Investigation into the Cleaning Methods of Smartphones and Wearables from Infectious Contamination in a Patient Care Environment (I-SWIPE)

Principal Investigator:
Stephanie Huffman, BSc, BSP, Pharmacy Resident

Co-Investigators:
Carly Webb, BSc(Pharm), ACPR
Sean Spina, BSc(Pharm), ACPR, PharmD, FCSHP

Institution(s): Island Health

Key Stakeholders:

i. Dr. Pamela Kibsey (Medical Microbiology)
ii. Lisa Young (Infection Prevention & Control - Manager)
iii. Sandra Dunford (Infection Prevention & Control)
iv. Mark Lerner (IMIT- Director, Device Engineering & Service Innovation)
v. Jonathan Addey (IMIT- Manager, Device Integration, Device Engineering and Service Innovation)
vi. Richard Jones (Director of Pharmacy)
vii. Dr. Matthew Billinghurst (Hospitalist)
viii. Dr. Rikus de Lange (Hospitalist)
ix. Maureen Hluchy (Manager, 7S, Royal Jubilee Hospital)

Protocol version number: Version ~~8~~ 9
Protocol version date: ~~Oct 20, 2018~~ Dec 20, 2018

1. Protocol Synopsis

As technology advances, many healthcare workers are using smartphones and wearable devices on a daily basis, especially while working in hospitals. These devices are often used during interactions with patients, but do not have a cleaning standard enforced to prevent the spread of bacteria. This study will show the extent of bacterial growth on these items that are being introduced into the patient environment and will demonstrate how to effectively eliminate the bacteria. To date, there have not been any clinical trials which have examined bacterial elimination on devices such as smartphones and wearable technologies in a hospital setting.

Given the current lack of evidence on how to appropriately disinfect smartphones and wearable technologies, we propose to examine the benefit of using a quick method of bacterial elimination with an ultraviolet C (UV-C) disinfection device. The primary outcome will be to determine the effectiveness of a UV-C disinfection device in eliminating bacteria on smartphones and wearable technologies.

2. Background and Rationale

As the technology becomes commonplace, electronic and wearable devices are utilized by healthcare workers involved in patient care on a more frequent basis and are routinely being used without an enforced cleaning standard. Koehler et al. discovered that 87% of healthcare professionals used a mobile device during clinical practice. Of this population, 71% used a smartphone[1]. Furthermore, it was estimated by 2021, 99% of mobile phones in North America would be smart mobile devices[2]. Due to the advance of smartphone technology and addition of various clinical applications that can be easily accessed, healthcare professionals are now using their smartphones to communicate with other clinicians and patients, consult medical literature for treatment guidelines, review patient charts and lab work, and use diagnostic aids such as medical calculators[3]. Power et al. studied the effect of integration of smartphones into clinical pharmacy practice within the Vancouver Island Health Authority in British Columbia, Canada (herein referred to as Island Health) which concluded that pharmacists readily accepted using smartphones in their practice, felt positively about using them, and as a result had increased confidence and competence to resolve drug therapy problems[4]. Another method of communication employed by many healthcare workers is the Vocera® Badge, a wearable, hands-free communication device which allows the user to call or page other healthcare workers when involved in a patient care. For those who prefer to use their own mobile device, Vocera Communications® (San Jose, California) offers a secure communication software application[5]. This smartphone software was explored in a study also conducted within Island Health by Webb et al., who demonstrated improved speed and satisfaction of hospital communication with smartphones using the Vocera® application compared to pagers[6]. Thus, smartphones and wearable devices are shown to be preferred by healthcare workers and use can be expected to continue to expand within hospital settings.

Hospital-acquired infections affect 1 in 10 patients in Canada, which amounts to 200,000 people per year. Of these patients, 10,000 will die from their infection. The treatment for these infections costs Canadians four to five billion dollars each year[7]. Concurrently, antimicrobial resistance is becoming a global health emergency[8] with a serious lack of new antibiotics being developed. As an example, the Staphylococcus aureus bacteria, while not always pathogenic, carries an increased risk of causing serious infections such as sepsis, pneumonia, endocarditis, or osteomyelitis in a healthcare setting. Susceptible populations include people with chronic conditions such as diabetes or cancer, whom are often present in a hospital setting. This bacterium can become resistant to certain antibiotics, which further increases the severity of an infection[9].

Kramer et al. explored the persistence of bacteria, fungi, and viruses on inanimate surfaces (such as smartphones and wearable devices) and found that many isolates can last from days to months. Staphylococcus aureus, can last from seven days to seven months on an inanimate surface[10]. Another surface which can contain bacteria are healthcare workers' (HCW) hospital-provided identity badges, especially when attached to fabric lanyards. These items may be a potential source of nosocomial infections as they can come into contact with patients due to their pendulous nature. Kotsanas et al. discovered that identity badges and lanyards carried bacterial counts ranging from of 17-126 colony forming units (CFUs), with isolates of methicillin-susceptible staphylococcus aureus (MSSA), methicillin-resistant staphylococcus aureus (MRSA), enterococcus spores and enterobacteriaceae[11] (refer to Table 1). There have been a few additional clinical trials which have investigated bacterial contamination on smartphones and wearables, with the most relevant findings outlined in Table 1. The high rates of

hospital-acquired infections, antimicrobial resistance, and identified bacterial contamination on objects used in a healthcare setting increases the need to develop practices to prevent the spread of infection.

Table 1: Characteristics of studies evaluating bacterial contamination on smartphones and wearables

Source	Study Participants	Methods	Outcome	Summary of Results
Badr et al. [12]	-12 neurosurgeons -8 anesthetists -12 nurses	-Participants disinfected hands with alcohol-based hand rub then fingers of both hands were swabbed. -Participants then made a short phone call, followed by fingers of both hands being swabbed a second time. -Phone was swabbed at 3 sites where hand came into contact.	-Bacterial isolates on mobile phone and on HCWs hand.	-No growth on hands after alcohol-based rub. -Rate of bacterial contamination on hands increased to 93.7% after mobile phone use. -Rate of bacterial contamination on mobile phone rose to 93.7% with the same isolates as was on the HCWs hands.
Gunasekara et al. [13]	-45 anesthetic doctors	-Swabs were collected from fingertips of dominant hand, keypads of mobile phones, and wrist watches.	-Bacterial isolates on fingertips, mobile phones, and wrist watches.	-Highest contamination (84%) was observed from wrist watch swabs. -Second-highest contamination (70%) was on mobile phones.
Kotsanas et al.[11]	-71 healthcare workers	-Swabs were collected from lanyards, identity badge surfaces, and connections (e.g. clips, keys, pens) and cultured.	-Bacterial counts and isolates on badges, lanyards, and connections.	-Total bacterial count ranged from 17-49 CFUs on identity badges, 87-126 CFUs units on lanyards, and 3-21 CFUs on connections -MSSA, MRSA, Enterococcus spp.,and aerobic gram-negative bacilli were isolated on identity badges and lanyards.
Velvizhi et al. [14]	-100 healthcare workers working in the ICU	-In the first study, hands and wrists of both wristwatch and non-wristwatch wearers were sampled by direct plate inoculation. -In the second study, hands and wrists were sampled the same for non-wristwatch wearers but sampled wristwatch wearers immediately after they removed their watch.	-Colony count of hands -Colony counts of wrists -Isolates of organisms on wrists	-Watch wearers had double the number of bacteria on their hands and wrists compared to non-watch wearers. -Staphylococcus aureus was found more commonly on hands of watch wearers vs. non-watch wearers (64% vs. 36%). Of these, 22 isolates were MRSA on hands of watch wearers and 10 isolates were MRSA on hands of non-watch wearers. -Klebsiella pneumonia, E. coli, Pseudomonas spp., and Acinetobacter spp. were found more commonly on watch wearers' wrists.

The restriction for wearing items that may come into contact with a patient and potentially spread infection are considered a standard of practice. As per the Island Health Infection Prevention and Control Reference Guide, dress ties, lanyards, and hanging badges should be tucked in prior to taking part in clinical procedures. Hand and wrist jewelry, rings or watches should be removed when carrying out patient care[20]. As Table 1 outlined, objects such as lanyards, badges, and wristwatches are susceptible to bacterial contamination, therefore it is understandable that these items are accounted for. Hand hygiene is also a recommended practice standard across Canada as per Infection Prevention and Control Canada (IPAC)[18]. Hand hygiene compliance is a major considering factor when monitoring infection and prevention control rates at Victoria General Hospital (VGH) and Royal Jubilee Hospital (RJH)[16,17]. In accordance with IPAC's recommendations, the "Island Health Hand Hygiene Policy"[19] includes specific instructions for using soap and water or an alcohol-based rub to properly disinfect the hands. The hand hygiene guidelines also state an expectation for healthcare workers to employ hand hygiene before and after using their smartphone and wearable devices, but anecdotally this practice has not been observed.

Although hospitals are engaging various resources to decrease the presence of bacterial microorganisms, such as installing copper surfaces, using ozonated water throughout plumbing systems[7], and implementing strict hand hygiene protocols[15] in order to make progress in decreasing the spread of infection, one area that is not being explored significantly is the proper and routine cleaning of technology devices used daily by healthcare workers. There have been several studies which have evaluated bacterial contamination on smartphones and wearable items, however, none were able to determine the best method of decontamination for continued use in clinical practice. Decontamination is the process of decreasing antimicrobial presence in an area or on a surface, consisting of either cleaning, disinfection or sterilization. Cleaning involves the removal of visible soil, either organic or inorganic material, from surfaces using water and detergents or enzymatic products. Disinfection is a process which eliminates or inactivates most or all harmful microorganisms while sterilization is a method to kill all microorganisms and their spores. In a healthcare setting, devices are often *disinfected* rather than *sterilized*, as sterilization of all patient-care items is not necessary and depends on the items' intended use[21]. For the purpose of this study, we will be exploring a method of disinfection.

Island Health's protocol "Medical Devices and Information Management/Information Technology Equipment Cleaning and Disinfection"[22] considers mobile phones to be of medium risk for presence of infectious contamination as they are used by a staff member for a given period but are perceived as not coming into contact with the patient and their environment. The recommendations for *cleaning* practices for phones and similar devices include: cleaning the device at the start and end of each shift, cleaning the device when visibly soiled, cleaning hands prior to use, and washing hands after the device is used and before moving on to the next patient. The recommendations for *disinfecting* the devices are to perform hand hygiene, don gloves, use a wipe and wipe in one direction over the surfaces of the device then discard, followed by using a second wipe with the same process. The protocol does not indicate a specific wipe for this purpose. Also encompassed in this regulation is Island Health's policy "Non-critical Medical Devices and Information Management/Information Technology Equipment Cleaning and Disinfection"[23], which states that the products that are used for regular and thorough cleaning of mobile phones and similar devices must be compatible with the manufacturer's cleaning instructions and approved for use within the health authority. The above policies are based off of guidelines from the British Columbia Ministry of Health and Infection Prevention and Control hand hygiene protocols and computer equipment sterilization methods[24] and not on evidence from controlled clinical trials. There are currently no well-designed clinical studies which indicate the safest and most effective way to disinfect smartphones and wearables to reference.

At Island Health, the approved cleaning wipe products for use include alcohol Metrex CaviWipes™ [25] (Orange, California), accelerated hydrogen peroxide Virox Accel® Prevention Wipes[26] (Oakville, Ontario), and quaternary ammonia JohnsonDiversey Virex® II 256 wipes[27] (Charlotte, North Carolina). While it has been suggested that the cleaning of mobile phones using alcohol wipes effectively eliminates bacteria[28], the only study that has currently looked into disinfection practices on items similar to smartphones was performed by Kiedrowski et al.[29]. The objective of Kiedrowski's study was to examine which cleaning product out of hypochlorite bleach, 70% isopropyl alcohol, and lint-free microfiber cloths were the most effective at eliminating organisms on iPad surfaces. The study inoculated twenty iPads with clostridium difficile and MRSA and evaluated which surfaces had remaining colony forming units after being disinfected with the mentioned cleaning products. The results concluded that alcohol wipes were effective in eliminating MRSA but were inferior to moistened

microfiber cloths when removing clostridium difficile. Both bleach and microfiber cloths were effective in fully eliminating both bacteria. However, while these wipes may be convenient for healthcare workers to access throughout the hospital, they are not recommended for use by smartphone manufacturers. Apple Incorporated© (Cupertino, California)[30] recommends a soft, slightly damp, lint-free cloth for cleaning their devices and does not recommend the use of solvents, ammonia, or cleaners containing hydrogen peroxide. Care should be taken to avoid getting moisture into any of the openings. Similarly, Samsung Electronics© (Seoul, South Korea)[31] recommends daily cleaning with microfiber cloths and a weekly device cleanse with a wet wipe. While microfiber cloths have shown to be effective at disinfection and are compatible with smartphones, they are not approved for use within the health authority. At this time, the approved disinfection products for Island Health Authority do not correlate with the smartphone manufacturers' instructions.

Another method of decontamination which has recently been explored are ultraviolet wavelength C (UV-C) devices, which use the ultraviolet radiation to kill bacteria on multiple surfaces that can cause hospital-acquired infections. Three UV-C devices that have been studied are mobile UV, automated UV, and CleanSlate UV (Buffalo, New York)[32]. Mobile UV-C devices are taken into patient-care rooms or operating theatres, require manual operation, and have a higher operating cost[7] but have shown to be more effective at eliminating bacterial load than manual cleaning[34]. In a study performed by Wong et al.[34] at Vancouver General Hospital (Vancouver, British Columbia, Canada), mobile UV-C was shown to exceed accelerated hydrogen peroxide in the removal of MRSA load (3.3% vs 27.9%), vancomycin-resistant enterococcus (VRE) load (4.9% vs. 29.5%) and C. difficile load (0% vs. 22.7%) on surfaces such as over-bed tables, bed adjustment controls, sinks, toilet rims, and washroom handrails. Automated UV, on the other hand, is a device permanently installed in a room, is automatic, and has lower operating costs[7]. Auto UV-C devices installed in shared hospital bathrooms have demonstrated a reduction in bacterial contamination by 95-97% when the bathroom was exposed to the UV-C light for five to ten minutes[33]. Conversely, CleanSlate UV[32] is a UV-C device designed to disinfect small items such as smartphones, hospital-provided identification badges, and Vocera® badges and has been shown to have a 99% reduction in bacterial contamination after thirty seconds of use. MicroChem Laboratory[32] (Round Rock, Texas) conducted a study to test the efficacy of CleanSlate UV where a carrier was inoculated with Staphylococcus aureus, Salmonella enterica, Listeria monocytogenes, and Escherichia coli and exposed to UV-C for 30 seconds and 1 minute. The organisms showed over 99% reduction at both times, proving the efficiency of the sanitizing device.

Despite the fact that CleanSlate UV was shown to drastically reduce the number of bacterial organisms on small items, the device has not been investigated in real-world trials for disinfection of healthcare workers' smartphones and wearable devices. The CleanSlate UV is also not marketed towards disinfection of smartphone protective cases. As many smartphones are encompassed in a protective case within a healthcare setting, it is important to determine if disinfection can be achieved on these surfaces as well. Our study will attempt to bridge these gaps by implementing the CleanSlate UV disinfection device within a healthcare setting and using the device to disinfect smartphones and wearable devices which are encompassed in a protective case. This research study will aim to determine if UV-C is an ideal disinfection practice for smartphones and wearables, with the goal of eventually implementing a standard across the health authority.

Clinical Question:

In a patient-care setting where smartphones and wearable devices are often utilized by health care professionals, would disinfecting using UV-C be more effective at eliminating bacteria ~~bacterial load (CFUs)~~ when compared to usual cleaning?

3. Study Objectives/Purpose

The primary objective of this study is to determine if UV-C disinfection devices are more effective at eliminating bacteria ~~bacterial load~~ on smartphones and wearables when compared to usual care.

Primary Outcome:

- ~~Bacterial load (in CFUs) of~~ Isolated bacteria on smartphones and wearable devices compared before and after use of UV-C disinfecting device

Secondary Outcomes:

- ~~Gram-positive and gram-negative bacteria isolation~~
- ~~Bacterial load (in CFUs) of~~ Isolated bacteria on smartphones and wearable devices before use of UV-C disinfecting device, compared to ~~bacterial load of~~ isolated bacteria on individual hospital-provided ID badges
- Bacterial load (in CFUs) of inoculated smartphones and wearable devices prior to disinfection with UV-C, compared to bacterial load after disinfection with UV-C
- ~~Bacterial load (in CFUs) of smartphones and wearable devices at the end of a participant's shift, prior to disinfection with UV-C, compared to bacterial load at the start of a participant's shift, after disinfection with UV-C~~

4. Study Population:

The study sample for the smartphone arm will include a group of hospitalists, nurses, rehab assistants, physiotherapists, occupational therapists, and pharmacists at the Royal Jubilee Hospital (RJH), a group of pharmacists, nurses, and lab technicians at North Island Hospital, Campbell River General Hospital (CRG), and a group of hospitalists and pharmacists at Victoria General Hospital (VGH). The study sample for the Vocera® badge arm will include a group of nurses, rehab assistants, physiotherapists, and occupational therapists from the seventh floor (a surgery floor) at RJH, a group of lab technicians from CRG, a group of hospitalists and pharmacists at RJH and a group of hospitalists and pharmacists at VGH. A small group of nurses from CRG will be involved in the Vocera® Collaboration Suite arm, as the Vocera® badges were replaced in that particular area. There will also be a smaller study sample for the smartwatch arm, including a group of hospitalists, nurses, rehab assistants, physiotherapists, occupational therapists and pharmacists at RJH, a group of pharmacists, nurses, and lab technicians at CRG, and a group of hospitalists and pharmacists at VGH. Participation will be voluntary.

Most pharmacists at RJH and VGH have corporate iPhones and will therefore be using them throughout the study. This will not be considered an inclusion factor, however, as a pharmacist can still participate using their own smartphone if they do not have a corporate one. Hospitalists, nurses, rehab assistants, physiotherapists, lab technicians, and occupational therapists do not have corporate iPhones and will therefore use their own smartphones throughout the duration of the study. Similarly,

hospitalists and pharmacists will use their own smartwatches in this study if they are regularly used within their clinical practice.

Total number of participants = 185

- Smartphone arm (n = 110)
    - Pharmacists at RJH, VGH and CRG (n=50)
    - Hospitalists at RJH and VGH (n=30)
    - Nurses at RJH and CRG (n = 30)
- Vocera® badge arm (n=40)
    - Nurses at RJH 7th floor (n=20)
    - Rehab assistants, physiotherapists and occupational therapists at RJH 7th floor (n=10)
    - Lab technicians at CRH (n=10)
- Vocera® Collaboration Suite arm
    - Nurses at CRH 2nd and 3rd floor (n= 20)
- Smartwatch arm (n=15)
    - Pharmacists at RJH, VGH and CRG (n=5)
    - Hospitalists at RJH and VGH (n=5)
    - Nurses, rehab assistants, physiotherapists and occupational therapists at RJH (n=5)

Inclusion Criteria:

- Smartphone arm:
    - Hospitalists, nurses, and pharmacists who work within RJH and regularly use their smartphones during work within the hospital
    - Hospitalists and pharmacists who work within VGH and regularly use their smartphones during work within the hospital
    - Pharmacists, nurses and lab technicians who work within CRG and regularly use their smartphones during work within the hospital
- Vocera® badge arm:
    - Nurses, rehab assistants, physiotherapists, and occupational therapists who regularly work on the 7th floor of RJH
    - Lab technicians who regularly work on the 2nd or 3rd floor at CRG
- Vocera® Collaboration Suite arm:
    - Nurses who regularly work on the 2nd or 3rd floor at CRG
- Smartwatch arm:
    - Hospitalists, nurses, rehab assistants, physiotherapists, occupational therapists, and pharmacists who work within RJH and regularly use their smartwatches during work within the hospital
    - Hospitalists and pharmacists who work within VGH and regularly use their smartwatches during work within the hospital
    - Pharmacists, nurses and lab technicians who work within CRG and regularly use their smartwatches during work within the hospital

Exclusion Criteria:

- Smartphone arm:

    - Hospitalists, nurses, rehab assistants, physiotherapists, occupational therapists, lab technicians, and pharmacists who use mobile phones other than smartphones
    - Clinicians who work less than or equal to 16 hours per week during the study period
- Vocera® arm:
    - Clinicians who do not use Vocera® badges or Collaboration Suite within the hospital
    - Clinicians who work less than or equal to 16 hours per week during the study period
- Smartwatch arm:
    - Clinicians who do not regularly use a smartwatch during their work day

Participant Enrollment:

The principal investigator will present an overview of this project at appropriate pharmacist, hospitalist, and nursing staff meetings. If the principal investigator is unable to attend the staff meetings, a co-investigator will present an overview in her place. Following the presentation, individuals will be informed to email the principal investigator if they would like to volunteer to be involved in the study. Potential participants will also be contacted via promotional email to all leaders in pharmacist, hospitalist and nursing teams with a request to distribute to each staff member. Individuals will be informed that participation is strictly voluntary and that their managers will not be informed of who is or is not participating in the study. All potential and recruited participants may ask questions regarding the study during the staff meeting presentations or at any time throughout the study by emailing the principal investigator. All individuals who have been recruited either verbally or by email will be required to fill out an online consent form to confirm their enrollment and commitment to comply with the interventions of the study (Appendix A).

5. Study Design & Procedures

This study is a multi-centered prospective before-and-after study across three hospitals at Island Health (Royal Jubilee Hospital, Victoria General Hospital, Campbell River General Hospital). The study has support from medical microbiology and infection control, pharmacy, hospitalist physicians, the Clinical Nurse Leader on 7S at RJH, and Information Technology and Information Management (IMIT). Refer to Figure 2 for the full study design.

Primary Intervention:

The intervention for each device will consist of disinfection at the beginning and end of each participant's shift with the CleanSlate UV. Participants will place their device in the CleanSlate UV disinfection device for thirty seconds at the beginning and end of their shift. During the thirty second disinfection cycle, participants are instructed and required to wash their hands. Hand sanitizer bottles will be placed beside each CleanSlate UV device. Participants will also be instructed to remove any visible soil prior to placing items in the sanitizing device and to ensure the items are placed apart from each other and do not overlap.

The CleanSlate UV device will be installed in convenient locations to allow for ease of access for participants:

- RJH
    - Clinical pharmacist office (RB 217)
    - Pharmacy dispensary (D&T Level 0)

    - Hospitalist office (RB 251)
    - 7th floor of the Patient Care Centre building (surgery wards)
- VGH
    - Pharmacist office/meeting room
    - Hospitalist office
- CRH
    - 2nd floor Collaboration Centre (ICU)
    - 3rd floor Collaboration Centre (surgery/medicine wards)

Comparator:

The technology devices will be normalized to each participant's hospital identification badges, as it is a common wearable item that will be exposed to the same bacterial environments.

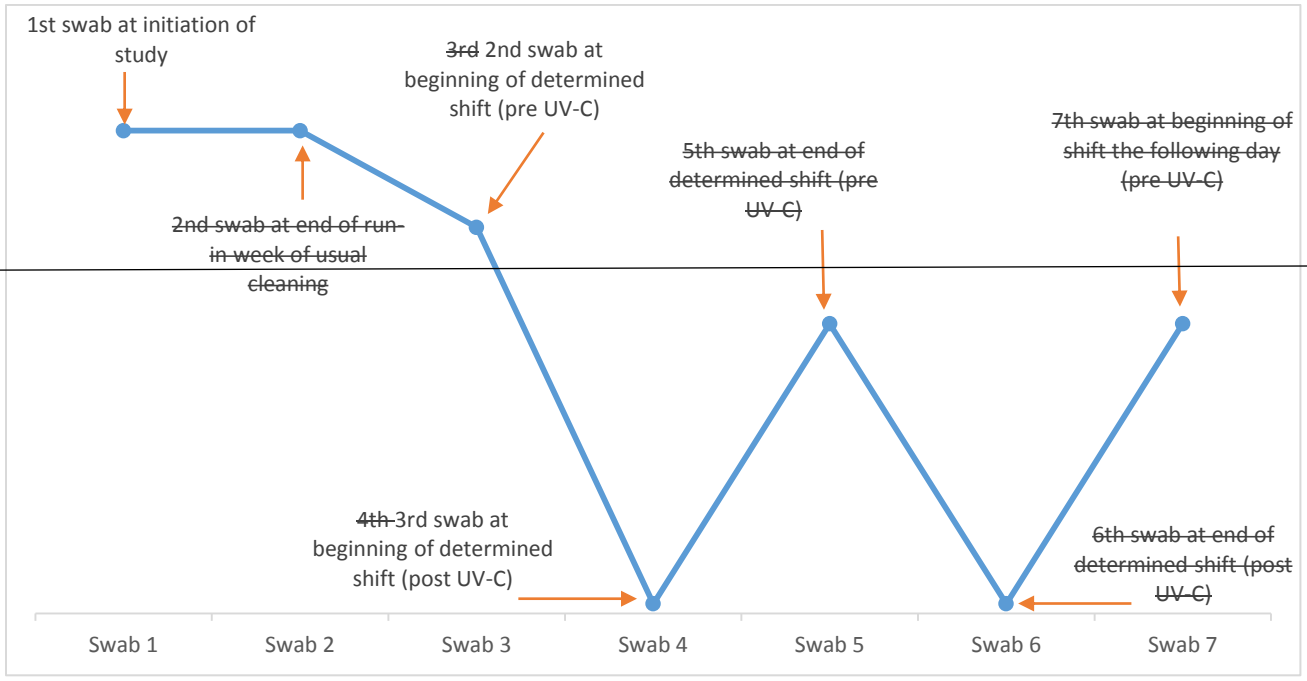
Secondary Intervention:

Fifteen used smartphones that are ready for destruction and four broken Vocera® badges will be provided for inoculation with the following bacteria: *Clostridium difficile, Escherichia coli, Pseudomonas species, MRSA, Enterococcus species, yeast, Candida species,* and *influenza*. Bacterial load (in CFUs) will be determined prior to inoculation. The devices will then be placed in a Cleanslate UV disinfection device for thirty seconds. A swab of each device will be collected after the UV-C disinfection cycle has completed.

Laboratory Methods:

Swabs will be collected in a standardized method from participants' smartphones and wearable devices at baseline upon study entry, and again during the intervention period at a predetermined intervals~~.~~ before and after the use of the UV-C disinfecting device (see Figure 1). An initial swab will also be collected from each participant's hospital-provided identity badge for normalization. For the secondary intervention, swabs of the used smartphones and broken Vocera badges will be collected following a one-time use of the UV-C disinfecting device, which will take place after inoculation using standard microbiology protocols. The entire surface of each device will be swabbed using COPAN Eswab™[35](Murrieta, California). Swabs will be processed by the RJH medical microbiology lab. The swabs will be streaked out on appropriate bacterial culture media and incubated according to standard protocols. Bacterial colony counts as well as bacterial isolate identification will be assessed using the standard laboratory tests.

Figure 1: Swab Interval



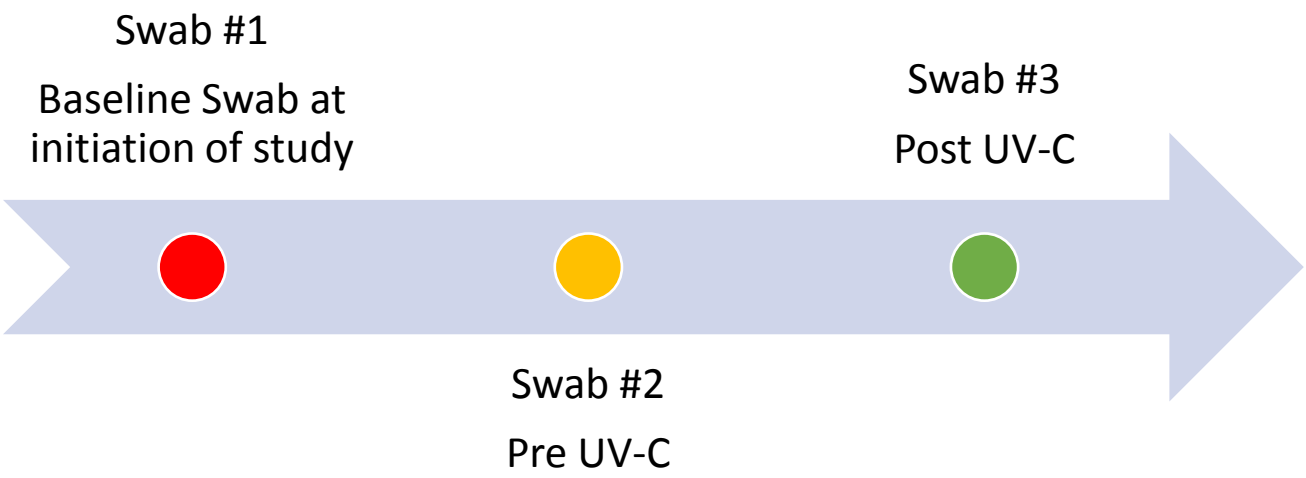
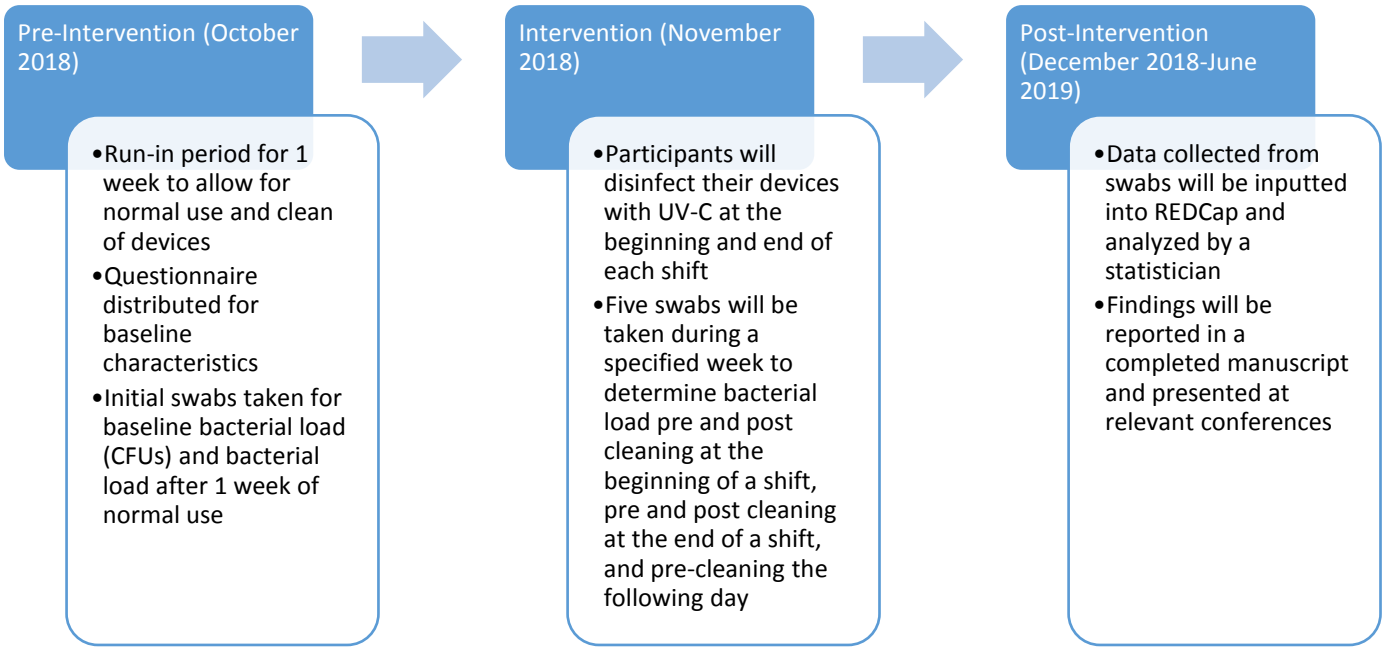


Figure 2: Study Design



6. Statistical Considerations

Sample size will be convenience based, as opposed to based on a power calculation, as there is insufficient evidence to provide predictors for a power calculation (mean and median values). The overall length of the study will be limited to one year (as per Island Health pharmacy residency program requirements), with data being collected within the span of one month.

7. Data Collection and Data Management

An online informed consent form (Appendix A) will be sent to each participant at time of recruitment. Each participant will click the "accept" button in lieu of signing a form. The document will outline the purpose of the study, methods of data collection, and ensure participant confidentiality. Participation is voluntary and participants may choose to exit the study at any time. All participants will be asked to complete a questionnaire (Appendix B) upon enrollment in order to gather baseline characteristics for use and location of the devices. The only identifying information that will be collected include profession, email, and location of employment. Personal identification such as name and email will be de-identified and each participant will be assigned a study number.

The primary intervention will require each participant to disinfect their device with the CleanSlate UV disinfection device at the beginning and end of their shift. ~~Each device will be labelled with a radio-frequency identification tag to connect with the radio-frequency identification located within the CleanSlate UV device. The tags will assist in monitoring compliance of each participant.~~ The data collected from the intervention will consist of a total of ~~seven swabs~~ three swabs taken from each participant (see Figure 1). An initial swab will be taken of each device at the start of the intervention phase to determine ~~a baseline bacterial load~~ baseline bacterial isolation. ~~A second swab will be collected~~

~~at the end of the initial week to determine bacterial load after usual care.~~ The consecutive swabs will be collected before and after the UV-C disinfection ~~at the beginning of a shift, before and after to the disinfection at the end of the shift, and before disinfection of the next shift the following day~~ on a random day after the intervention has been initiated. The entire surface of each device will be swabbed using COPAN Eswab™[35](Murrieta, California). A research assistant will be hired to collect the swabs due to the anticipated large number of participants and number of hospitals involved in the study. The data to be analyzed from these swabs will include ~~bacterial load (in colony forming units) and~~ bacterial isolates.

The secondary intervention will involve inoculation of smartphones and wearable devices that will no longer be used by healthcare workers. These devices will be inoculated with predetermined bacterial loads (in CFUs) of *Clostridium difficile, Escherichia coli, Pseudomonas species, MRSA, Enterococcus species, yeast, Candida species,* and *influenza* by a medical microbiologist. The contaminated devices will be placed in the CleanSlate UV device for the thirty second disinfection cycle. One swab will be collected from each device following the UV-C disinfection. The data to be analyzed from these swabs will include bacterial load.

All data will be collected, processed, and stored within Island Health's secured network drive and in a secured database called REDCap. A statistician from REDCap will be hired to assist with data analysis due to the anticipated large volume of collected data. All data collected will be auditable. Only the project investigators and hired statistician, all of whom are Island Health employees, will have access to the data.

8. Knowledge Translation

a. Publication of Results

The primary investigator will present the results at the British Columbia Pharmacy Residents' Research Night in May 2019. A manuscript will be completed by the end of June 2019 to meet the residency program requirements. The investigators will publish the results upon completion.

b. Presentations

The investigators will present the results at invited talks and conferences.

c. Policy Change

The co-investigators will work with Island Health leadership to incorporate study results into new policies and procedures.

9. References

1. Koehler, N, Vujovic, O, McMenamin, C. Healthcare professionals' use of mobile phones and the internet in clinical practice. *Journal of Mobile Technology in Medicine*. 2013;2(1S). Accessed Jun 21, 2018. doi: 10.7309/jmtm.76.

2. Cisco Mobile. Cisco visual networking index: Global mobile data traffic forecast update, 2016–2021 white paper. https://www.cisco.com/c/en/us/solutions/collateral/service-provider/visual-networking-index-vni/mobile-white-paper-c11-520862.html. Updated 2017. Accessed Jun 21, 2018.

3. Ventola CL. Mobile devices and apps for health care professionals: Uses and benefits. *P & T : a peer-reviewed journal for formulary management*. 2014;39(5):356. http://www.ncbi.nlm.nih.gov/pubmed/24883008. Accessed Jun 25, 2018.

4. Power JMH, Spina SP, Forbes DA, et al. Integration of smartphones into clinical pharmacy practice: An evaluation of the impact on pharmacists' efficiency. *Health Policy and Technology*. 2014;3(4):296-305. https://www.sciencedirect.com/science/article/pii/S2211883714000495. Accessed Jul 23, 2018. doi: 10.1016/j.hlpt.2014.08.002.

5. Vocera Communications. Smartphones and wearable devices. https://www.vocera.com/products/wearables-devices. Updated 2018. Accessed Jul 24, 2018.

6. Webb C, Spina SP, Young S. Integrating smartphone communication strategy and technology into clinical practice: A mixed methods research study. *Health Policy and Technology*. 2016;5(4):370-375. https://www.sciencedirect.com/science/article/pii/S221188371630051X. Accessed Jul 23, 2018. doi: 10.1016/j.hlpt.2016.07.004.

7. Hunt B, Dixon R. CHAIR - coalition for healthcare acquired infection reduction presentation. *Dorset Echo (Weymouth, England)*. 2018:1-103.

8. World Health Organization. The world is running out of antibiotics, WHO report confirms. http://www.who.int/news-room/detail/20-09-2017-the-world-is-running-out-of-antibiotics-who-report-confirms. Updated 2017. Accessed Jun 22, 2018.

9. Centers for Disease Control and Prevention. Staphylococcus aureus in healthcare settings. https://www.cdc.gov/hai/organisms/staph.html. Updated 2011. Accessed Jul 23, 2018.

10. Kramer A, Schwebke I, Kampf G. How long do nosocomial pathogens persist on inanimate surfaces? A systematic review. *BMC Infectious Diseases*. 2006;6(1):130. http://www.ncbi.nlm.nih.gov/pubmed/16914034. Accessed Jun 20, 2018. doi: 10.1186/1471-2334-6-130.

11. Kotsanas D, Scott C, Gillespie EE, Korman TM, Stuart RL. What's hanging around your neck? pathogenic bacteria on identity badges and lanyards. *The Medical journal of Australia*. 2008;188(1):5. http://www.ncbi.nlm.nih.gov/pubmed/18205553. Accessed Jun 20, 2018.

12. Badr RI, Badr HI, Ali NM. Mobile phones and nosocomial infections. *International Journal of Infection Control*. 2012;8(2). Accessed Jun 20, 2018. doi: 10.3396/ijic.v8i2.014.12.

13. Gunasekara, T D C P, Kudavidanage BP, Peelawattage MK, et al. Bacterial contamination of anaesthetists hands, personal mobile phones and wrist watches used during theatre sessions. *Sri Lankan Journal of Anaesthesiology*. 2009;1. Accessed Jun 20, 2018.

14. Velvizhi G, Anupriya G, Sucilathangam G, Ashihabegum MA, Jeyamurugan T, Palaniappan N. Wristwatches as the potential sources of hospital-acquired infections. *Journal of Clinical and Diagnostic Research*. 2012;6(5):807-810. Accessed Jun 20, 2018. doi: 10.1097/01.GOX.0000526414.31723.89.

15. World Health Organization, WHO Patient Safety. WHO guidelines on hand hygiene in health care. *World Health organization*. 2009.

16. Island Health Infection Prevention and Control. VGH Infection Prevention and Control – Quality Placemat Quarter 3 September 8 – November 30, 2017. Accessed Jul 24, 2018.

17. Island Heath Infection Prevention and Control. RJH Infection Prevention and Control – Quality Placemat Quarter 3 September 8 – November 30, 2017. Accessed Jul 24, 2018.

18. Infection Prevention and Control Canada. IPAC Canada Practice Recommendations - Hand hygiene in Health Care Settings. 2017.

19. Island Health. 15.1 Hand hygiene policy. *Island Health Authority*. 2014:1-6.

20. Island Health. Island health Infection Prevention and Control Reference Guide. *Island Health*. 2014:1-90.

21. Centers for Disease Control and Prevention. Guideline for disinfection and sterilization in healthcare facilities (2008). https://www.cdc.gov/infectioncontrol/guidelines/disinfection/introduction.html. Updated 2017. Accessed Jul 24, 2018.

22. Island Health. 15.7P Medical devices and information management/information technology equipment cleaning and disinfection. *Island Health Authority*. 2016:1-4.

23. Island Health. 15.6PRT Non-critical medical devices and information management/information and technology equipment cleaning and disinfection. *Island Health Authority*. 2016:1-6.

24. British Columbia Ministry of Health Services. Best practice guidelines for the cleaning, disinfection and sterilization of medical devices in health authorities. 2011.

25. Metrex Research. Metrex CaviWipes material safety data sheet. . 2015. https://www.metrex.com/sites/default/files/content/education-file/education-file-upload/CaviWipes%20Canadian%20MSDS%20(7-14-2015).pdf. Accessed Jul 23, 2018. doi: 10.1353/fge.2012.0051.

26. Virox Technologies. Accel prevention wipes. *Material Safety Data Sheet*. 2014.

27. JohnsonDiversey. Virex II 256 material safety data sheet. *Material Safety Data Sheet*. 2009.

28. Basol R, Beckel J, Gilsdorf-Gracie J, et al. Bacteria on shared mobile phones can lead to infections. *Nursing Critical Care*. 2014;9(4):5-7. Accessed Jun 21, 2018. doi: 10.1097/01.CCN.0000451027.49482.59.

29. Kiedrowski, Lee M., MS, Perisetti, Abhilash, MD, Loock, Mark H., BS, Khaitsa, Margaret L., PhD, Guerrero, Dubert M., MD. Disinfection of iPad to reduce contamination with clostridium difficile and methicillin-resistant staphylococcus aureus. *AJIC: American Journal of Infection Control*. 2013;41(11):1136-1137. https://www.clinicalkey.es/playcontent/1-s2.0-S0196655313001934. Accessed Jun 20, 2018. doi: 10.1016/j.ajic.2013.01.030.

30. Apple Incorporated. How to clean your apple products. https://support.apple.com/en-ca/ht204172. Updated 2008. Accessed Jun 20, 2018.

31. Samsung. How to clean your mobile device. https://www.samsung.com/ae/discover/how-to/how-to-clean-your-mobile-device/. Updated 2016. Accessed Jun 20, 2018.

32. CleanSlate UV. CleanSlate UV efficacy summary. *Document # 3042 0001*. 2017.

33. Cooper, Jesse, BSc, Bryce, Elizabeth, MD, FRCPC, Astrakianakis, George, MEng, PhD, Stefanovic, Aleksandra, MD, FRCPC, Bartlett, Karen, MSc, PhD. Efficacy of an automated ultraviolet C device in a shared hospital bathroom.

AJIC: American Journal of Infection Control. 2016;44(12):1692-1694. https://www.clinicalkey.es/playcontent/1-s2.0-S019665531630685X. Accessed Jun 22, 2018. doi: 10.1016/j.ajic.2016.07.004.

34. Wong T, Woznow T, Petrie M, et al. Postdischarge decontamination of MRSA, VRE, and clostridium difficile isolation rooms using 2 commercially available automated ultraviolet-c–emitting devices. *American Journal of Infection Control*. 2016;44(4):416-420. https://www-sciencedirect-com.ezproxy.library.ubc.ca/science/article/pii/S0196655315010718. Accessed Jun 22, 2018. doi: 10.1016/j.ajic.2015.10.016.

35. Copan Diagnostics Incorporated. How to use COPAN's eswab. http://www.copanusa.com/education/videos/how-tos-and-training/copan-eswab-how-use-training-video. Updated 2018. Accessed Jul 25, 2018.

10. Appendices

- Appendix A – Informed Consent
- Appendix B – Questionnaire
- Appendix C – Exit Survey