Evaluating Utility Gloves as a Potential Reservoir for Pathogenic Bacteria

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Abstract

Purpose: This pilot study sought to determine the rate and degree to which gram-negative Klebsiella pneumoniae, Escherichia coli and Pseudomonas aeruginosa and gram-positive Staphylococcus aureus occurred on the inside of utility gloves used at University of Maine at Augusta, Dental Health Programs' dental hygiene clinic.

Methods: Five steam autoclave utility gloves were randomly selected to serve as control and a convenience sample of 10 used utility gloves were selected from the sterilization area. A sample was collected from a predetermined surface area from the inside of each steam autoclave utility glove and used utility glove. Each sample was used to inoculate a Petri plate containing 2 types of culture media. Samples were incubated at 37º C for 30 to 36 hours in aerobic conditions. Colony forming units (CFU) were counted.

Results: Confidence intervals (CI) estimated the rate of contamination with gram-negative K. pneumoniae, E. coli and P. aeruginosa on the inside of steam autoclave utility gloves to be n=33 95% CL [0.000, 0.049], used utility gloves to be n=70, 95% CL [0.000, 0.0303]. Data estimated the rate of contamination with gram-positive S. aureus on the inside of steam autoclave utility gloves to be n=35, 95% CL [0.233, 0.530], used utility gloves to be n=70, 95% CL [0.2730, 0.4975]. Culture media expressed a wide range of CFU from 0 to over 200.

Conclusion: The risk of utility glove contamination with gram-negative bacteria is likely low. The expressed growth of S. aureus from steam autoclave utility gloves controls raises questions about the effectiveness and safety of generally accepted sterilization standards for the governmentally mandated use of utility gloves.

Keywords: pathogenic bacteria, infection control, utility gloves, dental hygiene

This study supports the NDHRA priority area, **Occupational Health and Safety:** Investigate methods to decrease errors, risks and or hazards in health care and their harmful impact on patients.

Introduction

Multi-drug resistant (MDR) bacteria such as methicillin-resistant Staphylococci aureus (MRSA) have evolved from hospital-acquired infections to community-acquired infections. Increasingly, MDR bacterial infections have the potential to cross the boundaries of hospital intensive-care units to those most susceptible.[1-3] The global emergence and accelerated evolution of MDR bacteria has resulted in a call by researchers for more effective infection control measures in an attempt to halt their dissemination.[2,4]

It has long been recognized that the single most effective means of preventing the spread of disease is proper hand hygiene measures which includes the use of protective gloves.[5-7] Beginning in 1986, governmental organization such as Centers for Disease Control and Prevention (CDC), and Occupational Safety & Health Administration (OSHA) have recommended and mandated respectively the use of utility gloves as part of dental health-care providers (DHCP) personal protective equipment (PPE) to prevent percutaneous and chemical injury during sterilization and disinfection procedures.[8,9] Unlike disposable examination gloves, utility gloves are not considered a medical device and manufacturing standards are not regulated by the U.S. Food and Drug Administration.[5,8,9] Utility gloves are meant to protect DHCP's from percutaneous/chemical injury rather than a means to prevent cross-contamination and/or cross-infection.[5,8,9] There is no universally established protocol for the donning, use, disinfection and sterilization; protocols are largely designed and implemented by dental hospitals, academic dental clinics and private dental practices with minimal guidance by those governmental and professional agencies that recommend and mandate their use.

A review of the literature detailed the evolution of handwashing and protective gloves as a means of infection control in health care. It also analyzed the elements of disease transmission, the role of resident and transient hand flora in cross-contamination/cross-infection, and the top 5 MDR bacteria as a possible underestimated reservoir for pathogenic bacteria. When utility gloves are used to carry out disinfection and sterilization procedures, they are donned with bare hands. The written policy, which follows governmental guidelines, instructs "Utility gloves

must be washed with antimicrobial soap, rinsed and sprayed with a disinfectant after each use" should repeated use be anticipated in the same day.[10] Used utility gloves are steam autoclaved at the end of each day at 250 pounds per square inch for 20 minutes.

The "clean hand" technique implemented for donning and removing utility gloves requires multiple steps and can be repeated numerous times during a clinical day, increasing the risk of infection control error. As utility gloves are pulled on, the length of utility glove cuffs extend beyond the length of exam glove cuffs to the contaminated sleeve of lab coats increasing the risk of transferring bacteria to the inside of utility gloves. The very act of washing utility gloves with soap and water may inadvertently allow for contamination. Water could travel the length of the glove, transporting bacteria from the outside to the inside via loose utility glove cuffs. The contaminated utility glove would then serve as a reservoir for bacteria, causing the recontamination of DHCP's hands with each subsequent use. The inside of utility gloves may provide an underestimated growth medium, given the literature's verification that proliferation of bacteria increases rapidly in warm wet environments,[11,12] combined with numerous other factors, such as the accumulation of hand sweat, inadvertent water contamination during the disinfection protocol, and the survival times of pathogenic bacteria on inanimate surfaces.[13]

It was theorized this "perfect storm" of like conditions could diminish the safety for which their donning was intended to prevent. It is well established that dry or damaged hands can serve as a portal of entry as well as increase the risk of transient bacterial carriage and subsequent cross-contamination by way of DHCP's hands.[5,14]

No study was found to refute or support the presence or absence of pathogen bacteria on the inside of utility gloves. Four bacteria that accounts for 34% of all reported hospital-acquired infections were selected for the study.[15] Since the environmental survival of pathogenic bacteria parallels the environmental survival of MDR bacteria of the same species, the presence of pathogenic found inside utility gloves served as an indication that environmental conditions equally favored the growth of MDR bacteria introduced into the same environment.[12] A pilot study was conducted to lend empirical data and to help determine the need for the re-evaluation of the utility glove protocol by answering the following questions:

1. After a day of use, what frequency are gram-positive S. aureus, K. pneumoniae, E. coli and P. aeruginosa present on the inside of used utility gloves?
2. To what degree are utility gloves contaminated?
3. Does the degree of contamination match the expected outcome?

Methods and Materials

Institutional review board approval was granted. The researcher incurred all costs and no financial stakes from the design, conduction or analysis of this pilot study were gained.

Each Wednesday for 6 weeks, 5 steam autoclaved utility gloves from the clean utility glove storage container were randomly selected to serve as control. A convenience sample of 10 used utility gloves placed in the sterilization area for sterilization following an 8 hour clinic day were selected for sampling. The randomness of the used utility gloves samples was defined by the random number of times the gloves are worn, the random size ranging from small, medium, large and extra-large, the variation in hand washing techniques and the variation of unique bacteria found on individual hands.

Utilizing aseptic technique, the inside of each utility glove was turned inside on a fabricated hand form to expose the index finger, palm area and thumb. Utilizing standard biological swabbing technique, a sterile swab moistened with sterile saline was used to collect a sample from each of the utility gloves. The sampling area originated from the index finger, continued from the index finger into palm area and then extended to the tip of the thumb. The swab was used to inoculate the center area of 2 Fisher Brand Sterile 100 mm x 15 mm Polystyrene Petri dishes containing Mannitol Salt agar (Carolina Biological Supply Company, Burlington, NC) and MacConkey agar (Baltimore Biological, Baltimore, MD). A new sterile swab moistened with sterile saline was used to uniformly distribute the inoculum on the Mannitol Salt agar (MSA) employing a standard streak method. A second sterile swab moistened with sterile saline was used to distribute the inoculum on the MacConkey agar employing the same streak method. Additionally, a Petri plate of Mannitol Salt and MacConkey culture media were uncovered at the beginning of the sampling session and covered at the end of the session to serve as an airborne control.

The samples were incubated at 37º C for 30 to 36 hours in aerobic conditions. Each plate was evaluated for CFUs. MSA is selective for salt-loving bacteria such as Staphylococci and differential in that pathogenic species of Staphylococci typically produce yellow colonies with yellow zones. Initially, S. aureus was identified by colony morphology, gram stain and the microscopic examination. Subsequent identification of S. aureus was identified by distinct visual appearance of colony morphology on Mannitol Salt agar. Gram-negative K. pneumoniae, E. coli and P. aeruginosa were identified by the distinct visual appearance on the selective and differential MacConkey culture media. CFU were counted up to 200 per Petri plate. The CFU counts were assigned a range of values to further qualify the degree of contamination expressed per Petri plate as shown in Table I.

Analysis and Statistics

Confidence intervals (CI) were constructed to estimate the rate of contamination. CI's were viewed as the probability that any randomly selected utility glove would express CFU contamination with a 95% confidence level (CL). Data collected from the pilot week of this pilot study were included in the statistical analysis because the results were consistent with the study data.

Results

Rate of contamination: gram-negative K. pneumoniae, E. coli and P. aeruginosa: Petri plates of MacConkey agar expressed no growth for both steam autoclave utility gloves and used utility gloves. Table II summarizes the estimated rate of contamination expressed in confidence intervals for steam autoclave utility glove controls and used utility glove samples.

Degree of used utility gloves contamination: K. pneumoniae, E. coli and P. aeruginosa: No Petri-plate of MacConkey agar expressed gram-negative CFU. Therefore, the degree of contamination could not be calculated.

Rate of contamination: gram-positive S. aureus: Petri plates of Mannitol Salt agar expressed growth for both steam autoclave utility gloves and used utility gloves. Table III summarizes the estimated rate of contamination expressed in confidence intervals for steam autoclave utility glove controls and used utility glove samples.

Degree of used utility gloves contamination: gram-positive S. aureus: The degree of used utility gloves contamination was extremely varied over the seven week sampling period. Therefore the contamination rates were calculated separately for each of the sampling periods. The TNTC entries required an upper limit value to be included. A value of 1400 CFU was assigned to TNTC. Table IV presents the estimated mean intensity CFU with a 95% CL for each sampling periods.

To further explore the relative intensity of used utility gloves samples, the chronology of weeks were arranged to identify perhaps three levels of contamination intensity as illustrated on Table V. By comparing the lower CI and the upper CI limits with the mean, it is clear there is a wide range of contamination from week to week. Arranged in this way, the intensity of contamination is at the lowest level in weeks 3 and 6, followed by weeks zero (pilot week), 1, and 4, with weeks 2 and 5 at the highest level of contamination intensity.

Table I: Designation of CFU to Degree of Contamination per Petri Plate

CFU per Petri Plate	Degree of Contamination
<20	light
20 to 100	moderate
100 to 200	heavy
>200 too numerous to count (TNTC)	gross

Table II: Estimated Rate of Contamination with Gram-Negative K. pneumoniae, E. coli and P. aeruginosa

Steam Autoclave Utility Gloves	n=33 CL 95% (0.000, 0.049)
Used Utility Gloves	n=70 CL 95% (0.000, 0.030)

Table III: Estimated Rate of Contamination with Gram-Positive S. aureus

Steam Autoclave Utility Gloves	n=33 CL 95% (0.233, 0.530)
Used Utility Gloves	n=70 CL 95% (0.273, 0.498)

Table IV: Estimated Mean S. aureus CUF for Each Week of Data Entries

Week	Mean	Lower CI limit	Upper CI limit
0 (pilot week)	4.10	2.84	5.30
1	2.90	1.91	3.97
2	997.28	978.18	1016.80
3	0.20	0.00	0.48
4	5.90	4.43	7.46
5	153.47	145.95	161.22
6	0.10	0.00	0.30

Discussion

Frequency of used utility gloves contaminated and expected outcomes: It was hypothesized that gram-negative culture media would not express growth of K. pneumoniae, E. coli or P. aeruginosa. No petri plate expressed growth and therefore, the raw date matched the expected outcome of zero. CI based on 70 samples and a 95% CL estimated the rate of contamination was no higher than 3%.

It was hypothesized that gram-positive culture media would express growth of S. aureus but would not exceed the upper limits of the average carriage rate of 30% found in general population in the U.S.[17] The raw data yielded a higher than expected outcome of

38.5%. CI, based on 70 samples, and a 95% CL, estimate the rate of contamination to be between 27% and 50%. However, the unexpected growth of S. aureus from steam autoclave utility gloves controls confounded the used utility glove sample results.

The raw data of steam autoclave utility gloves showed a contamination rate of 37.1%. CI, based on 35 samples, and a 95% CL, estimate the rate of contamination to be between 23% and 53%.

Degree of contaminated with S. aureus: The raw data of steam autoclave utility glove controls and statistical analysis of used utility glove samples produced a wide variation of contamination levels ranging from under 20 CFUs to over 200 CFUs per Petri plate. Beyond the degree of contamination, CI's suggest a wide variation in the intensity of contamination.

When the used utility glove sample mean intensity confidence intervals are paired with the corresponding week of raw steam autoclave utility glove CFU control data, the contamination intensity and the range of contamination are closely matched (Table VI). The similarities of steam autoclave utility gloves to used utility gloves samples suggest the possibility of a correlation. It is reasonable to hypothesize steam autoclave utility gloves contamination was a contributing factor to the S. aureus growth expressed from the used utility gloves samples. Additionally, the 3 levels of contamination shown in Table V suggest there is some mechanism or process or event that occurs some weeks and not others that might explain the high level of variation between weeks.

Steam autoclave utility glove contamination with S. aureus: Weekly biological spore tests were conducted in the morning and utility gloved sampling was conducted in the afternoon of the same day. The spore test results indicated all autoclaves were functional. It seems unlikely that functional steam autoclaves would kill highly resistant spores and not kill the less resistant staphylococci bacteria. The possible mechanism, process or event that preceded steam autoclave utility gloves contamination from functional autoclaves present concerns about the standard steam autoclave sterilization procedures and the subsequent handling/ storage of sterilized utility gloves. A number of possible contributing factors must be considered:

- Over-loading autoclave: Overloading may not allow for sufficient penetration for the utility gloves located closer to the middle of the autoclave.
- Length of time utility gloves were stored: Utility gloves were stored in a covered storage container over the summer. It is possible that the utility gloves became contaminated due to an extended period of storage.

Table V: Three levels of Used Utility Gloves Sample Contamination Intensity Grouped by Week

Week	Mean CFU	Lower CI limit	Upper CI limit
3	0.20	0.00	0.48
6	0.10	0.00	0.30
0 (pilot week)	4.10	2.84	5.30
1	2.90	1.91	3.97
4	5.90	4.43	7.46
2	997.28	978.18	1016.80
5	153.47	145.95	161.22

Table VI: Comparison: Used Utility Gloves Lower and Upper CI of Contamination Intensity to Steam Autoclave Utility Gloves Raw Data

Week	Used Utility Gloves contamination intensity lower CI	Used Utility Gloves contamination intensity upper CI	Steam Autoclave Utility Gloves range of CFU per plate/raw data
3	0.00	0.48	0
6	0.00	0.30	<20
0 (pilot week)	2.84	5.30	<20 to >200
1	1.91	3.97	<20
4	4.43	7.46	<20
2	978.18	1016.80	100 to >200
5	145.95	161.22	100 to 200

Table VII: CI Estimated Rate of Petri Plate Contamination

MacConkey culture media	95% CI (0.011, 0.054)
Mannitol salt culture media	95% CI (0.022, 0.073)

- Condition utility gloves were stored: Utility gloves that were stored wet could have facilitated bacterial growth if S. aureus was already present. It has also been shown that S. aureus and MRSA have been recovered after periods of desiccation.[12]
- Airborne contamination: Airborne controls of Mannitol salt agar yielded a mean of 2.14 CFU per Petri plate for the 7 week trails.
- Damaged Utility Gloves: Damaged utility gloves such as tears or could provide and entry point for environmental S. aureus contamination.

Alternatively, contamination could explain the expression of S aureus on culture mediate from samples taken from steam autoclave utility gloves. Given

the technique sensitive method of preparing, handling and inoculation culture media, technique error cannot be ruled out.

Study limitations: steam autoclave utility gloves as "negative" controls: The study intended to evaluate the presence or absence of specific pathogenic bacteria inside utility gloves as a result of the protocol for donning and removing them during a day of clinical use. The contamination of steam autoclave utility gloves controls with S. aureus confounded used utility gloves sample results.

The study design did not include controls to estimate the rate of sterile swab and sterile saline contamination. Culture media was prepared by the researcher and inspected for contamination prior to use. The number of contaminated culture media was recorded each week. The estimated rate of contamination of solid culture media preparation was evaluated with CI (Table VII).

Testing such as blood agar, alpha-hemolysis, coagulase activity and catalase should have been conducted to further differentiate of S. Aureus CFU on the Mannitol Salt agar. There is no standardized method for sampling environmental surfaces largely due to the vast variety of surface areas chosen to sample by researchers. UMA, Dental Health Programs provides 4 sizes of utility gloves; small, medium, large and extra-large. The size variation helped to define the randomization of the utility gloves sampled but also served to weaken the strength of the study outcomes because the size of surface area sampled inside the utility gloves varied corresponding to the size of the utility glove.

The sample size was small for CI to be constructed. The confidence intervals would be narrower given a more precise estimate of the contamination rates. The arbitrary assignment of 1,400 CFU to any value beyond the CFU count of 200 for the purpose of measuring the intensity/degree to which utility gloves were contaminated does not accurately represent the true level of contamination and therefore, limits interpretation of the data represented on Tables I, V and VI.

The emergence and dissemination of MDR bacteria begs a concerted effort by all health-care providers to review and, if necessary, revise current infection control policies and procedures. The small sample size of this pilot study limits the conclusions that can be drawn. However, confidence intervals indicate the risk of utility glove contamination with gram-negative bacteria to be low. The findings of this study support current literature suggesting a low risk of transmission and/or infection with gram-negative bacteria in dentistry.[16]

Study design limitations and study design flaws notwithstanding, the unexpected contamination of steam autoclaved utility gloves illuminate a potential gap in infection control. The ramifications of DHCP's donning utility gloves contaminated with S. aureus are unclear. However, steam autoclave utility gloves's contaminated with S. aureus may put DHCP's at risk for infection and increase the risk of becoming hand carriers of pathogenic bacteria.[7,17]

Utility gloves, considered a non-medical device, are not regulated by the FDA. Therefore, the quality of utility gloves varies by manufacturer specifications. This researcher found no studies in the literature evaluating the efficacy of utility gloves for their intended purpose of protecting DHCP's from chemical and puncture injury nor were any studies found evaluating steam autoclave effects and/or efficacy on utility glove material. The data collected from this pilot study can serve as an impetus for a more scientific and controlled study.

Conclusion

The risk of utility glove contamination with gram-negative bacteria is low. The expressed growth of S. aureus from steam autoclave utility gloves controls raises questions about the effectiveness and safety of generally accepted sterilization standards for governmentally mandated use of utility gloves. Subsequent research should be conducted to more thoroughly differentiate, count and statistically analyze microbial flora found on the inside of utility gloves. Research should also be conducted to determine if there are differences in material quality between manufacturers and to evaluate the effectiveness of steam autoclave sterilization. In the era of evidence-based practice, the lack of studies representing the mandated use of utility gloves, combined with non-standardized protocols, increases the potential risk of discrepancies in infection control outcomes.

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