosis Normality (H2O2_on_Mattresse_)	-1.2270	0.219821	Cannot reject normality
Omnibus Normality (H2O2_on_Mattresse_)	2.2414	0.326044	Cannot reject normality
Variance-Ratio Equal-Variance Test	1.7713	0.296600	Cannot reject equal variances
Modified-Levene Equal-Variance Test	1.1190	0.299178	Cannot reject equal variances

Figure 10. The test of assumptions

Equal-Variance T-Test
μ1 - μ2: (steam_on_mattresse_) - (H2O2_on_Mattresse_)

Alternative Hypothesis	Mean Difference	Standard Error of Difference	T-Statistic	d.f.	Prob Level	Reject H0 at α = 0.001
μ1 - μ2 ≠ 0	0.4800667	0.1108578	4.3305	28	0.00017	Yes

Figure 11. Equal variance T-test of mean log reduction of two different methods on mattress/overlay

According to Figure 9, the mean log reduction for steam and Accel wipes on mattresses/overlays were 1.461 and 0.981 respectively. The standard deviation for mean log reduction of steam and Accel wipes on mattresses/overlays were 0.258 and 0.343 respectively.

According to Figure 10, the data is normally distributed since all six tests return "cannot reject normality". The variances of data were equal as well. Therefore, the inferential

statistical analysis that the author looked at is the parametric test called “Equal Variance T-test”.

According to Figure 11, the p-value is 0.00017. This shows that the differences between two disinfection methods were statistically significant. Therefore, one rejected the null hypothesis and concluded that there is a difference in disinfection efficacy between Accel wipes and steam vapor on mattress/overlays. Steam vapor showed better disinfectant efficacy compare to Accel wipes on Mattresse/overlays.

For the second hypothesis of this study, the p-value when a=0.05 is 0.00017; therefore, there is very little chance that alpha error was present.

In this study, the p-value is approximately zero. Hence, one concluded that there was no beta error for the second hypothesis of this study as well.

For the third hypothesis, statistical analysis was conducted in NCSS9 and the result is shown in the following figures:

Descriptive Statistics

Variable	Count	Mean	Standard Deviation	Standard Error	99.9% LCL of Mean	99.9% UC of Mean
hubscrub_on_bathchair_toliet_seat_	15	1.90834	1.5274	0.3563319	0.0920044	
H2O2_on_bathchair_toliet_seat_	15	0.7456787	1.559655	1.152667	0.3806969	0.0982955

Note: T* (hubscrub_on_bathchair_toliet_seat_) = 4.1405, T* (H2O2_on_bathchair_toliet_seat_) = 4.1405

Figure 12. Descriptive statistics for mean log reduction of two different methods on bath chair/toilet seats

Tests of Assumptions

Assumption	Value	Prob Level	Decision (α = 0.050)
Skewness Normality (hubscrub_on_bathchair_toliet_seat_)	-0.1173	0.906596	Cannot reject n
Kurtosis Normality (hubscrub_on_bathchair_toliet_seat_)	-1.9506	0.051104	Cannot reject n
Omnibus Normality (hubscrub_on_bathchair_toliet_seat_)	3.8186	0.148182	Cannot reject n
Skewness Normality (H2O2_on_bathchair_toliet_seat_)	0.6238	0.532769	Cannot reject n
Kurtosis Normality (H2O2_on_bathchair_toliet_seat_)	-0.1629	0.870605	Cannot reject n
Omnibus Normality (H2O2_on_bathchair_toliet_seat_)	0.4156	0.812353	Cannot reject n
Variance-Ratio Equal-Variance Test	1.1414	0.807995	Cannot reject equal variances
Modified-Levene Equal-Variance Test	0.0100	0.921216	Cannot reject equal variances

Figure 13. Test of assumptions

Equal-Variance T-Test

μ1 - μ2: (hubscrub_on_bathchair_toliet_seat_) - (H2O2_on_bathchair_toliet_seat_)

Alternative Hypothesis	Mean Difference	Standard Error of Difference	T-Statistic	d.f.	Prob Level	Reject H at α = 0.
μ1 - μ2 ≠ 0	0.3747333	0.1346359	2.7833	28	0.00953	Yes

Figure 14 Equal-Variance T-test of mean log reduction of two different methods on bath chair/toilet seats

According to Figure 12, the mean log reduction for Hubscrub and Accel wipes on bath chair/toilet seats were 1.527 and 1.153 respectively. The standard deviation for mean log reduction of Hubscrub and Accel wipes on bath chair/toilet seats were 0.356 and 0.381 respectively.

According to Figure 13, the data is normally distributed since all six tests return “cannot reject normality”. The variances of data were equal as well. Therefore, the inferential statistical analysis that the author looked at is the parametric test called “Equal Variance T-test”.

According to Figure 14, the p-value is 0.00953. This shows that the differences between two disinfection methods were statistically significant. Therefore, one rejected the null hypothesis and concluded that there is a difference in disinfection efficacy between Hubscrub and Accel wipes on bath chair/toilet seats. Hubscrub showed better disinfectant efficacy compare to Accel wipes on bathchair/toilet seats.

For the third hypothesis of this study, the p-value when a=0.05 is 0.00917; Hence, alpha error was unlikely for the third hypothesis of this study.

There was no beta error for the third hypothesis of this study as well.

For the fourth hypothesis, statistical analysis was conducted in NCSS9 and the result is shown in the following figures:

Descriptive Statistics

Variable	Count	Mean	Standard Deviation	Standard Error	99.9% LCL of Mean	99.9% UCL of Mean
steam_on_wheelchair_	15	1.508933	0.3250502	0.0839276	1.161435	1.856432
hubscrub_on_wheelchair_	15	1.830598	1.452	0.3541404	0.09143866	1.073402

Note: T* (steam_on_wheelchair_) = 4.1405, T* (hubscrub_on_wheelchair_) = 4.1405

Figure 15. Descriptive statistics for mean

log reduction of two different methods on wheelchair

Assumption	Value	Prob Level	Decision (α = 0.050)
Skewness Normality (steam_on_wheelchair_)	0.8691	0.384809	Cannot reject normality
Kurtosis Normality (steam_on_wheelchair_)	-2.4558	0.014058	Reject normality
Omnibus Normality (steam_on_wheelchair_)	6.7861	0.033606	Reject normality
Skewness Normality (hubscrub_on_wheelchair_)		0.1502	0.880608 Cannot
Kurtosis Normality (hubscrub_on_wheelchair_)		0.0623	0.950298 Cannot
Omnibus Normality (hubscrub_on_wheelchair_)		0.0264	0.986865 Cannot
Variance-Ratio Equal-Variance Test	1.1870	0.752875	Cannot reject equal va
Modified-Levene Equal-Variance Test	0.0227	0.881339	Cannot reject equal va

Figure 16. Test of Assumptions

Mann-Whitney U or Wilcoxon Rank-Sum Test for Difference in Location

Variable	Mann Whitney U	W Sum Ranks	Mean of W	Std Dev of W	
steam_on_wheelchair_	109.5	229.5	232.5	24.10645	
hubscrub_on_wheelchair_		115.5	235.5	232.5	24.10645

Number Sets of Ties = 1, Multiplicity Factor = 6

Alternative Hypothesis	Exact Probability* Prob Level	Reject H0 (α = 0.001)	Approx. Without Correction Z-Value	Prob Level	Reject H0 (α = 0.001)	Approx. With C Z-Value	Prob Level
Diff ≠ 0			-0.1244	0.900961	No	-0.1037	0.917402

*Exact probabilities are given only when there are no ties and the sample sizes in both groups are s

Figure 17 Mann-Whitney U tests for mean log reduction of two different methods on wheelchair

According to Figure 15, the mean log reductions for Hubscrub and steam vapor on wheelchair were 1.452 and 1.509 respectively. The standard deviations for mean log reduction of Hubscrub and steam vapor on wheelchair were 0.325 and 0.354 respectively.

According to Figure 16, the data is not normally distributed since two out of six tests return “reject normality”. The variances of data were equal. Therefore, the inferential statistical analysis that the author looked at is the parametric test called “Mann-Whitney U Test”.

According to Figure 17, the p-value is 0.917. This shows that the differences between two disinfection methods were not statistically significant. Therefore, one cannot reject the null hypothesis and conclude that there is no difference in disinfection efficacy between Hubscrub and steam vapor on wheelchairs.

For the fourth hypothesis of this study, the p-value when a=0.05 is 0.917 and we cannot reject the null hypothesis. Therefore, there is no possible alpha error since we did not reject the null hypothesis.

In this study, the p-value is 0.917. Therefore, there is a really small chance that the null hypothesis is actually false. Hence, one concluded that beta error was unlikely for the fourth hypothesis of this study.

Discussion

According to results of four hypothesises tested, steam vapor and Hubscrub industrial washer have demonstrated better disinfection efficacy compared to Accel wipes in terms of the log-reduction after performing the disinfection procedures. The mean log reduction of ATP luminometer readings for steam, Hubscrub and Accel wipes were 1.490, 1.485, 1.067 respectively. Based solely on the degree of reduction of environmental contaminants, steam vapor and Hubscrub are better disinfectants than Accel wipes. However, in order to determine if the difference between these disinfection methods are significant enough to completely replace one method with another, one needs to look carefully on how the log-reduction values are calculated. According to Table 1 of the results, the average of the ATP luminometer readings before the disinfection for steam vapor, Hubscrub and Accel wipes are 110.2, 94.2 and 103.0 respectively. The average of ATP luminometer readings after disinfection for steam vapor, Hubscrub and Accel wipes are 4.1, 3.8 and 11.0 respectively. According to Fred Shaw (Shaw, personal communication, 2015), the readings of the ATP luminometer can be interpreted as the following standards: A value of less than 10 means the surface is food-grade clean; A value between 10 and 30 is considered as generally clean; A value between 30 to 100 is considered as generally dirty and A value higher than 100 is considered as filthy dirty. Therefore, steam vapor and Hubscrub have

demonstrated the ability to effectively reduce the environmental contaminant to food-grade clean while Accel wipes manage to reduce the number just a bit above the food-grade clean levels. Based on the nature of the equipment being tested, none of them are being used as food containers or used in a way that would come into contact with food. Therefore, although steam vapor and Hubscrub demonstrate better disinfection efficacy in terms of log-reduction, Accel wipes is still a valid disinfection method in health care facilities.

In addition to the ability to effectively reduce the number of environmental contaminants on surfaces of the medical equipment, the cost of the disinfection methods is also an important aspect on determining whether one should use certain methods over other methods. The operation costs of steam vapor, Hubscrub industrial washer and Accel wipes are all relatively inexpensive; however, the initial purchase of the steam cleaner and industrial washer are much costlier than purchasing a box of Accel wipes. Therefore, in terms of cost-effectiveness, Accel wipes would be the best disinfection method among all three methods tested. This finding is consistent with a cost-effective study on different disinfection methods where they found that hydrogen peroxide is the most cost-effective disinfection method among eight methods tested(Doan, et al., 2012).

However, it is not wise to use Accel wipes or 0.5% hydrogen peroxide as the only disinfection method for medical equipment. This is due to the incapability of elimination of biofilm by 0.5% hydrogen peroxide solution (Presterl et al., 2007). In addition, Mah and O'Toole found that biofilm plays an important role in development of bacterial resistance to antimicrobial agents such as hydrogen peroxide (Mah and O'Toole, 2001). Therefore, for environmental surfaces that are likely to form biofilm, Accel wipes are not suitable for disinfection.

In addition to the problem of biofilm, Accel wipes are not suitable for disinfection of critical equipment that will penetrate human tissues such as surgical equipment (Rutala and Weber, 2004). This is because critical equipment are required to reach sterilization after cleaning since any presence of pathogens on critical equipment pose a significant health risk to patients. This is consistent with cleaning and disinfection guidelines provided by BC Ministry of Health (2007) and Ontario Agency for Health Protection and Promotion (2007). Both of these two guidelines listed 0.5% hydrogen peroxide solution as a low-level disinfectant and should be only used on non-critical medical equipment which are defined as items that only touch intact skin and not mucous membranes, or does not directly touch the patient.

Since the medical equipment being rented out at the Canadian Red Cross are all non-critical items and careful washing procedures are completed to physically disrupt the structure of biofilm; Accel wipes are as effective as steam vapor and Hubscrub industrial washer to achieve sufficient level of disinfection.

Limitation/Future studies

The first major limitation of the study was the availability of the equipment being tested. In the study, different pieces of equipment were used for different disinfection procedures. Although the author utilized the method of log-reduction to prevent potential bias involved, some differences can still be observed. For example, the cleanliness of medical equipment before disinfection was not the same. The average ATP luminometer

readings for the equipment before disinfection are 110.2, 94.2, and 103.0 for steam vapor, Hubscrub industrial washer and Accel wipes respectively. This may introduce a degree of bias into the derivation of log-reduction value since if two methods reduce environmental contaminants to the same level of cleanliness, the one with higher bacterial load originally would display a higher mean-log reduction.

The second limitation of the study is the availability of the staff members. Since the sampling for the project were done in two separate weeks, the staff members responsible for cleaning at the Canadian Red Cross are different individuals. Therefore, this introduces an inconsistency in the way one cleans the medical equipment with steam vapor or Accel wipes. For example, some individual might perform the steam cleaning longer than other staff members during disinfection and hence human errors might be introduced.

The third limitation of the study is the availability of the ATP luminometer. During the study, the sample collections were performed on-site at the Canadian Red Cross facility and the reading and interpretation of the sample was done at BCIT one day after the sample collecting. The samples were stored in household refrigerator overnight before the readings were taken. Ideally, the sample should be collected and read by the luminometer directly after sampling in order to provide the most accurate results. Therefore, the actual numbers of environmental contaminants may be larger than the readings of samples.

The last limitation of the study is the cost of the measuring equipment. Due to the limitation on the budget of the research project, 30 total samples were done for each disinfection methods and 15 samples were done on specific types of equipment for each disinfection methods. By increasing the sample size, one would further eliminate potential bias and generate a data set that is more accurate and precise.

In a word, the limitations of the study can be summarized into two main categories—time and cost. Ideally, the environment, the staff involved and the equipment being tested should be identical for all disinfection methods. However, it is not achievable due to time and budget constraints.

Some potential future studies the author would like to suggest are listed below:

1. Compare the performances of one disinfection method on different types of surfaces such as plastics and cloth.
2. Compare the performances of different disinfection methods on the same type of medical equipment.
3. Observation study on how the staff members clean and disinfect the medical equipment compared to the standard procedures provided by the industry.
4. Compare and contrast between ATP methods and traditional plate count methods on evaluation of disinfection methods.

Conclusion/Recommendation

In conclusion, based on the mean log reduction of the three different disinfection methods, steam vapor and Hubscrub industrial washer demonstrated better disinfection abilities compared to Accel wipes. However, all three disinfection methods are effective when cleaning and disinfecting non-critical medical equipment. Based on the cost-effectiveness analysis, Accel wipes are the most cost-effective method of disinfection. However, being solely dependent on Accel wipes might lead to problems such as development of

bacterial resistance towards chemicals. In addition, Accel wipes are not suggested when cleaning critical medical equipment because critical equipment must reach sterilization before second use. As a result, combination usages of all three disinfection methods are recommended at health care facilities. For the Canadian Red Cross facility, since all equipment being rented out are non-critical medical equipment, all three methods are effective at disinfection. Therefore, for larger equipment that cannot be put in the Hubscrub industrial washer, steam vapor is recommended. For larger equipment that can be washed by the Hubscrub, Hubscrub is recommended. And for smaller equipment that can be easily cleaned with Accel wipes, Accel wipe is recommended. It is recommended to use the most convenient methods out of the three based on different equipment since all of them are effective on cleaning non-critical medical equipment.

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