5-2023

The effect of different types of plastic and rubbers often found in healthcare facilities on the survival of potentially pathogenic bacteria

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The Effect of Different Types of Plastic and Rubbers often found in Healthcare Facilities on the Survival of Potentially Pathogenic Bacteria

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Departmental Honors Thesis

The University of Tennessee at Chattanooga

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Examination Date: April 10th, 2023

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Acknowledgments

First and foremost, I would like to praise and thank God, who has granted countless blessing, knowledge, and opportunity so that I would be able to successfully finish my thesis. I would start by acknowledging and thanking Dr. Spratt for being a wonderful thesis director and guiding me through this entire process. I truly could not have finished this project if it were not for him, and I am truly grateful. I would also like to thank Dr. Levine for all his help with my project. Dr. Levine provided many of the materials used in the study, helped edit the posters I presented, and he conducted the statistical analysis for this study. I would also like to thank Dr. Giles for all his help especially with editing. I truly could not have finished this thesis if it were not for my family. I am so grateful for all the support and love from my parents and brothers. And lastly, but not least, I would like to thank my friend, Lana, for always being there for me and giving me the courage to never give up.

Abstract

This study focused on the survival of different species of bacteria on different types of plastics and rubbers found in healthcare facilities. The gram-positive coccus *Staphylococcus aureu*s and the gram negative bacillus *Escherichia coli*, known to have importance as potential pathogens in healthcare facilities, were tested on two types of plastic (polyurethane and Polyvinyl Chloride (PVC)) and two types of rubbers (latex and nitrile) typically found on reusable healthcare surfaces. Known quantities of bacteria were aseptically placed on disinfected plastic surfaces in triplicate, air-dried, and then incubated at room temperature for 30 minutes, 20 hours, and 40 hours. After incubation, samples were collected from the plastic and rubber surfaces using sterile swabs and serially diluted before being plated on tryptic soy agar for plate counts. *S. aureus* had much higher survival rates, up to 37%, compared to *E. coli*, which only had survival rates of up to 11%. Both *E. coli* and *S. aureus* had the highest survival rates on the PVC materials as opposed to any other material. E. coli showed the lowest maximum survivability on latex gloves at 6.0%. *S. aureus* had the lowest maximum survivability on nitrile gloves at 1.4%. The data also shows that *E. coli* had lower rates of survival at 30 minutes, 20, and 40 hours as compared to *S. aureus*. *S. aureus* had lower rates of survival at 40 hours on both the nitrile and latex gloves as opposed to *E. coli* at 40 hours on the rubber materials. The relevance of these findings is that depending on the materials used in healthcare facilities, there may be better choices of plastics or rubbers to suppress the growth of unwanted environmental bacteria. Additionally, the potential for the addition of antimicrobial chemicals to plastic and rubber materials to help suppress microbial numbers on these surfaces may help reduce HAIs linked to environmental exposures.

Section 1

1.1 Introduction

Treatment of patients in healthcare facilities is most often associated with positive outcomes. However, some patients may end up having higher morbidity and mortality rates due to healthcare-associated infections (HAIs) they contracted while being treated (abłońska-Trypuć et al., 2022). Nearly 1.7 million people in the United States are thought to contract HAI illness each year, resulting in close to 99,000 deaths (Healthcare-acquired infections (HAIS)). Although the endogenous bacterial flora of the patient is thought to be the primary cause of HAIs, 20 to 40% of HAIs are estimated to be the result of cross-contamination with other patients, possibly via contact with surfaces in the clinical environment (Jabłońska-Trypuć et al., 2022). Many Gram-negative bacteria and Gram-positive bacteria can contaminate surfaces and cause HAIs (Kilpatrick et al., 2011). These pathogens can spread to human skin even on just one touch with a contaminated surface. *Escherichia coli*, *Salmonella* spp., *Staphylococcus aureus* (100% of cases), *Candida albicans* (90%), rhinoviruses (61%), HAV (33%), and rotaviruses (16%) are the diseases that can be spread most readily from inanimate surfaces to the skin (Jabłońska-Trypuć et al., 2022). The bacteria on one's hands can spread to different surfaces, where they can re-infect patients and medical personnel (Kilpatrick et al., 2011). The risks posed by contaminated surfaces cannot be disregarded given the extremely low compliance rate for hand washing among healthcare professionals (Kilpatrick et al., 2011).

One of the most common materials that patients may come in contact within modern healthcare facilities is plastics. Medical-grade plastics or polymers must be designed and produced under a physician’s license to pass the verification and evaluation requirements of regulatory agencies (BMP Medical, 2023). Not only must medical grade plastics provide

biocompatibility for particular applications involving patient safety and withstand the high wear and repeated sterilization cycles medical plastic products are subject to (if they can be reused), but they must also support very low numbers of microorganisms to ensure the health and safety of patients (*What are the best types of plastic for medical equipment or devices?, 2021).* Some of the most common plastics used in healthcare settings are nylon, polyethylene terephthalate (PET), polyimide (PI), polycarbonate (PC), acrylonitrile butadiene styrene (ABS), polyetheretherketone (PEEK), polyurethanehane (PU), polyvinyl chloride (PVC), polypropylene (PP), polyethylene (PE), and polystyrene (PS) (Craftech Industries, 2022). PVC is the plastic material that is most frequently used in medical applications, followed by PE, PP, PS, and PET (Craftech Industries, 2022). Another material the patients come into contact within the healthcare setting is rubbers, usually as gloves. The most commonly used gloves are nitrile and latex. Since most healthcare providers use gloves to interact with patients, it is crucial to understand the survivability of microbes on the surface of gloves.

This study focused on the survivability of two species on various rubber and plastics: *Escherichia col*i [EC], and *Staphylococcus aureus* [SA], both of which are just two of many pathogens associated with HAIs in clinical settings. These bacteria have been chosen due to their prevalence on clinical surfaces. The rubbers and plastics which were used in this study are PVC, polyurethane, nitrile, and latex. These materials have been chosen due to their ubiquity in healthcare settings. The data generated here should help establish surface-specific propensity for bacterial colonization and may inform disinfections protocols in clinical settings.

1.2 Background and Literature Review

HAIs are illnesses that are contracted in a hospital or healthcare facility, which manifest within 48 hours or more after hospital admission or within 30 days after release after patient treatment (Revelas, 2012). HAIs are neither active nor developing at the time of admission, and they have no connection to the primary ailment that brought the individual to the medical facility (Revelas, 2012). There are several factors that make HAI even more concerning in the twenty-first century. These factors include the many medical procedures that bypass the human body's natural protective barriers and medical staff moving from patient to patient, providing a way for pathogens to spread (Revelas, 2012). Additional factors include hospitals housing a large number of sick individuals whose immune systems are frequently weak, a rise in outpatient treatment [which means individuals who are in hospitals are sicker on average], inadequate sanitation protocols, equipment sterilization, and sanitation of hands (Revelas, 2012). Furthermore, the consistent utilization of antimicrobial agents in healthcare settings creates selection pressure on existing microorganisms and assists in the emergence of resistant forms of pathogens (Revelas, 2012).

Both adult and pediatric patients can contract HAIs. Infections of the urinary tract constitute the most prevalent HAIs in adults, whereas bloodstream infections, pneumonia, and urinary tract infections are the most common infections in children (Revelas, 2012). HAIs are more common among pediatric patients under the age of one, infants with extremely low birth weights (1000g), and young patients in the PICU or NICU (Revelas, 2012).

Group A *streptococci* (GAS) accounted for the majority of HAI issues throughout Ignaz Semmelweis' time period (Revelas, 2012). In fact, the nurse and midwives that work alongside Semmelweis made the connection between GAS and childbed fever. Gram-positive cocci, in

particular *streptococci* and S. aureus, were the HAIs of primary concern throughout the following 50 to 60 years (Revelas, 2012). Moreover, the SA phage type 94/96 pandemic that occurred between 1940 and 1950 brought these issues to a head, leading to a significant increase in HAIs (Revelas, 2012). Additionally, gram-negative bacteria, especially *Pseudomonas aeruginosa* and *Enterobacteriaceae*, emerged to be associated with HAIs in the 1970s (Revelas, 2012). Different types of antimicrobial medications that were effective against gram-negative bacilli during the late 1980s and early 1990s, but they only offered temporary relief (Revelas, 2012). And the emergence of *vancomycin-resistant enterococci* (VRE) and *methicillin-resistant S. aureus* (MRSA) during this time, indicated the return of the "blue bugs" (Revelas, 2012). *S. aureus*, *coagulase-negative staphylococci*, and *enterococci*, the three most prevalent gram-positive pathogens, caused 34% of HAIs from 1990 to 1996 (Revelas, 2012). *E. coli*, *P. aeruginosa*, *Enterobacter spp*., and *Klebsiella pneumoniae*, the four most prevalent gram-negative pathogens, caused 32% of HAIs from 1990 to 1996 (Revelas, 2012). More recently the trend of shorter inpatient stays has made it more challenging to track HAIs by location (Revelas, 2012). For instance, the current average postoperative hospitalization is approximately 5 days, which is less than the incubation period of 5 to 7 days for *S. aureus* surgical wound infections (Revelas, 2012). Additionally, one of the main issues facing hospitals recently is acquired antibiotic resistance (Revelas, 2012). The primary gram-positive infections of concern are *VRE* and *MRSA*, whereas the primary gram-negative pathogens are *P. aeruginosa*, *Klebsiella*, and *Enterobacter* which carry chromosomal or plasmid-mediated beta-lactamase enzymes (Revelas, 2012).

HAIs place a significant financial and administrative burden on healthcare systems. HAIs are thought to affect two million people annually in the United States, resulting in 99,000 deaths

overall, and cost $33 billion annually (Al-Tawfiq & Tambyah, 2014). The SENIC (Study for Effectiveness of Nosocomial Infection Control) research put the cost of HAIs at $4.5 billion in 1992; after accounting for inflation, it increased to over $6.6 billion in 2007 (Al-Tawfiq & Tambyah, 2014). Inadequate research has been done on how HAIs affect the economies of low- and middle-income nations (Al-Tawfiq & Tambyah, 2014). In a study of ICUs in Mexico City, central line-associated bloodstream infections, a type of HAI, were linked to a 20% higher attributable death rate and a mean additional hospital expense of $11,591 dollars (Al-Tawfiq & Tambyah, 2014).

The ability of the microbe to survive on an environmental surface is a crucial component in the transmission of microbes from individual to individual or from the environment to an individual (Neely, 2000). The specific bacterial species, the size of the inoculum, and the substance under test were all found to be factors in the survival of the bacteria on a given surface (Neely, 2000). A study conducted at the Shriners Hospitals for Children and the Department of Surgery in Dayton Ohio found that bacteria survived on the surface at 102 microorganisms per swatch for less than 1 hour (Neely, 2000). The duration of survival varied from 2 hours to more than 60 days at 10(4) to 10(5) bacteria per swatch (Neely, 2000). The swatches were taken from 100% cotton, 100% cotton terry, 60% cotton-40% polyester blends, 100% polyester, 25% spandex-75% nylon blends, 100% polyethylene plastic, and 100% polyurethane. The results of the study show that while isolates tend to survive better on synthetic materials compared to cotton materials, isolates survived the longest on plastic materials (Neely, 2000). These findings highlight the importance of thorough cleaning and diligent contact control practices in settings that cater to immunocompromised individuals (Neely, 2000).

A study conducted on the survival of bacterial strains on wood compared to polycarbonate, aluminum, and stainless steel found that the total viable cell count for oak (transversal and tangential) was significantly lower than for polycarbonate, stainless steel, and aluminum, and the colony forming unit (CFU) bacterial counts on wood materials decreased more quickly. The bacterial counts on day 0 between wood material and the other materials were very different, making it challenging to compare this decrease (Chen et al., 2020). The only exception was that *Acinetobacter baumannii* (AB) did not survive differently on polycarbonate or oak (Chen et al., 2020). In fact, the minimum detectable limit (MDL) for *E. faecalis*, *K. pneumoniae*, and SA was reached on oak materials in 0 to 2 days, while the MDL was not achieved on polycarbonate, stainless steel, or aluminum until 15 days (Chen et al., 2020).

The objective of this study is to help provide baseline statistics for the potential of microbial survivability on various types of plastics commonly used in healthcare settings. Both latex and nitrile gloves, commonly used gloves, are used in this study. Samples from a fit ball and a cold pack, both made from polyvinyl chloride (PVC), commonly used in rehabilitation clinics, are also used in this study. Additionally, samples from a balance pad, made from polyurethane, which is also commonly used in rehabilitation and other healthcare settings, are also used in this study. This study focused on the survivability of two species of microbes on these plastics: EC and SA, both of which are pathogens commonly associated with HAIs in healthcare settings. After the application of known quantities of these bacteria to the devices, surviving cells were enumerated for as long as 40 hours after inoculation. Understanding the extent of microbial survival on the surfaces of plastics in healthcare settings will raise awareness of this potential source of bacterial contamination that could possibly lead to HAIs in healthcare.

Section 2

2.1 Materials:

This study was conducted in UTC's Clinical Infectious Disease Control (CIDC) research group's lab, in Holt Hall (room #305). The lab strains of *Escherichia coli* [EC], and *Staphylococcus aureus* [SA] were obtained from the UTC Microbiology culture collection (traceable to ATCC strain 25922 [EC], and ATCC strain 25923 [SA]) and maintained on either Tryptic Soy Agar (TSA) slants or in Tryptic Soy Broth (TSB). Both TSA and TSB were made according to manufacturer instructions and autoclaved before being aseptically transferred into sterile Petri dishes or sterile test tubes. All TSA plates were stacked and allowed to dry excess moisture for 72 hours before being used. Sterile saline (0.85% NaCl) was made according to standard instructions and autoclaved before being aseptically transferred into sterilized test tubes. For dilutions, the volumes of sterile saline were carefully measured using highly accurate automatic pipettes with sterile pipette tips and following aseptic techniques.

Plastics and rubbers selected for use in this study included: PVC, polyurethane, latex, and nitrile. The ColPac, Fit Ball, and Balance Pad samples were obtained from the UTC Department of Physical Therapy [PT] [Appendix 1]. The nitrile gloves (Fisherbrand, Fisher Scientific, Suwanee, GA) were obtained from the CIDC research lab and the Cardinal Health Protexis latex gloves were obtained from CHI Memorial [Appendix 1]. Each of the different types of plastic and rubbers were cut to produce uniformly sized pieces for the study. At least nine pieces of each plastic type were prepared to allow for replicated sampling in the experiments. To prepare the plastic samples for experiments autoclaving could not be used on any heat-sensitive materials. Thus, the disinfection process required the use of a chemical disinfectant, Roccal-D Plus (Pharmacia & Upjohn Co, Div Pfizer, Inc, New York, NY). To disinfect pieces of plastic

required that they be dipped into a bowl of the disinfectant three times and shaking them between each dip. After the plastic samples had been soaked with the solution, the plastics and rubbers were washed off with sterile water (sterilized in polypropylene squirt bottles in the autoclave) and dried using sterile KimWipes (folded to fit inside of glass Petri dishes, autoclaved, and dried in the drying oven for 48 hours at 60 ℃). The disinfected pieces of plastic were then placed into glass Petri dishes in a drying oven (60 ℃) where they were dried for approximately 48 hours. Additionally, the pipet tips used in the serial dilution scheme and to transfer diluent were autoclaved, dried in the 60 ℃ drying oven, and stored in a cool dark place prior to usage.

2.2 Methods:

To conduct experiments disinfected pieces of a particular plastic were used, along with one of the two species of bacteria being tested. Then the lab strains of EC and SA (one culture at a time) were used to inoculate specific types of disinfected plastic and rubbers to initiate time course experiments of bacterial survival on those materials.

For each experiment known quantities of the bacterium being tested were counted using serial dilutions to generate viable plate counts. Once the dilution series was made, the plates used to count the number of cells in the overnight culture (ONC) were placed in a 37 ℃ incubator for 48 hours. To produce aliquots of the diluted culture to transfer to the plastic pieces, the dilution series tube that generated the 10^{-3} dilution (which had been made using TSB, rather than the 0.85% Saline because of the importance of mimicking the presence of organic matter on the surfaces when the bacteria were dried down [Spratt et al., 2019] was used for the culture transfer to the plastics and rubbers. The diluted culture (0.025 ml) was aseptically transferred to a predetermined area of 4 cm^2 onto each of the nine replicated plastic pieces. Afterward, the

diluent culture on the plastic pieces was air dried using compressed, filtered air for approximately 10 minutes or until it was visibly completely dried. Each of the pieces of plastic or rubbers and dried cultures were placed inside sterile glass Petri dishes. Once the final replicate was air-dried, the time course experiment started. Incubation of the dried samples took place on the lab bench at room temperature.

To collect any surviving bacteria from the plastic and rubber pieces, sterile transport swabs (with liquid Stuart's Medium, Fisherbrand, Fisher Scientific, Suwanee, GA) were used to swab the areas on the plastics and rubbers where the bacterial cultures had been placed and dried. For each experiment the replicated pieces of plastic and rubber (three at a time) were swabbed at 30 minutes, 20 hours, and 40 hours post drying to yield time course data extending out to 40 hours from the drying time. Each replicated sample was swabbed for approximately 10 seconds, with the swab then placed into 5 mL of sterile saline solution (note to ensure that this tube could be capped, only the swab and about 3 cm of the swab's plastic shaft were placed into the saline, using flame sterilized scissors to cut the plastic shaft). The swab within the saline solution was then vortexed for approximately 30 seconds before 0.5 mL was transferred using a sterile pipette to a test tube containing 4.5 mL sterile saline. Afterward, the test tube was also vortexed for approximately 30 seconds. Then they were used to inoculate a sterile TSA plate for enumeration of the surviving cells at the period of time elapsed during the time course experiment. This data was used to determine the colony-forming units per milliliter (cfu/ml) of diluent produced at each specified time for each bacterium on each plastic and rubber type in a replicated fashion.

2.3 Experimental Design:

At the start of every experiment, the bacterial culture being used was grown on a TSA slant for approximately 72 hours at room temperature. The following are the steps taken to collect cells from the TSA tubes: the TSA test tube containing the growing bacterial culture 'lip' was flamed after removing the cap, then the flame-sterilized inoculating loop is inserted into the test tube to remove a small number of bacteria, and then inserted into a 3 mL sterile TSB test tube using aseptic technique. The 3 mL TSB containing the bacteria culture was then placed in a shaking incubator at 37℃ overnight to grow. After 24 hours of incubation, this TSB culture was then used to make the serial dilution, following the procedure outlined in Figure 1. As noted above, the 10^{-3} dilution in this series had been made using TSB to ensure that the cells being placed on the plastic surfaces were dried in an organic matrix. The TSB 10^{-3} dilution was placed in an ice bath to stop any growth of the cultures as all of the pieces of plastic were inoculated with bacterial cells. The chilled test tube containing the 10^{-3} dilution was then used within 10 minutes to place 0.025 mL quantities of the bacteria on the surfaces of the plastic samples. This 10^{-3} dilution was removed from the ice bath, vortexed for 30 seconds, and then 0.025 mL was "painted" onto a predetermined 2cm x 2cm section on the plastic samples using a sterilized pipette tip to distribute the bacterial cells. The bacterial cells were dried using a light stream of filtered air for approximately 30 minutes [approximately 10 minutes per plastic sample], or until there were no visible undried bacteria left on the surface of the device. Once dried the T1 and T2 plastic samples were moved to a cool dark place for the time course experiment (until the 20- and 40-hours' time marks). As for the T0 plastic samples, thirty minutes after the drying was complete the 3 replicated pieces of plastic were swabbed using sterile transfer swabs, aiming to

remove as many of the bacteria present as possible, for approximately 10 seconds, being sure to rotate the swab to ensure the entire surface of the swab was in contact with the 2cm x 2cm area that the bacteria was placed. The swabs were then immediately placed into test tubes containing 5 mL of saline, mixed, and then diluted. These dilutions (10^{-1} and 10^{-2}) coming from the swab were transferred to sterile TSA plates and incubated. The inoculated TSA plates were then inverted and incubated at 37 C for 24 hours. This procedure was repeated at 20 hours (T1) and 40 hours (T2) on each of the triplicated plastic samples. Once grown, colony counts for each plate for each bacterium and plastic sample were counted and recorded for the incubation period in the time-course experiment.

2.4 Calculation and Statistical Analysis:

In order to conduct do a statistical analysis, determination of the total number of bacteria in the overnight culture used in the serial dilution scheme had to be made. To do this, the highest statistically valid colony number from the viable plate count was multiplied by the total dilution factor that was plated and then divided by the total volume places on the plates, 0.1 ml. This allowed the CFU/ mL to be calculated for each dilution in the dilution scheme.

Next, the viable plate counts from the inoculated plastics and rubbers had to be calculated in order to calculate the percentage of bacteria survival on each device. To calculate the total number of CFU/5 mL, the colonies produced from the 10^{-1} and 10^{-2} TSA plates were first counted, and then the number was divided by 10^{-1} to yield CFU/ 1 mL. Then all three numbers were averaged before the number was multiplied by 5 to represent the number of bacteria in each 5 mL test tube. Once this value was calculated, it was divided by the number of bacteria in the 10^{-3} dilution and multiplied by 100 to obtain a percentage [Appendix 2 and 3].

Section 3

3.1 Results

Comparisons of the percent survival of either EC or SA when placed on the moldable surface materials found on most of the surfaces studied. Note that summations of the percent survival for EC and SA on the different types of plastic and rubber are also found in Appendix 4 at the end of this report. The largest difference in survival for EC and SA was for both PVC materials. But the largest difference in maximum survival was for the PVC cold pack. When looking closely at the maximum percent survival of both microbes we can see that, on the PVC fit ball EC had a maximum survival of 7.8% compared to SA at 33.1% maximum survival. EC had a maximum survival of 11.2% on the PVC cold pack compared to the 36.9% maximum survival of SA. EC had a maximum survival of 7.0% on the polyurethane pad compared to the 17.7% maximum survival of SA. On latex gloves EC had a maximum survival of 6.0% compared to SA at 23.4% survival. And on nitrile gloves, EC had a maximum survival of 6.4% compared to SA at 1.4% survival. [Figures 4 and 5]

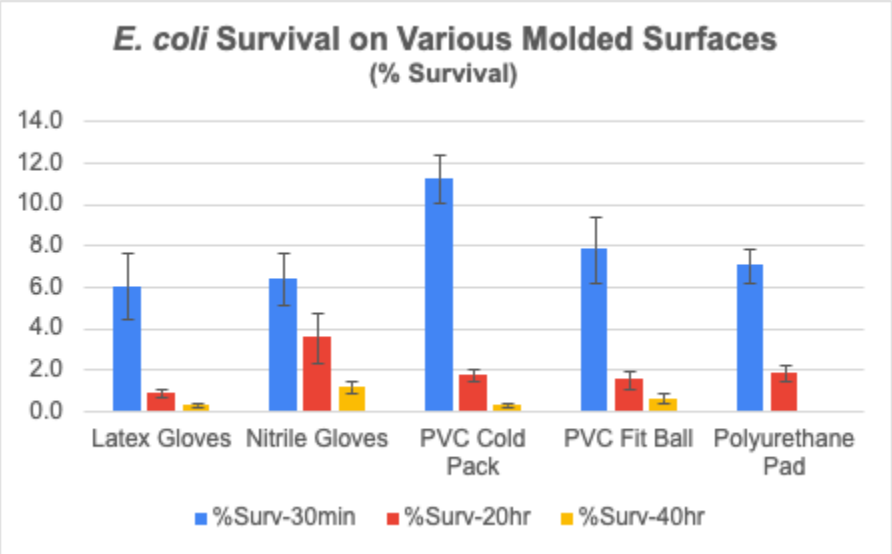

Figure 1: *E. coliv*survival at T= 30 minutes, T= 20 hours, and T=40 hours; This figure shows the percentage of bacteria survivals at 3 different time intervals on different materials.

When looking at the data collected for the PVC fit ball the average percent survivability was 7.8% (EC) and 33.1% (SA) at T=30 minutes post-drying time [Figure 3 and 5]. At 20 hours, percent survivability was calculated to be 1.5% (EC), and 19.9% (SA) [Figure 7]. Lastly, at 40 hours, percent survivability yielded 0.6% (EC), and 3.7 % (SA) [Figure 1]. The results of the statistical analysis indicate that at 30 minutes SA survived to a higher degree than EC for the PVC fit ball with a p-value of 0.07. This p-value indicates that the data is not statistically significant. SA lived longer at 20 hours on the PVC fit ball compared to EC with a p-value less than 0.05. This would mean that the data is statistically significant.

When looking at the data collected for the PVC Cold Pack the average percent survivability was 11.2% (EC) and 36.9% (SA) at T=30 minutes post-drying time [Figure 3]. At 20 hours, percent survivability was calculated to be 1.8% (EC), and 28% (SA) [Figure 5]. Lastly, at 40 hours, percent survivability yielded 0.3% (EC), and 7.1 % (SA) [Figure 6]. For the PVC Cold pack, after 20 hours on this surface SA survival was over 10 times higher than was observed for EC (28% vs 2%). The results of the statistical analysis show that SA lived longer (20 and 40 hours) on the PVC cold packs compared to EC with a p-value of less than 0.05. This means that it is statistically significant. At 30 minutes SA survived to a higher degree than EC on PVC cold packs with a p-value of 0.08. This p-value would mean the data is not statistically significant.

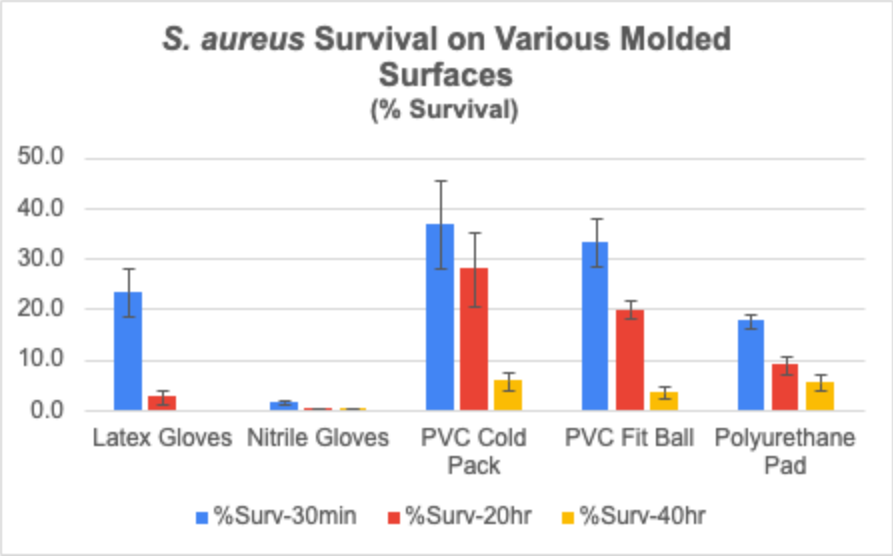

Figure 2: *S. aureus* survival at T= 30 minutes, T= 20 hours, and T=40 hours; this figure shows the percentage of survival of SA on the different materials tested at the three-time intervals tested.

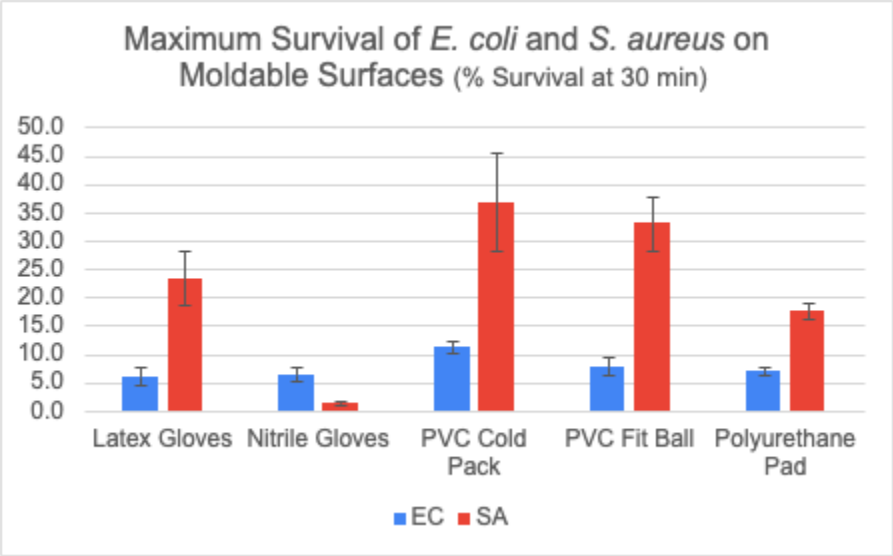

Figure 3: Maximum survival of *E. coli* and *S. aureus* at 30 minutes on all of the materials tested; this figure shows the comparison of maximum survival for both microbes tested on all of the materials tested.

When looking at the data collected for the polyurethane pad differences in the percent survivability for EC and SA were reduced compared with the PVC surfaces. For example, at 20 hours percent survivability for EC was 1.8%, while 8.9% of SA survived [Figure 8]. Survival of these bacteria dropped off steeply after 40 hours, with 0.0% for EC, and only 5.5% for SA [Figure 5]. The results of the statistical analysis show that at 30 minutes SA survived to a higher degree than EC for the polyurethane pad with a p-value of 0.08. This value would mean that the data is not statistically significant. SA lived longer at 20 hours and 40 hours on the polyurethane pad compared to EC with a p-value of less than 0.05. This would mean that the data is not statistically significant.

When looking at the data collected for the latex and nitrile gloves survival of EC and SA was very different. After 20 hours both EC and SA survival was minimal, showing approximately 1% (EC) vs. 5% (SA), although no SA survived on latex gloves after 40 hours, while there was minimal survival of EC at this incubation time [Figure 10]. When the survival of EC and SA was determined for nitrile gloves, for the first time EC showed greater survival than SA at all times measured, although percentage survival on nitrile gloves was fairly low compared with many of the other surfaces compared here [Figure 3 and 9]. For SA the percent survival on nitrile gloves was only 0.5% after 20 hours [Figure 4]. When compared with latex gloves after 20 hours SA survival was approximately 2.5% [Figure 4]. The results of the statistical analysis show that at 30 minutes SA survived to a higher degree than EC for latex gloves with a p-value of

0.02. This would mean that the data is statistically significant. Additionally, at 30 minutes SA survived to a higher degree than EC on nitrile gloves with a p-value of 0.07. This would mean that the data is not statistically significant. On the other hand, EC survived longer at 20 and 40 hours for both latex and nitrile gloves.

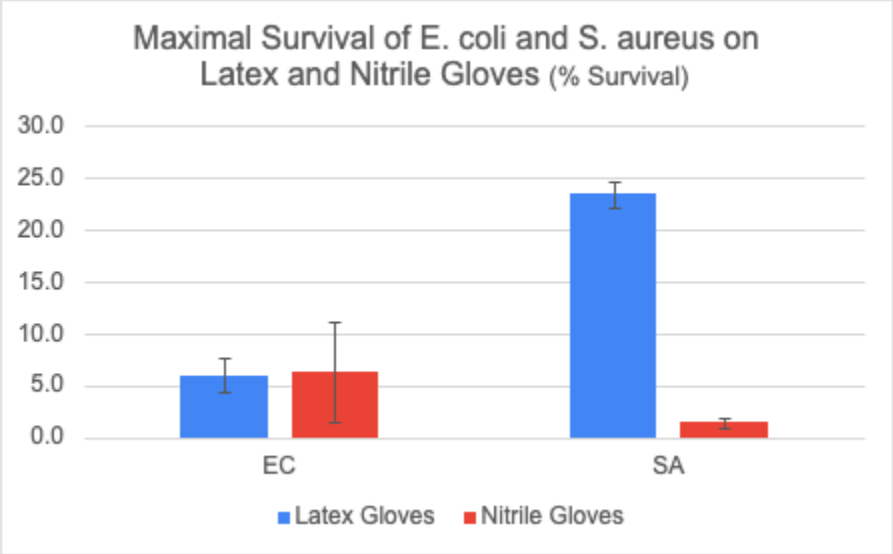

Figure 4: Maximum survival of *E. coli* and *S. aureus* comparison at 20 and 40 hours for 2 types of rubbers tested; Independent Sample T-tests, $p \leq 0.05$; this figure compares the survival of both microbes on the 2 rubber materials tested.

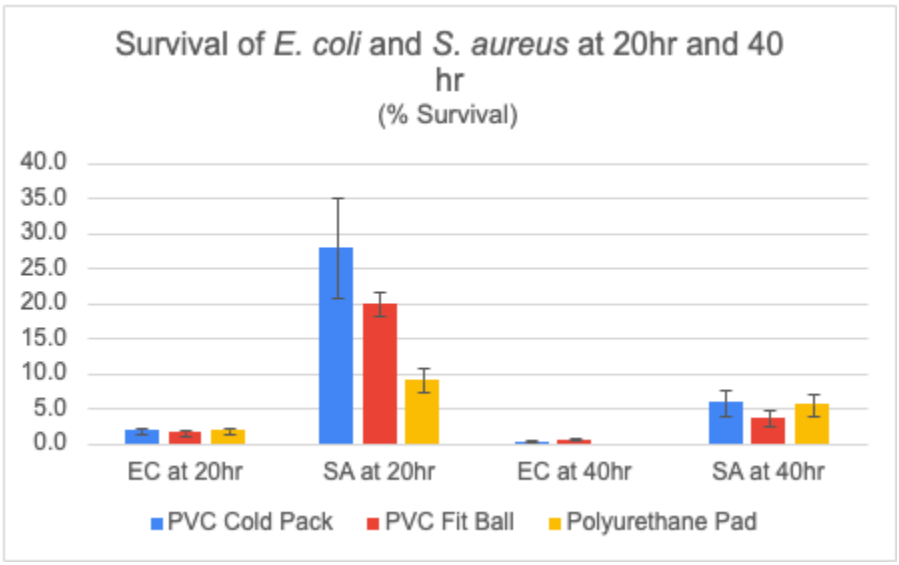

Figure 5: Survival of *E. coli* and *S. aureus* comparison at 20 and 40 hours for 3 types of plastics tested; Independent Sample T-tests, $p \leq 0.05$; this figure compares the survival of both microbes on the 3 plastic materials tested.

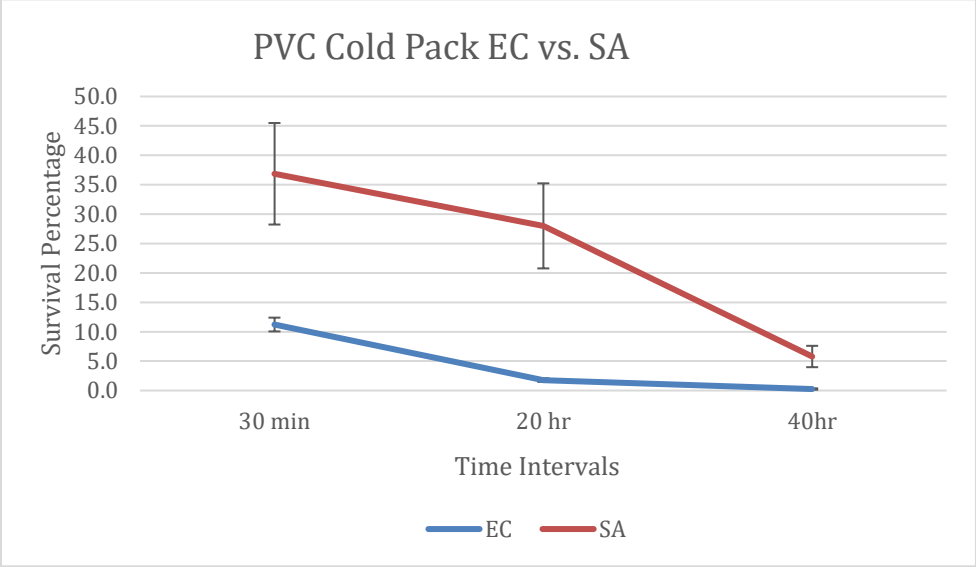

Figure 6: Survival of *E. coli* and *S. aureus* comparison at 30 minutes, 20 and 40 hours for the PVC Cold Pack; this figure compared the survival of both microbes on PVC Cold Pack at all 3 times swabbed.

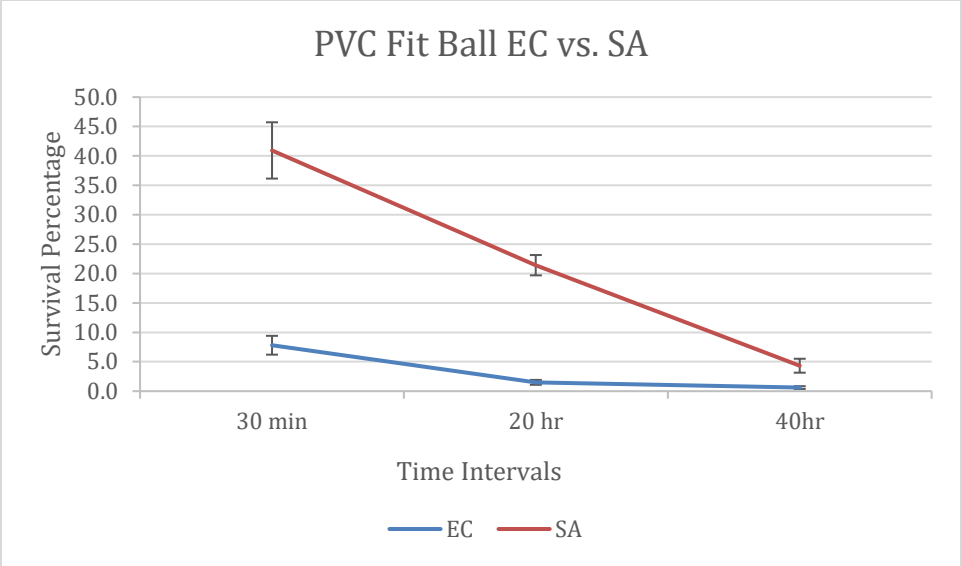

Figure 7: Survival of *E. coli* and *S. aureus* comparison at 30 minutes, 20 and 40 hours for the PVC Fit Ball; this figure compared the survival of both microbes on PVC Fit Ball at all 3 times swabbed.

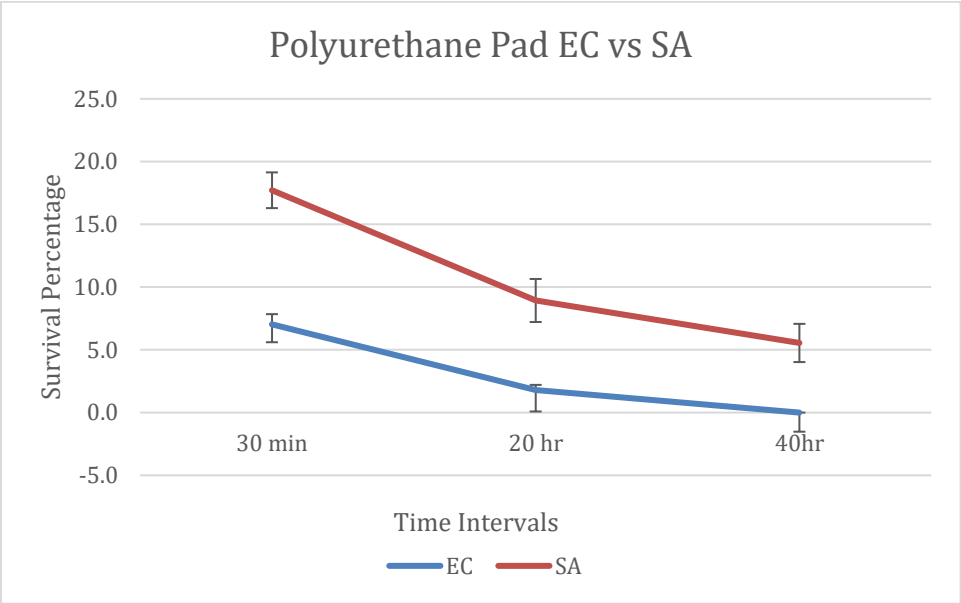

Figure 8: Survival of *E. coli* and *S. aureus* comparison at 30 minutes, 20 and 40 hours for the Polyurethane Pad; this figure compared the survival of both microbes on Polyurethane pad at all 3 times swabbed.

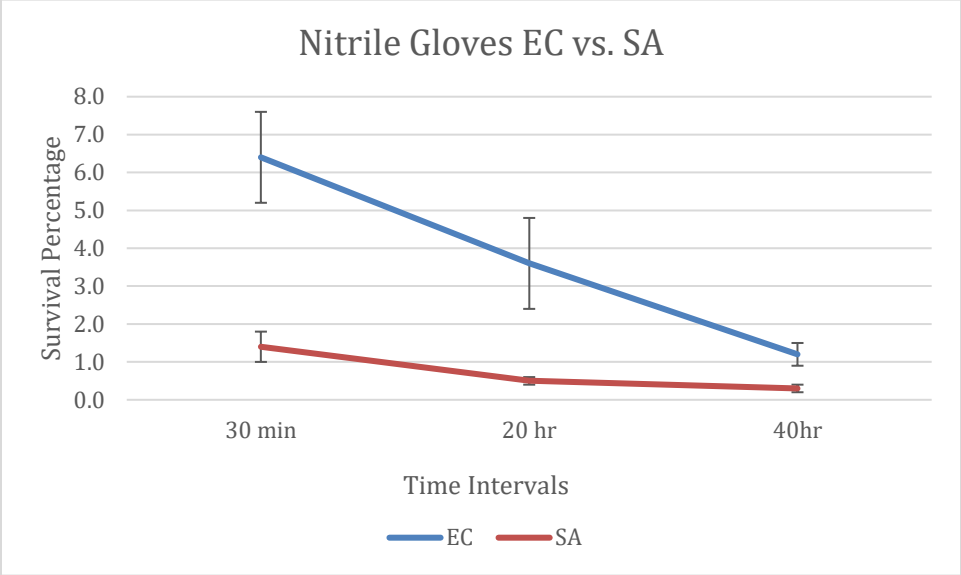

Figure 9: Survival of *E. coli* and *S. aureus* comparison at 30 minutes, 20 and 40 hours for the Nitrile Gloves; this figure compared the survival of both microbes on Nitrile Gloves at all 3 times swabbed.

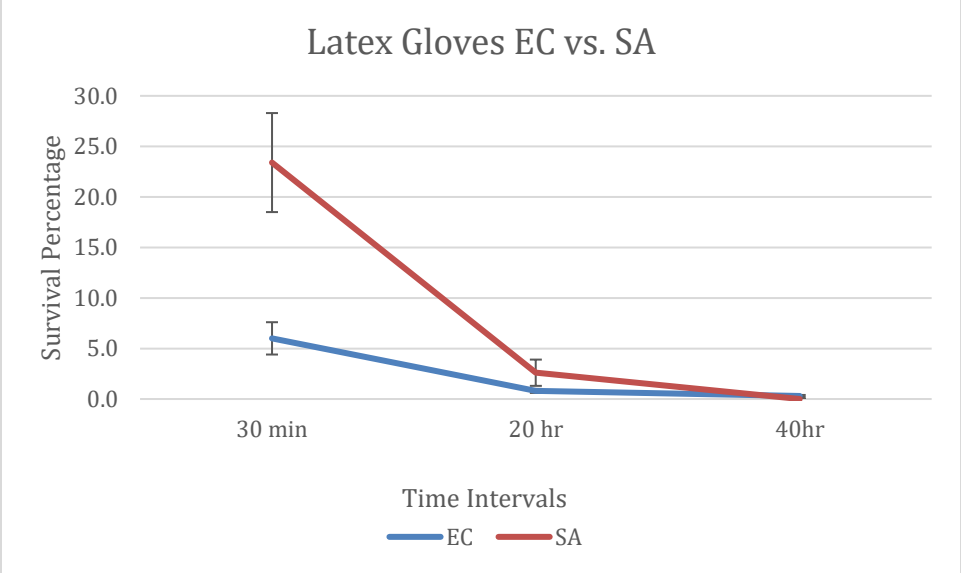

Figure 10: Survival of *E. coli* and *S. aureus* comparison at 30 minutes, 20 and 40 hours for the Latex Gloves; this figure compared the survival of both microbes on Latex Gloves at all 3 times swabbed.

3.2 Comparison of *E. Coli* and *S. Aureus*: Relationship Between Bacterial Percent Survivability and Device

As expected, there is a difference in survival between the EC and SA and each material they were tested on. We can see that SA had much higher survival rates, up to 37%, compared to EC, which only had survival rates of up to 11%. Both EC and SA had the highest survival rates on the PVC materials as opposed to any other material. EC had the lowest maximum survivability on latex gloves, 6.0%. SA had the lowest maximum survivability on nitrile gloves, 1.4%. We can also note that EC showed lower rates of survival at 30 minutes, 20, and 40 hours as compared to SA. We can also observe that SA had lower rates of survival at 40 hours on both the nitrile and latex gloves as opposed to EC at 40 hours on the rubber materials. We can also observe that EC and SA had higher rates of survival on PVC and polyurethane at all times, with a few exceptions. For example, EC had a higher rate of survival at 40 hours on nitrile gloves as opposed to PVC and polyurethane.

Section 4

Discussion

Infections that individuals develop while undergoing medical treatment are referred to as healthcare-associated infections. The definition of HAIs is an infection acquired in a facility after a patient has resided there for at least 48 hrs. This definition comes from the Centers for Medicare and Medicaid Services (CMS, 2018), which regulates whether Medicare or Medicaid will pay for services in hospitals and outpatient clinics. Essentially, this rule requires that if an HAI occurs after 48 hours following admission, the facility is deemed responsible and must pay for any treatments necessary to treat the HAIs. (Haque et al., 2018). According to the US Centers for Disease Control and Prevention, approximately 1.7 million hospitalized patients each year develop HAIs while receiving treatment for other medical conditions, resulting in mortality for more than 98,000 of these patients, 1 in 17, due to HAI-related causes (Klevens et al., 2007). According to the Agency for Health Care Research and Quality, HAIs are among the top 10 main causes of mortality in the USA and are among the most frequent hospital care complications (Haque et al., 2018). Seven of 100 hospitalized patients in developed nations and ten hospitalized patients out of 100 in developing nations contract HAIs (Danasekaran et al., 2017). Outpatient clinic patients pose a unique problem for studies of HAIs, as they tend to be much more mobile than those in hospitals and are rarely monitored as vigilantly as hospital patients for infections. Outpatient clinics themselves are also rarely monitored for environmental bacterial contamination and thus may represent potential sources of pathogens contracted by their patients.

Bacteria that cause HAIs can be spread in a variety of ways. Previous research has suggested that HAIs are more frequently associated with direct patient contact, either patient-to-

patient or healthcare giver-to-patient. More recently, interest in possible patient cross-contamination via and contact with contaminated clinical surfaces has gained attention (CDC, 2016). In the clinical context, contaminated surfaces have been found to be linked to around one-third of all HAIs each year (Schabrun, 2006). In addition to helping to lower the high expenses associated with HAIs, determination of the role(s) played by bacterial (or other pathogens) contamination of surfaces in the initiation of HAIs due to cross-contamination of patients should help to improve outcomes for patients using those facilities. To better understand links between bacterial contamination of surfaces and the initiation of HAIs new data will be required that includes some estimates of how long bacteria may live on inanimate surfaces. The results from the studies conducted here, related to the survival of EC and SA on moldable surfaces commonly used in healthcare, may prove to be important in determining the causes of HAIs. This data suggests that the chances for cross-contamination of these surfaces due to patient-to-patient contact may point to the need for better cleaning and disinfection of all clinic surfaces, particularly between treatments of different patients.

In this study, both EC and SA were found to be able to survive in a dry state for as long as 40 hours on different types of moldable surface materials covering clinic surfaces. Overall, SA was found to survive in much higher numbers on the surfaces tested here than EC. We can see that on latex gloves EC had a maximum survivability of 6.0% compared to SA at 23.4%. Comparatively on nitrile gloves EC had a maximum survivability of 6.4% compared to SA at 1.4%. When looking at the PVC cold pack EC had a maximum survivability of 11.2% compared to SA at 36.9%. On the PVC fit ball, EC had a maximum survivability of 7.8% compared to SA at 33.1%. And on the polyurethane pad, EC had a maximum survivability of 7.0% compared to SA at 17.7%. EC survived on latex gloves, nitrile gloves, PVC cold pack, and the PVC fit ball

for up to 40 hours. The only material tested that EC did not survive on for 40 hours was polyurethane. SA survived on nitrile gloves, PVC cold pack, PVC fit ball, and the polyurethane pad for up to 40 hours. The only material that SA did not survive on for 40 hours was latex gloves. It is important to note that from a clinical perspective, any number of viable cells of bacteria have the potential to be infectious.

From the data we can observe that the survival of EC was, in general, much lower on the tested surfaces than SA, just barely surpassing 10%, while more than 30% of the SA placed on these surfaces survived. Although 10% survivability of EC does seem quite small, in actuality, this represents thousands of bacterial cells surviving on the material surface. On the other hand, it is interesting to note that SA durvived at higher rates compared to EC. A study done in Germany found that many gram-positive bacteria, such as SA, can survive on dry surfaces for months (Kramer et al., 2006). But overall, gram-negative bacteria have been found to survive longer than gram-positive bacteria on surfaces (Kramer et al., 2006). The same study found that humid conditions increased the survivability of most bacteria and only SA of the tested bacteria survived longer at low humidity (Kramer et al., 2006). Increasingly, lower temperatures also improved the survivability of many bacteria including SA and EC (Kramer et al., 2006).

A study conducted in France found that bacteria put onto platforms made of aluminum and stainless steel survived at much greater rates than those placed on surfaces made of wood or polycarbonate, with a significance value of p 0.001 (Chen et. al., 2020). Additionally, SA survived significantly longer than all other bacteria examined (KP, AB, and *Enterococcus faecalis*) on aluminum and stainless-steel platforms. (Chen et. al., 2020). Another study examining the survival of bacteria on various surfaces discovered than EC and SA could last on aluminum surfaces for more than 25 days (Shimoda et. al., 2019). Furthermore, it was shown that

EC and SA may endure on enamel surfaces for up to 10 days (Shimoda et. al., 2019). Additionally, a study conducted by Ormsby et al. in 2022 found that EC strains can endure on plastic for at least 28 days. Even more importantly, these pathogens maintained and, in some cases, increased their pathogenicity (as assessed using a *Galleria mellonella* model as a proxy for human infection) (Ormsby et al., 2023).

More recent research has shown that internal devices including urine catheters, ventilators, and central lines operate as reservoirs for bacterial growth and possible infections (Covid-19 Impact on HAIs, 2022). Most of these indwelling devices have surfaces made of some form of plastic, similar to the moldable surfaces we tested in this study. Thus, the findings of this study suggest that we should also be focusing on molded surfaces that come into touch with patients as potential sources of cross-contamination. Bacteria deposited on and dried on the surfaces of plastic and rubber materials examined here were found to live for up to 40 hours. Patients undergoing treatment or even simply visiting a doctor's office might potentially be exposed to infectious bacteria with only one touch of a contaminated surface.

Recent technological advancements have made it possible to create antimicrobial surfaces, linings, and sprays that are antimicrobial against bacteria that are difficult to kill. Antimicrobial polymers, such as polycarbonate, polyurethane, polyphosphoester, and polyetheretherketones, as well as amphipathic antimicrobial peptides, have all been included in the design of this technology and have the potential to prevent or slow the growth of bacteria through cellular effects (Antimicrobial Technology, 2018). Additionally, a combination of two or more of these innovations may be able to efficiently minimize the survival of pathogenic bacteria on the surfaces of devices that are frequently found in the healthcare environment (Antimicrobial Technology, 2018). One thing that remains is that cleaning and disinfection must be

continuously maintained in order to reduce the number of surviving clinically relevant bacteria on molded surfaces in healthcare. From the results of the study, we can observe that E. coli had the highest survivability on PVC cold pack, then the PVC fit ball, then the polyurethane pad, then the nitrile gloves, and had the lowest survivability on latex gloves. S. aureus had the highest survivability on the PVC cold pack, then the PVC fit ball, then the latex gloves, then the polyurethane pad, and had the lowest survivability on nitrile gloves.

Section 5

Limitations and Future Research

This study has shown that clinically important bacteria are able to survive on plastic and rubber-molded surfaces in healthcare for long periods of time. The study was successful in producing meaningful data that expands on the limited knowledge currently available about the probable persistence of clinically important bacteria on plastics and rubber surfaces in healthcare.

However, this research did have a number of limitations. This study was *in vitro*, meaning that the outcomes presented were obtained through experiments in a laboratory context, and are not necessarily indicative of the capacity of bacteria to survive in a clinical situation. For the purpose of this study, the bacteria were exposed to room air, air drying, and a generally stable environment. Additionally, the inoculated plastics and rubbers were also maintained with minimal movement, contact with outside sources, or intense sunlight—all of which have been found to promote the development or decline of bacterial species (Spratt et. al. 2019). However,

it is crucial to remember that in the clinical context, bacteria that survive on healthcare surfaces are subjected to a variety of environmental conditions, both harsh and stable.

The bacteria that were "painted" onto the surfaces of the plastics and rubbers were suspended in TSB, a medium rich in nutrients that would aid in the bacteria's survival after being dried onto the surfaces of the devices. Through the development of an organic coating to the cells as they rapidly dried (Spratt et. al., 2019). Such organic coatings of bacteria could be envisioned for the surfaces tested here due to the presence of fecal matter, mucus, blood, or other bodily fluids. And it is still crucial to investigate the potential that TSB may be promoting the survival of the bacteria found here. Aliquots of bacteria and 100% TSB have been observed to significantly boost the lifespan of bacteria after drying compared to when suspended in solutions such as NaCl saline because of TSB's content of lipids, carbohydrates, and proteins (Spratt et. al., 2019).

This study had a low number of replications. The study was only triplicated. This in turn causes issues with statistical significance. Many of the comparisons turned out to be barely not statistically different. It is highly likely that the data would have all been significant with higher numbers of replication. A power analysis would say 6 replications would be sufficient, but we were close with an N of 3.

While this study did generate valid data, additional studies with plastics and rubbers being swabbed within clinics, where they are constantly exposed to varying environments, are also necessary to produce new data for the survivability of clinically pathogenic bacteria on healthcare surfaces.

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Appendix 1

Image 1: This image shows an example of nitrile gloves. For the study, square pieces were cut out of the palm areas.

Image 2: This image shows an example of latex gloves. For the study, square pieces were cut out of the palm areas.

Image 3: This image shows an example of the PVC cold pack. For this study, square pieces were cut out.

Image 4: This image shows an example of the PVC fit ball. For this study, square pieces were cut out.

Image 5: This image shows an example of a polyurethane pad. For this study, square pieces were cut out.

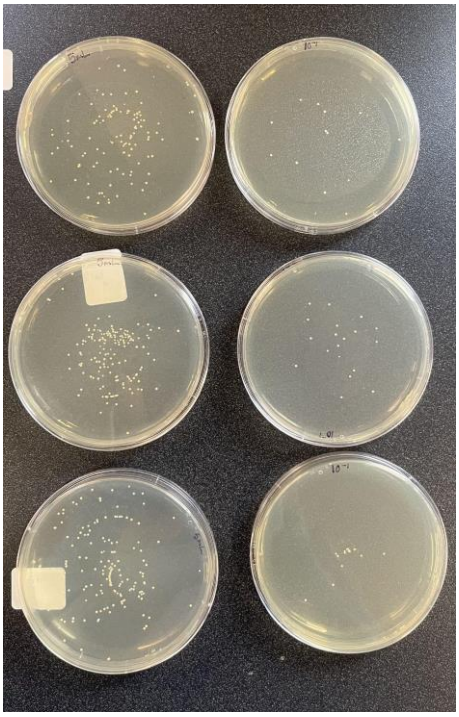

Image 6: Example of S. Aureus on TSA

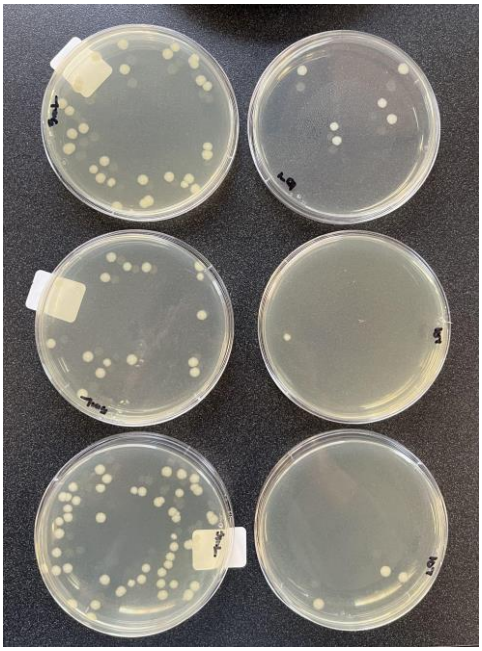

Image 7: Example of E. Coli on TSA

Appendix 2

Sample calculation

E. coli on Cold Pack PVC

	SD	10^{-5}=TMTC	10^{-6}=263	10^{-7}=48
Triplicates	Initial CFU/3mL	Colonies at T=30 Minutes	Colonies at T=24 Hours	Colonies at T=48 Hours
#1	2.63E+9	113	19	2
#2	2.63E+9	152	18	1
#3	2.63E+9	178	33	7

Percent Survivability

CFU/3mL in original bacterial overnight culture= $263 \times 10^6 / 0.1 = 2.63 \times 10^9$

CFUs from Serial Dilution to Cold Pack PVC (CFU/0.025) = $((2.63 \times 10^9) \times (0.001)) \times (0.025)$ = 65,800 or 6.58×10^4

	T= 30 minutes	T= 20 hours	T= 40 hours
#1	$113 / 10^{-1} = 1130$	$19 / 10^{-1} = 190$	$2 / 10^{-1} = 20$
#2	$152 / 10^{-1} = 1520$	$180 / 10^{-1} = 180$	$1 / 10^{-1} = 10$
#3	$178 / 10^{-1} = 1780$	$33 / 10^{-1} = 330$	$7 / 10^{-1} = 70$

T= 30 Minutes Average CFU/5mL

((1130+1520+1780)/3) x 5 = 7383 CFU/5mL

T= 20 Hours Average

((190+180+330)/3) x 5 = 1167 CFU/5mL

T=40 Hours Average

((20+10+70)/3) x 5 = 167 CFU/5mL

Percent Survivability at T= 30 Minutes = (7383 / 65,800) x 100 = 11.2%

Percent Survivability at T= 20 Hours = (1167 / 65,800) x 100 = 1.8%

Percent Survivability at T= 40 Hours = (167 / 65,800) x 100 = 0.3%

Appendix 3

Sample calculation

***S. Areus* on Nitrile**

	SD	10^{-5}=TMTC	10^{-6}=793	10^{-7}=87
Triplicates	Initial CFU/3mL	Colonies at T=30 Minutes	Colonies at T=24 Hours	Colonies at T=48 Hours
#1	7.93E+09	72	16	13
#2	7.93E+09	81	26	23
#3	7.93E+09	13	13	0

Percent Survivability

CFU/3mL in original bacterial overnight culture= $793 \times 10^6 / 0.1 = 7.93 \times 10^9$

CFUs from Serial Dilution to Cold Pack PVC (CFU/0.025) = $((7.93 \times 10^9) \times (0.001)) \times (0.025) =$ 198250 or 1.98×10^5

	T= 30 minutes	T= 20 hours	T= 40 hours
#1	$72 / 10^{-1} = 720$	$16 / 10^{-1} = 160$	$13 / 10^{-1} = 130$
#2	$81 / 10^{-1} = 810$	$26 / 10^{-1} = 260$	$23 / 10^{-1} = 230$
#3	$13 / 10^{-1} = 130$	$13 / 10^{-1} = 130$	$0 / 10^{-1} = 0$

T= 30 Minutes Average CFU/5mL

((720+ 810+ 130)/3) x 5 = 2767 CFU/5mL

T= 20 Hours Average

((160+ 260+130)/3) x 5 = 917 CFU/5mL

T=40 Hours Average

((130+230+0)/3) x 5 = 600 CFU/5mL

Percent Survivability at T= 30 Minutes = (2,767 / 198,250) x 100 = 1.4%

Percent Survivability at T= 20 Hours = (917 / 198,250) x 100 = 0.5%

Percent Survivability at T= 40 Hours = (600 / 198,250) x 100 = 0.3%

Appendix 4

4.1 *Escherichia coli* data

E. coli: Latex Gloves

SD:	10^-5	TMTC	10^-6	112	10^-7	15	# in ONC:
							1.12E+09
		T= 30min	T= 20 Hr	T=40 Hr			
#1	10^-1	31	3	3			From SD to material
	10^-2	6	0	0			CFU/0.025 ml
							28,000
#2	10^-1	16	7	1			
	10^-2	1	1	0			From Swab to TSB CFU/5mL (AVG) 10^-1
#3	10^-1	54	4	1			T=30min
	10^-2	3	0	0			T=20 Hr
							T=40 Hr

Cells on Swab	% Survivability Swab to SD cfu/mL
1,683	6.0
233	0.8
83	0.3

E.coli: Nitrile Glove

SD:	10^-5	TMTC	10^-6	86	10^-7	8	# in ONC:
							8.60E+08
		T=30 min	T= 20 Hr	T=40 Hr			
#1	10^-1	40	28	6			From SD to material
	10^-2	2	0	0			CFU/0.025 ml
							21,500
#2	10^-1	18	8	7			
	10^-2	1	1	1			From Swab to TSB CFU/5mL (AVG)
#3	10^-1	24	10	2			T=30min
	10^-2	2	0	0			T=20 Hr
							T=40 Hr

Cells on Swab	% Survivability Swab to SD cfu/mL
1,367	6.4
767	3.6
250	1.2

E. coli: PVC Fit Ball

SD:	10^-5	TMTC	10^-6	227	10^-7	56	# in ONC:
							2.27E+09
		T=30 min	T= 20 Hr	T=40 Hr			
#1	10^-1	133	7	1			From SD to material
	10^-2	9	1	1			CFU/0.025 ml
							56,800
#2	10^-1	70	17	12			
	10^-2	5	3	0			From Swab to TSB CFU/5mL (AVG)
#3	10^-1	63	27	8			T=30min
	10^-2	3	1	0			T=20 Hr
							T=40 Hr

Cells on Swab	% Survivability Swab to SD cfu/mL
4,433	7.8
850	1.5
350	0.6

E.coli: Cold Pac Blue PVC

SD:	10^-5	TMTC	10^-6	263	10^-7	48	# in ONC:
							2.63E+09
		T=30 min	T= 20 Hr	T=40 Hr			
#1	10^-1	113	19	2			From SD to material
	10^-2	10	2	0			CFU/0.025 ml
							65,800
#2	10^-1	152	18	1			
	10^-2	14	1	1			From Swab to TSB CFU/5mL (AVG)
#3	10^-1	178	33	7			T=30min
	10^-2	21	6	3			T=20 Hr
							T=40 Hr

Cells on Swab	% Survivability Swab to SD cfu/mL
7,383	11.2
1,167	1.8
167	0.3

E.coli: Balance Pad Polyurethane

SD:	10^-5	TMTC	10^-6	292	10^-7	19	# in ONC:			
							2.92E+09			
		T=30 min	T= 20 Hr	T=40 Hr						
#1	10^-1	126	14	0			From SD to material			
	10^-2	21	0	0			CFU/0.025 ml			
							73,000			
#2	10^-1	106	26	0						
	10^-2	10	3	0			From Swab to TSB	Cells on Swab	% Survivability	
							CFU/5mL (AVG)		Swab to SD cfu/mL	
#3	10^-1	76	39	0			T=30min	5,133	7.0	
	10^-2	2	7	0			T=20 Hr	1,317	1.8	
							T=40 Hr	0	0.0	

E. coli, Percent Survival on Healthcare Moldable Surface Materials

Material	%Survival - 30mi	%Survival - 20 hr	%Survival - 40hr
Latex Gloves	6.0	0.8	0.3
Nitrile Gloves	6.4	3.6	1.2
PVC Cold Pack	11.2	1.8	0.3
PVC Fit Ball	7.8	1.5	0.6
Polyurethane Pad	7.0	1.8	0.0

4.2 *Staphylococcus aureus* data

S. aureus: Latex Gloves

SD:	10^-5	TMTC	10^-6	72	10^-7	8	# in ONC
							7.20E+08
		T= 30min	T= 20 Hr	T=40Hr			
#1	10^-1	76	21	0			
	10^-2	15	0	0			From SD to material cfu/0.025ml
#2	10^-1	52	4	0			1.80E+04
	10^-2	9	1	0			
#3	10^-1	125	3	0			
	10^-2	14	0	0			

From Swab to TSB CFU/5mL (AVG)	Cells on Swab	% Survivability Swab to SD cfu/mL
T=30min	4,217	23.4
T=20 Hr	467	2.6
T=40 Hr	0	0.0

S. aureus Nitrile Glove

SD:	10^-5	TMTC	10^-6	793	10^-7	87	# in ONC:
							7.93E+09
		T= 30min	T= 20 Hr	T=40Hr			
#1	10^-1	72	16	13			From SD to material CFU/0.025 ml
	10^-2	3	2	1			198,250
#2	10^-1	81	26	23			
	10^-2	10	1	1			
#3	10^-1	13	13	0			
	10^-2	2	1	0			

From Swab to TSB CFU/5mL (AVG)	Cells on Swab	% Survivability Swab to SD cfu/mL
T=30min	2,767	1.4
T=20 Hr	917	0.5
T=40 Hr	600	0.3

S.aureus: Fit Ball PVC

SD:	10^-5	TMTC	10^-6	257	10^-7	36	# in ONC:
							2.57E+09
		T= 30min	T= 20 Hr	T=40Hr			
#1	10^-1	308	203	12			
	10^-2	64	34	3			From SD to material CFU/0.01 ml
#2	10^-1	566	293	75			6.43E+04
	10^-2	84	35	13			
#3	10^-1	403	272	56			
	10^-2	51	29	4			

From Swab to TSB CFU/5mL (AVG)	Cells on Swab	% Survivability Swab to SD cfu/mL
T=30min	21,283	33.1
T=20 Hr	12,800	19.9
T=40 Hr	2,383	3.7

S. aureus Cold Pac Blue PVC

SD:	10^-5	TMTC	10^-6	202	10^-7	10	# in ONC:		
							2.02E+09		
		T= 30min	T= 20 Hr	T=40Hr					
#1	10^-1	188	166	118			From SD to material		
	10^-2	35	22	14			CFU/0.025 ml		
							50,500		
#2	10^-1	305	192	27					
	10^-2	29	16	2			From Swab to TSB	Cells on Swab	% Survivability
							CFU/5mL (AVG)		Swab to SD cfu/mL
#3	10^-1	202	120	108			T=30min	11,583	22.9
	10^-2	18	13	7			T=20 Hr	7,967	15.8
							T=40 Hr	4,217	8.3

S. aureus Cold Pac Blue PVC Take 2

SD:	10^-5	TMTC	10^-6	216	10^-7	21	# in ONC:		
							2.16E+09		
		T= 30min	T= 20 Hr	T=40Hr					
#1	10^-1	502	473	57			From SD to material		
	10^-2	86	72	5			CFU/0.025 ml		
							54,000		
#2	10^-1	636	416	61					
	10^-2	72	3	9			From Swab to TSB	Cells on Swab	% Survivability
							CFU/5mL (AVG)		Swab to SD cfu/mL
#3	10^-1	507	414	69			T=30min	27,417	50.8
	10^-2	79	25	8			T=20 Hr	21,717	40.2
							T=40 Hr	3,117	5.8

S. aureus Balance Pad Polyurethane

SD:	10^-5	TMTC	10^-6	182	10^-7	22	# in ONC:		
							1.82E+09		
		T= 30min	T= 20 Hr	T=40Hr					
#1	10^-1	125	94	18			From SD to material		
	10^-2	15	13	2			CFU/0.025 ml		
							45,500		
#2	10^-1	164	90	57					
	10^-2	19	10	9			From Swab to TSB	Cells on Swab	% Survivability
							CFU/5mL (AVG)		Swab to SD cfu/mL
#3	10^-1	153	125	72			T=30min	7,367	16.2
	10^-2	16	14	9			T=20 Hr	5,150	11.3
							T=40 Hr	2,450	5.4

S. aureus Balance Pad Polyurethane take 2

SD:	10^-5	TMTC	10^-6	168	10^-7	26	# in ONC:		
							1.68E+09		
		T= 30min	T= 20 Hr	T=40Hr					
#1	10^-1	179	76	70			From SD to material		
	10^-2	20	6	6			CFU/0.025 ml		
							42,000		
#2	10^-1	138	49	58					
	10^-2	9	6	5			From Swab to TSB	Cells on Swab	% Survivability
							CFU/5mL (AVG)		Swab to SD cfu/mL
#3	10^-1	168	40	16			T=30min	8,083	19.2
	10^-2	19	0	1			T=20 Hr	2,750	6.5
							T=40 Hr	2,400	5.7

S. aureus, Percent Survival on Healthcare Moldable Surface Materials

Material	%Survival - 30mi	%Survival - 20 hr	%Survival - 40hr
Latex Gloves	23.4	2.6	0.0
Nitrile Gloves	1.4	0.5	0.3
PVC Cold Pack (AVG	36.9	28.0	7.1
PVC Fit Ball	33.1	19.9	3.7
Polyurethane Pad (A	17.7	8.9	5.5
PVC Cold Pack (#1)	22.9	15.8	8.3
PVC Cold Pack (#2)	50.8	40.2	5.8
Polyurethane Pad (#	16.2	11.3	5.4
Polyurethane Pad (#2	19.2	6.5	5.7