Handwashing: A Study of the History, Methods, and Psychology Surrounding Hand Hygiene

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Abstract

This paper covers three different areas concerning handwashing. First a review of the history of handwashing is done, going from ancient times to its introduction into modern medicine via Dr. Ignaz Semmelweis. This section gives a sobering reminder not to instantly reject data that comes in conflict with prevalent thought.

Then current medical knowledge about handwashing is examined, and the conclusion reached states that handwashing is best done with non-antibacterial soap.

Finally, a review of the psychology of handwashing shows that medical professionals often tend toward neglect if unwatched and unmotivated by an outside source. However, those suffering from obsessive compulsive disorder tend to wash their hands so often that it damages the normal flora and anatomy of the hands.

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We do it every day, often without thinking about it. Some of us forget and face the consequences of minor sickness over the next few days. The action referred to here is the commonplace act of handwashing. It has become such an unconscious act in today's society that it often goes unnoticed, but this was not always the case. In this honors thesis, topics covered will include the history of hand-washing, the positive effects of hand-washing, and the not so well-known effects of the psychology of hand-washing. As well as covering the previously mentioned topics, this paper will seek to answer the following questions: how should one practice hand-washing, what are some of the underlying psychological barriers that prevent hand-washing, and how should the medical and scientific community overcome these barriers that lead to easily preventable nosocomial infections.

A magazine from childhood greatly influenced me in choosing this topic. The Smithsonian Institute currently publishes a number of science magazines for children of all ages. One magazine in particular, Muse, was a childhood favorite of mine, and it heavily influenced the way that I thought about the world and the science behind creation. One issue of the magazine on handwashing stands out in my memory as one of the pivotal pieces of literature that influenced my decision to become a biomedical sciences major and pursue a career in medicine. The issue told the tragic story of Ignaz Semmelweis and his failed attempt to persuade his colleagues to recognize the error of their unwashed hands. Another article in the same issue also discussed modern day medicinal practices concerning the washing of hands and the struggles associated with

hospital workflow. It also highlighted the dissonance between doctors' perceptions and their actual handwashing practices. I was so profoundly impacted by these stories that I still vividly remember many of the details and consequences of these stories. This honors thesis will delve into those topic, and will summarize and apply this childhood magazine issue to a more academic platform. Thus, this paper will be a testament to the magazine that has shaped the last four years of my life and will probably shape the next four decades as well.

The history of hand-washing extends far back into human history. As one of the oldest known books in existence, the Bible should be examined for a comprehensive look into the earliest practices of handwashing. It is mentioned throughout the Old Testament many times for ceremonial purposes, the first time being in Exodus 30:17-21: "The LORD spoke to Moses, saying, 'You shall also make a laver of bronze, with its base of bronze, for washing; and you shall put it between the tent of meeting and the altar, and you shall put water in it. Aaron and his sons shall wash their hands and their feet from it.'" It seems that this practice must have been at least familiar to Moses before this passage because of a lack of explanation, which points to an even earlier place of origin in another culture. Beyond this surface of ritual handwashing however, the Bible gives instructions to common Israelites about cleanliness and highlights the importance of handwashing as disease prevention. In Leviticus, the laws of the people are given from God to the Levites, and the topic of handwashing is spoken of again. Leviticus 17:15 says, "When any person eats an animal which dies or is torn by beasts, whether he is a native or an alien, he shall wash his clothes and bathe in water, and remain unclean until evening; then he will become clean." Once again, more specific to handwashing,

Leviticus 13:6 says even more specifically in relation to disease, "The priest shall look at him again on the seventh day, and if the infection has faded and the mark has not spread on the skin, then the priest shall pronounce him clean; it is only a scab. And he shall wash his clothes and be clean." The command to wash appears again and again throughout the Old Testament in this way, and remains one of the earliest mentions of handwashing in human history. Some Babylonian texts have been known to contain reference to cleanliness as a means of disease prevention, and one excerpt specifically mentions hands as a method of becoming unclean (Linssen, 2004). However, this Babylonian literature is predated by the laws given in the Old Testament and therefore may be derivative of an earlier source transferred to the Babylonians via a conquered Jewish people. As a Christian, one must believe that the Bible is the word of God. Even though the laws and customs of the Old Testament that previously stood in the way of salvation have been cleared away by the work of Jesus Christ on the cross, many of the laws in the Old Testament were implemented as demonstration of God's divine knowledge and his willingness to protect those who were obedient to him.

As the Jewish people spread throughout the Middle East and Europe, they maintained their customs and observed Old Testament law to the best of their abilities over a thousand years later. It is partly for this reason that the Jewish people remained set apart and became victims of the heavy anti-Semitism that was commonplace in the Europe of the Middle Ages. For example, when the bubonic plague swept up through Europe in the 14th century, the Jewish population was the least affected ethnic group by a wide margin, partially because of isolation within their own communities, but largely because of the ritual handwashing that was still observed (Jean & Guillaume de, 1953). While the Black

Death killed over a hundred million people, Jews were seemingly untouched, and as a result, burning hatred and suspicion aroused the general populace against their healthy countrymen. In many major cities and populated areas, great persecution and purges took place, sometimes wiping out a Jewish population altogether (Pasachoff & Littman, 2005). The simple practice of handwashing prevented disease spread within the Jewish population, and although the reasoning behind the practice was faith-based, the scientific knowledge that came from the mind of God proved to be sound by his people's escape from the plague.

The modern father of handwashing in the medical field was a man by the name of Ignaz Semmelweis. This Hungarian physician was born in the year 1818 to a wealthy German family in Budapest, Hungary (Carter & Carter, 2005). His early life and education were spent within the city as the fifth child out of ten. After attending catholic primary school as a boy, he moved to Vienna in 1837 to practice law. However, by personal choice, he soon switched his area of study and started working toward his doctorate in medicine. In 1844, Ignaz Semmelweis graduated from the program at the University of Vienna with a Doctorate of Medicine with a specialization in midwifery and began his illustrious, yet tragic, career as an assistant at the Vienna General Hospital.

The story of Semmelweis' entry into history begins and ends with tragedy. As he progressed in his career, he became acutely aware of an interesting phenomenon concerning a massively disproportionate amount of disease among his fellow doctors (Nuland, 2003). The Vienna General Hospital had two obstetric wards, one operated by doctors and one operated by midwives. Puerperal disease was prevalent at the time among pregnant women. Among the common populace, the doctors were feared as

harbingers of death and the disease. As a result, every effort was made among pregnant women to be placed in the ward serviced by the midwives. As a doctor, and part of the medical community, Dr. Semmelweis was alarmed and aghast by this occurrence and pervading opinion among his patients in the city of Vienna. His training at the University had included research methods and statistical study, and therefore he vowed to track the source of this fear. After some research, Semmelweis came to the shocking conclusion that women admitted to the doctor's ward at the hospital were six times more likely to die of puerperal disease than their counterparts in the midwife ward. Overall, 13% of the women seen by doctors died of Puerperal disease—a disturbingly high number for a class of medical professionals who were supposedly better educated and much more highly trained than their less-decorated midwife counterparts. The doctor often mentioned how miserable he felt when he observed the rampant loss of life (Carter & Carter, 2005).

Although he had identified the rational basis of the fear via actual statistics, Dr. Semmelweis still was unable to find a medical reason for the occurrence. Once again, tragedy played a major role in his life narrative. Semmelweis began to realize a connection between the deaths and the actions of the doctors when a close colleague of his, Jakob Kolletschka, died as a result of a fatal autopsy wound. The actual damage done from the wound was slight, but a disease had racked his friend's body, much similar to the disease that their patients in the ward were suffering from. At this point, Ignaz Semmelweis fit the first piece into his puzzle of knowledge and realized that the autopsies that the doctors were performing were somehow related to the diseases from which their patients were suffering. He then began to more closely examine the actions of the midwives and found that not only were they obviously not performing autopsies, but

they also had strict devotion to personal cleanliness in their ward. Through the statistical analysis and methodical research of Ignaz Semmelweis, handwashing had entered the scene as an obvious major difference between the doctors and the midwives.

As Dr. Semmelweis drew parallels between the autopsies and the deaths, he began to realize that the doctors themselves were the ones transferring the disease from person to person. Immediately he began a practice of washing his own hands and instituted a policy of using chlorinated lime as a cleansing agent to remove the particles from the hands of the doctors after autopsy. This policy was carried out, and the change in patient outcome was drastic. Immediately instances of death due to Puerperal disease plummeted, and after some time, Ignaz Semmelweis began to write prolifically concerning his discovery and the importance of cleansing one's hands when moving from autopsy to operation. Not only did he implement a handwashing policy, but he also began thoroughly washing all instruments and other materials associated with the patients who were diagnosed with Puerperal disease. Childbirth deaths reached previously unheard-of lows in the Vienna General Hospital, and for a while the deaths within the doctors' ward were significantly fewer than the childbirth deaths within the midwives' ward (Carter & Carter, 2005).

Slowly and inexplicably, childbirth deaths began to rise once again in the doctor's ward. Puerperal disease was back, and the troubled Ignaz Semmelweis once again searched for a reason. To his dismay and disgust, his colleagues were subtly refusing to wash their hands and had begun to return to their old ways, despite the solid empirical evidence offered to them by the hospital's morgue (Carter & Carter, 2005). What Semmelweis had come into conflict with was prevailing medical knowledge of the time. The greater medical community in the 1840s still adhered to the medieval beliefs of the

miasmas and the four humors of the body. This previous structure of thinking revolved around the fact that disease travelled from host to host via harmful clouds called miasmas, and that the body was balanced by four fluids called humors. These four fluids were blood, yellow bile, black bile, and phlegm, and they affected all disease and temperaments within the body. Therefore, bloodletting was still a common practice, and diseases were thought to be a result of humor imbalance. The particles that Ignaz Semmelweis had correctly discovered and identified were dismissed by his compatriots, first subtly, and then openly. The medical community outside Vienna also scoffed at his ideas, and the notion that the doctors themselves could be the cause of such high mortality rates was dismissed as ridiculous and unprofessional. Semmelweis strove in vain to convince his colleagues using the statistical evidence that he had gathered, but his efforts were fruitless. Puerperal disease returned, and the curse of the doctor's ward once again brought fear to the obstetrics ward in Vienna.

Ignaz Semmelweis, although his discovery was of astronomical importance, had no medical or scientific basis for his reasoning—his thesis rested on statistics alone. Sadly, he was declined for reappointment in 1849, and began an angry campaign against the ruling medical establishment, calling his colleagues ignorant, blind, and accusing them of murder because of their refusal to wash their hands. Unfortunately, he was just slightly ahead of his time, as Pasteur and Koch were just a decade away from discovering and creating the germ theory (Gest, 2003). Pasteur and Koch formed their data from experiments based on hypothesis, boiling and fermenting in a laboratory setting, and setting up repeatable experiments for fellow doctors to test. Their irrefutable results slowly changed the minds of the prevailing medical establishment. However, Ignaz

Semmelweis had missed his time, and had none of these careful laboratory proceedings to back his claims. His decline from medical prominence and inability to persuade his colleagues slowly broke him down, and by 1865 he suffered from severe mental dementia and a host of other pre-Alzheimer's symptoms. As a result, his family placed him in an insane asylum because of his irate behavior at the preventable deaths. He died on August 13, 1865, shortly after internment in the asylum. Although the father of handwashing today, he was rejected by his professional field, separated from his family, and ineffective in his ability to save his patients. The "Semmelweis Reflex" is a term coined after his tragic story, which is the knee-jerk response of a society to reject new evidence that goes contrary to previously held beliefs or paradigms (Levitt & Dubner, 2009). Fortunately, Semmelweis has been vilified both inside and outside the clinic and laboratory, and is now remembered as the father of modern handwashing practice.

In modern medicine, handwashing has fully become accepted as a commonplace practice, and is enforced by either law or by the hospital itself. The germ theory has supported with sound theory the statistical data presented by Semmelweis as a result of the combined work of Pasteur and Semmelweis. The work of these three has made the necessity of handwashing irrefutable. Although no-one disagrees about the effectiveness of handwashing, sometimes non-compliance is an unconscious act. According to the CDC, in the US over 722,000 in-hospital patients get some kind of nosocomial infection, which is an infection received in a healthcare setting that would not have otherwise been contracted (CDC, 2011). Conscious and thorough handwashing practices are the main way that these infections can be prevented.

The Bible and Semmelweis laid the foundation for methods of handwashing, but modern technology and a century of soap usage has modified handwashing techniques and soap quality. The early soap used as a disinfectant by Semmelweis was a chlorinated lye, but modern soaps and disinfectants have broadened out into many different categories. Chemically, soap is made of two different components: an alkali component, and a fat component. The alkali component is chemically polar, and the fat component is nonpolar. These molecules align themselves in water in micelles, where the lipid component is on the inside, and the polar component is on the outside (Sabadini, Ungarato, & Miranda, 2014). This orientation allows for almost any substance to become a solute in water, as all polar and non-polar molecules now become bound together by the soap interface. Within the alkali component, bar soaps are typically made from sodium hydroxide, whereas liquid soaps are made from potassium hydroxides. Many disinfectants today however come mainly in the liquid form, because of a possibility that certain types of bacteria may be transmitted by the physical surface of the soap bar. However, according to a laboratory study done by Dial Technical center in 1988, the transfer effects of a physical soap bar are almost nonexistent because of the bactericidal effects of the soap (Heinze & Yackovich, 1988). Although some bacteria may remain on the soap after handwashing occurs, the basic environment of the soap destroys the bacteria that remains on the surface, thus eliminating the possibility that a colony may develop and contaminate further users.

It is important to note, however, that the conductors of the above experiment were employed by a soap company. They did not skew their results or collect misleading data, but the results of their experiment would lead one to believe that bar soap may be as

effective as liquid soap or an alternative antiseptic in handwashing. But antiseptic qualities of the product in storage are not always the same as the product's antiseptic qualities when applied to hands. This brings up a common discussion among medical professionals, which is a debate concerning the use of alcohol products or hand sanitizers verses using mere soap and hot water. One common misconception is that the alcohol rub dehydrates the hands and evaporates faster, thus becoming uncomfortable and also reducing the antiseptic effectiveness of the handwashing product. However, it is actually true that although the alcohol does evaporate, the alcohol has more than enough time to act, and the antibacterial product left on the skin is able to work. Another misconception about handwashing methods is that washing with water is ineffective or that washing with antibacterial soap is more effective than using regular non-bactericidal soap. To answer all these commonly held thoughts and to refute a few of them, it is necessary to examine and outline various factors concerning handwashing and a few methods of handwashing. In this section, bacterial classification and its place in hand anatomy will be discussed. Then, methods and techniques of handwashing will be covered. Finally, the actual product used in handwashing and the numerous factors involved in removing bacteria and maintaining long-term hand hygiene will be discussed.

First it is important to understand that the vast majority of bacteria on the hands is important normal flora that prevents other opportunistic bacteria from gaining a foothold in the skin. The skin itself is split into several layers, with the general layers being the epidermis, which is the outermost layer, and the dermis, which is the inner and much thicker layer (Amirlak, 2015). The dermis is supplied with blood and lymph vessels and directly houses the hair follicles, sweat glands, oil glands, and other various receptors that

send information about the environment to the brain. The epidermis on the other hand is extremely thin and provides protection to the body from sun, abrasions, and infection. The epidermis consists of five different layers: the stratum corneum, stratum lucidium, stratum granulosum, stratum spinosum, and stratum basale. The stratum basale is the deepest layer and is the layer that supplies life and substance to all other layers via the multiplication of the keratinocytes present. As no direct blood vessels or lymphatic vessels run through the epidermis, the nutrients required for cell division come from the dermis and feed the cells in the basale as they multiply. All other layers above this subsequently receive cells from the regenerating basale layer and thus form casings of slowly dying cells connected via desmosomes and a complex cellular matrix that gives strength to the skin. The stratum spinosum is where immunologically active cells reside and cells slowly moving outward cross through from the stratum basale. At this stage, the cells are now in the stratum granulosum where the cells now lose their nuclei (hence the name) and release lipid into the cellular matrix, forming the main chemically protective and impenetrable layer of the epidermis. The stratum lucidum, although not present everywhere in the body, is present on the palms of the hands and therefore is critical in the discussion of handwashing. Above this layer is the stratum corneum, where the mainly dead cells maintain their cellular connections and extracellular matrix. This forms the outermost barrier and the rugged environment for the bacteria that are an intrinsic part of normal human skin physiology.

The bacteria carried on the hands can be split into two main categories depending on where it is normally found and how long it normally rests on the hands. Residential bacteria are the normal flora of the hands that reside beneath the stratum corneum, and in

the case of hands just above the stratum lucidum. These bacteria mainly consist of the type *Staphylococcus epidermis* (Lerebour, Cupferman, & Bellon-Fontaine, 2004). *S. hominus* and several types of coryneform bacteria make up the rest of the normal skin flora, along with some species of fungi. These types of bacteria have important functions as normal skin flora, particularly in preventing other opportunistic bacteria from gaining a foothold within the deeper stratum corneum and competing with bacteria picked up from surface contact for the natural microbial resources found on and in the skin. These types of bacteria have extremely low chances of causing infection and damage within the body, but if they are wiped out, the colonization by other bacteria types are can lead to serious infection and systemic damage. The other type of bacteria is classified as transient (Kapil, Bhavsar, & Madan, 2015). This broad category classifies any type of bacteria that remains purely on the surface of the skin and does not really grow or colonize the skin. However, this bacteria type can spread across the skin and remain active for long periods of time, waiting for hand contact with another more habitable surface. One classic example of bacteria of this type would be *Streptococcus pyogenes*, which is the bacteria responsible for causing Puerperal fever and is the original transient bacteria that was killed off by the chlorinated lime used by Ignaz Semmelweis in his previously mentioned famous fight against childbed fever in the 1800s.

On the hands, the concentration of these bacterial and fungal species is measured in colony forming units (CFU), or the number of cells present that can are viable and able to multiply via binary fission. The World Health Organization recognizes that the specific CFU on the hands is around the range of 39,000 to 4,600,000 CFU per square centimeter (Cdc & Who, 2008). Palms specifically accrue a great quantity of bacteria because of

their size and their organic contact with bacteria-carrying surfaces such as door handles, handrails, and other hands. However, a much overlooked hotbed of transient bacterial residence is the underside of the fingernail. This fact leads to some interesting recommendations concerning fashion among medical professionals. According to the Center for Disease Control, nails that are longer than six millimeters are considered long, and are have more colony forming units of bacteria than their shorter counterparts by almost a factor of ten (CDC, 2016a). To solve this problem, it is encouraged that nails are kept short and women refrain from wearing fake fingernails while working in the medical profession or with patient care.

The topic of fingernail bacterial colonization leads to another aspect of handwashing, the method. The CDC recommends a simple but lengthy procedure for everyone inside and outside of the medical profession for standard handwashing. First, wet your hands with running water. Then, apply soap and lather your hands on four different surfaces: back of hands, palms, in between the fingers, and finally under the nails. Scrub for twenty seconds, rinse with clean water, and dry with a clean towel (CDC, 2016b). There are two steps in particular here that often are overlooked. First, many people unknowingly dry their hands on their pants or on a used towel, thus basically negating the act of washing their hands to get rid of bacteria. While dirt may be removed, the transient bacteria that is picked up on everyday surfaces goes right back onto the skin if a clean towel or air is not used. Secondly, the nails are often overlooked during handwashing, even though, as was previously mentioned, they are hotbeds of bacterial activity and transfer. As a travel medicine doctor with a private practice in Encino, California and hospital lecturer specializing in infectious diseases, Dr. Aaron Shelub recommends a simple step to

include in a regular handwashing routine (Shelub, 2012). To apply soap and remove bacteria from under the nails, in the middle of the lather step, place hands with palms facing inward and curl the fingertips until they are touching their chiral opposite. Then, fit one set of nails under the other, and reverse the position, thus pressing soap underneath both sets of nails. Other researchers only use an eight second time slot for scrubbing the hands, but this has been proven to be inadequate for most people to achieve a full lather.

The product medium used in concert with water is just as important has the method used, and in most cases is even more important. The original ritual handwashing methods used by the priests in the Old Testament used only water but this method has been shown to wash away only 77% of the bacteria present, thus allowing the remaining bacteria to multiply and repopulate the skin after a short period (Burton et al., 2011). The earliest soap used in a medical setting was chlorinated lime, which Dr. Semmelweis used to kill the *S. pyogenes* that had plagued his patients, but soaps and antibacterial hand products have advanced and branched out since that time. Today, there are four basic sets of materials used to wash hands. First, depending on resources available, one can use just water to wash. Next, non-antibacterial soap with water can be used. This second kind is usually done for the purpose of removing fat or dirt from the hands, but is surprisingly good at removing bacteria from the skin. Third, washing with antibacterial soap is the most common set of materials used in most civilized countries. However, this type of washing has not been proven to be any more effective than normal washing with simple soap (Oughton, Loo, Dendukuri, Fenn, & Libman, 2009). The final type of hand hygiene involves using an alcohol rub or hand sanitizer to kill bacteria on the hands. Although this

is not technically a form of handwashing, it is in direct competition with handwashing and is a viable alternative and must therefore be considered.

In a study published in the International Journal of Environmental Research and Public Health, handwashing with soap was compared against handwashing with water only (Burton et al., 2011). The effectiveness against bacteria associated with influenza was the determining factor. Influenza is currently one of the biggest killers, especially of children, in the world today. Mainly because of its diarrheal effects, the combined fatalities due to influenza are greater worldwide than the deaths caused by HIV/AIDs, malaria, and measles combined. It is overwhelmingly agreed upon by all major humanitarian aid organizations and governments that, in this case, preventative care and public education is much more cost-effective and lifesaving than palliative treatment. This disease is especially prevalent in third world countries and thus the effectiveness of each product greatly matters where soap and clean running water may be scarce. In the study, twenty volunteers touched commonly contaminated areas in public places, such as handles, railings, seats, and doors. The subjects were then split into two groups with one handwashing with water only and one handwashing with soap. Samples were taken of the subjects hands both before and after handwashing and this process was repeated several times until 480 total samples were collected. The overall results showed that there was a 44% chance that the subjects who had touched public surface picked up bacteria associated with fecal material and therefore highly associated with influenza or diarrheal effects. After handwashing with only water, the bacterial contamination concentration reduced to 23% of its original concentration. The subjects who washed with water and a non-antibacterial soap were found to reduce their bacterial concentration to 8%. The type

of bacteria present on the subject did not affect the outcome of the experiment. Therefore we can see that non-antibacterial soap usage greatly reduces bacterial contamination when compared with trials using only water.

In the above experiment, water with non-antibacterial soap was tested against water only. In the following section, it is important to now compare the second and third possibilities for materials used in handwashing; non-bacterial soap verses bacterial soap. To give some introductory information, in the United States about 75% of the hand soaps sold in stores are antibacterial. However, according to Colleen Rogers, a leading PhD and microbiologist at the Food and Drug Administration, there is little connection between antibacterial soap and increased bacteria protection or removal (Rogers, 2015). Internal studies within the FDA proved that the two soaps are equally effective and proposed a mandate in 2013 that requires companies putting antibacterial soaps on store shelves to provide "substantial data" that their products somehow increase hand hygiene. This reasoning stems from the fact that antibacterial soaps contain the compound Triclosan. Triclosan in high concentrations acts as a biocide, killing the bacteria, but at lower concentrations present in the handwashing process is more active as a bacteriostatic, thus keeping bacterial growth minimal (Giuliano & Rybak, 2015). Triclosan binds to an enol-acyl carrier protein reductase enzyme that is involved in fatty acid synthesis, and disables the enzyme. This leads to fatty acid synthesis inhibition, which prevents the cell from replicating and creating new cell membrane. This compound has been found to have very effective bactericidal effects in a petri dish, but in the action of handwashing its effects become minimal, as the reaction mechanism hardly takes place to a noticeable effect during the comparatively quick action of handwashing. For this reason, Triclosan-bearing

soaps have gained a reputation for being excellent cleaning products, where the product remains on the target surface for a long time. On the other hand, Triclosan is suspected to be the cause of hormonal disruption in the body, and may have harmful long-term effects. These effects can include possible hormone disruption, as has been shown in a rat model, but it remains unconfirmed whether these effects can be transferred to humans via hand application (Stoker, Gibson, & Zorrilla, 2010). On top of that, Triclosan, if exposed to the skin for a long enough period to really damage transient bacteria populations, will also sometimes wipe out the normal resident bacterial flora. This will only increase the chances of infection and deeper colonization by harmful disease-carrying bacteria. Bacteria populations can also develop a resistance to Triclosan by using a different method or slightly different enzymes for fatty acid synthesis, thus nullifying the effects of that family of drugs. The repercussions of this resistance can be particularly acute and dangerous when in a hospital setting, as people with compromised immune systems come under attack from a superbug that seems impervious to the normal treatments prescribed by doctors (Giuliano & Rybak, 2015). Thus, handwashing with non-bactericidal soap is much more preferable to washing with antibacterial soap, because the risks are serious while the benefits are minimal; being mostly driven by advertising and business profit rather than actual supportive science.

The final two categories that must be compared are washing with hand soap verses using an alcohol hand sanitizer to cleanse the hands. Hand sanitizer brands such as Germex and Purell claim that their products kill 99.9% of germs. These claims are true, but the actual health benefits of this fact are dubious. The 99.9% claim comes from laboratory studies done on inanimate objects, where the bactericidal effects of the product

are undeniable. As mentioned before, hands have necessary protective bacteria that is residential on the skin and helps prevent transient or harmful bacteria from gaining a foothold within the stratum corneum. The majority of the 99.9% of bacteria killed are a result of the longer lasting effects of hand sanitizer on the hands. According to Barbara Almanza, a sanitation professor at Purdue University, hand sanitizers work by clearing the layer of oil off the hands and preventing bacteria from surfacing and being transmitted onto another surface (Bowker, 2000). This is a result of the 60% alcohol present in all hand sanitizers. However, once again the bacteria that will be surfacing through the protective oil layer is the natural resident flora of the hands. If hand sanitizers are wiping out the natural flora with the 60% alcohol and destroying the protective oil layer, then it would follow they must be at least killing the transient bacteria on the surface as well. According to the Clinical Infectious Diseases publication, in a study done by volunteers using H1N1 avian influenza virus, both hand sanitizer and soap and water were effective at removing the virus from the hands, but the soap and water method still was proven to be more effective than hand sanitizer (Grayson et al., 2009). But the above case involves a virus, which is very different from a bacterium, both in biology and makeup. In an article published in the Infection Control and Hospital Epidemiology Journal, *Clostridium difficile* was used as the target of handwashing and all methods discussed here were used. *C. diff.* is a common cause of nosocomial infection and can cause severe to life-threatening intestinal distress in the elderly. Handwashing with normal soap, handwashing with antibacterial soap, and application of hand sanitizer were all tested against this very relevant pathogen. The results showed that hand sanitizers were by far the least effective and left the greatest number of CFU on the hands after

application by several orders of magnitude. Notably, the handwashing with plain soap and hot water was the most effective, and the handwashing with antibacterial soap was only slightly less effective than the plain soap. It is also important to note that hand sanitizers are only effective when the hands are not visibly dirty or excessively dirty. Therefore, it can be concluded that although hand sanitizers may remove 99.9 % of germs as advertised, they are not able to adequately remove harmful bacteria and may damage the normal flora of the hands, thus leading to a dangerous susceptibility to harmful opportunistic transient bacteria shortly after the use of hand sanitizer.

It is important to briefly note that *Staphylococcus epidermis*, the main component of the normal flora of the skin, is a necessary part of the flora for several reasons. As it makes up 90% of the flora, when overly bactericidal products are used, the main population that suffers is the *S. epidermis* population. *S. epidermis* naturally produces lanthionine-containing antibacterial peptides, known as bacteriocins that act to kill competitors and other bacteria on the skin (Cogen, Nizet, & Gallo, 2008). This not only protects themselves, but also naturally removes transient bacteria from the surface. The presence of *S. epidermis* also helps to keep the immune system highly functioning, by always being a constant foreign body close by. This interaction takes place through receptors on the keratinocytes that recognize the presence of the bacteria. If this helpful bacteria is removed, the skin not only loses a benign competitor against much more dangerous germs, but the skin's innate immune system is weakened by a lack of natural bacterial upkeep. According to the bacterial review cited above, there has been little to no study done on the effects of disease in the presence of decreased skin flora, but the authors recommended further research into this symbiotic relationship.

Overall, studies have shown that the most effective method for handwashing includes getting a healthy lather of soap on all surfaces of the hands, including the often forgotten fingernails. Shorter fingernails also greatly reduce the amount of transient bacteria on the hands. In terms of products used, when water, soap and water, antibacterial soap and water, and hand sanitizer are compared against one another, plain soap with water emerges as the best product overall. Not only is non-bactericidal soap and hot water the most effective product for handwashing, but it is also probably the least harmful in terms of future opportunistic bacteria reinfection and long-lasting Triclosan hormonal disruption. Soap and water removes dirt, excess oil, bacteria, and viruses alike from the surface of the stratum corneum while at the same time leaving the natural layer of protective oil and residential flora undisturbed, thus proving to be the best product category available for hand hygiene.

Now that the history and methods concerning handwashing have been covered, the psychology of handwashing must be also discussed. In the children's science magazine mentioned in the introduction of this paper, one of the main stories told about a handwashing dilemma at the Cedars Sinai medical center in Los Angeles (Dubner, 2006). While the physicians working there were well aware of the benefits of handwashing and the consequences of not washing their hands as they moved from patient to patient, nosocomial infection remained high and handwashing compliance remained low. The administration was lead in its fight to improve handwashing practices by a urologist named Leon Bender. According to the original article in the New York Times, Leon noted the high usage of hand sanitizer on a cruise, and realized that the cruise ship was extremely invested in making sure that infection did not spread. However, the spread of

infection remained a big problem at his hospital, one of the leading hospitals in the world, Cedars Sinai. Dr. Bender identified several main psychological problems that afflicted doctors worldwide and specifically kept handwashing compliance low at Cedars Sinai.

First, many doctors who have practiced for several years fall into the trap of arrogance. After fighting disease for so long, it seems preposterous that they themselves could be the carriers of bacteria, and they shift the blame within their own minds to their colleagues. This arrogance and denial has been present in experienced doctors since the days of Ignaz Semmelweis, when his original hypothesis and data was rejected on similar grounds. Secondly, the physicians at Cedars Sinai are some of the greatest medical professionals in the world, and as a result are extremely busy. The vast majority of them were under the unconscious impression that they were simply too busy to stop and wash their hands, as sinks were often far out of their workflow. Thirdly and most importantly, doctors were completely unaware of how often they actually washed their hands. Video cameras at the hospital showed a gross discrepancy between how often the doctors washed their hands and how often they self-reported as having washed. The data gathered by the video cameras was only reinforced by similar data collected at a hospital in Australia. In an Australian study, although self-reported handwashing compliance was at 73%, the actual recorded compliance was a mere 9%, a massive discrepancy in such a highly professional environment (McLaws & Azim, 2014). These misconceptions are common to human nature, and are the main reason that handwashing compliance can be so low.

To combat these psychological and workflow factors, Dr. Bender and the administration of Cedars Sinai tried a myriad of different solutions. They tried positive

reminders in the forms of faxes and emails, they peppered the walls with Purell dispensers, and they tried to affirm doctors that were found washing their hands by using a ten dollar gift card as a reward. However, although these methods helped slightly, compliance still remained below the necessary levels for accreditation by a joint commission of healthcare organizations. But the hospital's epidemiologist had a brilliant idea to combat psychological resistance and renew bacterial awareness. After a meal during a meeting by the Chief of Staff Advisory Committee, Rekha Murthy passed a petri dish around to the members of some of the highest ranking doctors at the hospital. She asked if she could culture their hands, and they gladly pressed hands into the spongy layer of agar. The cultured images that returned from the lab were disgusting colonies of a wide variety of bacterial invaders that had come from the doctors' palms. The hospital had hit on a solution to solve their compliance problems, and made a single simple image of the cultured hand flora the screensaver on every computer in the hospital. Doctors quickly overcame their previous misconceptions about handwashing, and compliance shot up to nearly 100% at the hospital. When presented with such unquestionable, solid data and a disgusting image, all psychological barriers were overcome, and the spread of bacteria ultimately decreased as a result.

The other side of the psychology of handwashing is rarely considered, but is common to mental disease. Too much handwashing can cause its own set of problems, and the previously covered topic of normal flora and skin anatomy can assist in understanding this. In rare cases, people can become obsessed with hand-washing. These people may be commonly known as "Germ Freaks" but are actually suffering from an obsessive-compulsive disorder that fixates on hand-washing. Obsessive compulsive disorder (OCD)

is a mental disease concerning repetitive behavior that is uncontrollable. The source of these behaviors is known to come from intrusive thoughts in the patients mind, but a specific biological or genetic cause is unknown. The Journal of Progressive Neurobiology has split symptoms of OCD are into five different kinds of behaviors or compulsive obsessions. Checking compulsions, washing compulsions, symmetry compulsions, hoarding compulsions and sexual or religious compulsions are all categories of behaviors that result from OCD. According to Dr. Paul Greene from Manhattan Center for Cognitive Behavioral Therapy, compulsive handwashing is the most common symptom associated with Obsessive compulsive disorder (Greene, 2013). This may be in part because it is the easiest to spot and because it can lead to raw or broken skin on the hands. OCD can drive people to change their handwashing habits in two abnormal ways—in the length of time spent washing, or in the number of times handwashing throughout the day. As previously mentioned, the CDC has recommended about 20 seconds used for scrubbing the hands after the lather stage, but compulsive hand washers can spend over 60 seconds washing their hands. Normal handwashing would occur before or after handling food, using the bathroom, handling garbage, or caring for the sick. However in people with OCD, intrusive thoughts could drive them to wash upwards of 20 times a day. Numbers higher than that can often cause disruption in the patient's life, leading to social and work-related problems for someone so distracted.

Because of the cleaning action of the soap and water, normal handwashing only requires 20 seconds to remove a significant amount of the transient surface bacteria. The .01 % of bacteria left behind is statistically insignificant in terms of its disease transferring capabilities. Beyond this time, and also in high frequency handwashing the

abrasive action of the scrubbing under water can begin to wear away at the skin, thus tearing the epidermis and exposing the layers of the dermis underneath. The damaged is not limited though to the anatomy however as the important defensive layer of residential bacterial flora is often also destroyed by obsessive compulsive handwashing. This makes the road to recovery fraught with infection, as a decrease in handwashing leads to growth of opportunistic bacteria, harmful or not, within the skin and upon the exposed lower layers. At this stage, even *S. epidermis* can become harmful. The protective layer of bactericidal material released that acted symbiotically on the skin surface can infect the blood and cause systemic damage (Cogen et al., 2008). In addition to this, the bacteria are protected by the material layer released and are therefore naturally drug-resistant. This is a perfect scenario where triclosan resistant bacteria now become harmful, because as medical professionals administer that product or other chemicals in that family, the effectiveness is decreased and stronger drugs must now be used to wipe this harmful population of previously benign bacteria from within the body. Thus, OCD handwashing not only can destroy the tissues of the hands as a result of prolonged handwashing, but can also remove the protective layer of harmless residential bacteria from the skin.

Handwashing has had a major effect on my career choice, and early exposure to scientific history, method, and psychology in the form of a kid's magazine was very formative. Although handwashing itself has been a part of human culture since the ancient times, as seen in various texts, the reasoning behind the practice was merely faith-based until the revolutionary work of Ignaz Semmelweis. With his ground-breaking clinical results, and the support of the germ theory, handwashing became a normal part of western human culture and medical practice. Today, it would be good to remember the

Semmelweis reflex when encountering new information. The methods covered in this paper have centered on the handwashing practices recommended by the CDC and FDA. As for materials used, final consensus from a medical standpoint based on recent research points to hot water and non-antibacterial soap as the best method for the cleanest hands with the fewest harmful effects. Although advertised to kill more germs or leave fewer bacteria on a petri dish, other products can be harmful to helpful bacteria and can pass over the much more dangerous transient bacteria, leaving the hands open for future infection. In the modern day, medical practitioners have come together in understanding the massive importance of handwashing, but can often unintentionally self-report statistics that are vastly higher than real numbers. To combat this, hospital administrators have used powerful images of bacteria-filled petri dishes taken from hand prints to give a constant reminder of how active the hand microbe flora really are. However, prolonged handwashing or overly frequent handwashing as a result of OCD intrusive impulses can destroy the anatomy and normal flora of the hands. Therefore it is important to have a healthy balance to protect against transient bacteria while keeping normal residential flora intact. Overall, handwashing has had tremendous impact within the medical field and on society in diminishing the spread of disease in society. Remember to wash your hands!

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