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Instrument Sterilization and Surgical Site Infections in Low and Middle Income Countries

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ABSTRACT

With the recent surge in oftentimes fatal bacterial resistance, surgical site infections (SSI) are now a prominent topic of scholarly discussion. These infections occur due to unsterile surgical practices infiltrating the operating room, and deadly pathogens with it. The developed world has lowered rates of SSI through scrupulous enforcement of CDC sterilization guidelines while low and middle income countries (LMICs) continue to fall victim to inefficient sterilization. LMICs often don't have the resources to reach these CDC guidelines and as a result endure surgical instrument contamination. Currently, there is a gap in funding and research related to the state of surgical instrument sterilization. This study aims to reveal first hand data regarding the gap in adherence to CDC sterilization guidelines for a variety of LMICs. Data was collected through virtual interviews with surgeons or surgical technologists globally. Interview responses were later scored for adherence to the CDC guidelines and correlated with rates of SSI per country. Results showed that the adequacy of surgical instrument sterilization processes (SP) in hospitals is directly correlated to SSI rates in LMICs. A one tailed test with a flow of SP adherence to SSI prevalence rendered the following strong correlation of R squared=0.772. This relationship demonstrates that investments to improve surgical sterilization processing will likely render lower rates of SSI. Lower SSI rates in LMICs could give rise to an increase in surgical tourism, a decrease in expensive treatments for highly resistant bacteria, and ultimately a decrease in surgical morbidity and mortality.

Introduction

In recent years, the surgical industry has grown exponentially, however its quality globally is lagging far behind its rate of proliferation (Robertson et al., 2021). Low and Middle Income Countries (LMICs) often lack the resources and training necessary to adequately perform these procedures, in turn making “postoperative death the third leading cause of” death worldwide, accounting for 7.7% of global deaths in 2016 (Nepogodiev et al., 2019). Operations may be executed seamlessly, but this mortality rate can often be attributed to additional procedural factors, including the sterility of instruments.

Lack of sterility can increase surgical site infection (SSI) rates following an operation, making SSI the second most common postoperative complication in the United States (Scarborough et al., 2016). There are three types of SSI, (from least to most superficial) they consist of 1) the organ/space SSI which occurs in an incision on an organ or in space between organs, 2) deep incisional SSI which can be found in the layer of fascia or muscle, and finally 3) superficial incisional SSI which occurs in subcutaneous tissue or the skin (Anderson et al., 2014). Infection commonly arises as a result of antibiotic resistance, which per the CDC is defined as what “happens when germs develop the ability to defeat the antibiotics designed to kill them.” Many hospital patients are prescribed or exposed to antibiotics during their stay, consequently, the prevalence of highly resistant germs is far greater in hospitals than outside (CDC, 2019).

If these highly resistant germs exist anywhere in the hospital they can easily be transported to other locations within the building including the sterile processing (SP) unit (the unit or room where surgical instruments are sterilized). This is especially common in institutions dearth of higher level education, funds or time where personnel fail to properly disinfect themselves throughout the day. However, even with top tier disinfection techniques, these pathogens are often resilient enough to survive even the harshest antibacterial protocols. To combat the prevalence of these fatal germs, High Income Countries (HICs) ensure consistency of high-quality sterilization techniques nationally. This led to a major decrease in surgical site infection (SSI) rates in the US from 2012 to 2018, however, this is far from the case in underdeveloped countries where bacterial resistance rates continue to run high (Dencker, 2021; Allegranzi, 2014). This difference in SSI prevalence is demonstrated by the fact that the SSI rate in HICs ranges from 1.2%-5.2% while in LMICs this range jumps from 1.2% to 70% (Fast et al., 2017). As stated by Griffith University nursing professor, Brigid Gillespie, the fact that 11% of general surgery patients worldwide "are likely to develop an infection 30 days after surgery" indicates that even as one country inches towards lower SSI rates, there is plenty of work to be done globally (Gillespie et al., 2021).

Literature Review

As seen above, several studies have revealed that sterile processing (SP) in low and middle income countries (LMICs) is far from satisfactory, detailing not only the evident lack of resources but also a gap in proper training (Robertson et al., 2021; Panta et al., 2019; Fast et al., 2019; Fast et al., 2017; O'Hara et al., 2015). Some recent studies divulge occurrences in the operating rooms of LMICs including visibly contaminated instruments entering the surgical incision site (Robertson et al., 2021). The researchers predict that these gaps lead to the jarring rate of SSIs which become fatal 38% of the time in such LMICs (Monahan et al., 2020).

Although some studies analyzing sterile processing (SP) efficacy in LMICs have been performed, few provide firsthand knowledge of the state of SP in developing countries (Robertson et al., 2021; Panta et al., 2019; Fast et al., 2019; Fast et al., 2017; O'Hara et al., 2015). The studies that do exist often target a particular location within a LMIC without providing multidisciplinary approaches to combatting this quality gap (Robertson et al., 2021; Panta et al., 2019; Fast et al., 2019; Fast et al., 2017; O'Hara et al., 2015). Such a specific scope tends to limit the benefit of the study's findings. Other studies pay closer attention to SSIs after a specific surgery (including cesarean section, laparoscopic surgeries and cardiac surgeries) without detailing the general sterile processing (SP) in the country studied, thus rendering the research inapplicable to national rates of SSI as a result of inappropriate SP (Ayala et al., 2021, Robertson et al., 2021, Zanetti et al., 2001). Another prevalent body of research evaluates the financial burden of SSIs in LMICs, yet it fails to acknowledge the predicted root of the problem: unsatisfactory sterile processing (Monahan et al., 2020). This data may describe the financial state of the country, providing a possible explanation for the lack of SP capability, but a connection to the rates of SSI in said country has yet to be established.

A far greater quantity of research exists with the purpose of informing physicians, medical professionals and patients on prevention methods for SSI. This may be helpful to audiences in High Income Countries (HICs), however they often ignore the limitations of LMICs (Anderson et al., 2014; McHugh et al., 2010). Additionally, many journals investigate aspects of Healthcare Associated Infections (HAI's) including the analysis of postoperative factors and prevention methods (Elingson et al., 2014; Emerson et al., 2012; Safdar et al., 2014). HAIs are the umbrella that SSIs and other infections fall under, however "SSIs are now the most common and costly HAI" according to Dr. Anderson Deverick, Duke Medical Professor of infectious diseases. That means not only are SSIs extremely prevalent, as noted by the fact that up to one third of LMICs surgical patients endure this infection, but they are also expensive pathogens to treat (Fast et al., 2017). The analysis of healthcare infection related costs could serve to create a sense of urgency appealing to a broader, nonscientific audience. However, it fails to address why these certain infections occur in the first place and the more targeted financial issue: monetary barriers restricting LMICs from preventing these infections.

Furthermore, the majority of these studies fail to acknowledge the correlation between unsatisfactory sterile processing (SP) and surgical site infection (SSI) rates in LMICs. This begs the question: what is the impact of surgical instrument sterilization processes in hospitals, on surgical site infection rates in low and middle income countries?

This study seeks to determine the root of SSIs in LMICs: inadequate sterile processing which is likely responsible for tens of thousands of postoperative deaths yearly. This will be studied through the collection of first-hand accounts through interviews, paired with research analysis.

Recommended Sterile Processing Standards

In 2016, the Center for Disease Control (CDC) updated its guidelines regarding sterile processing (SP). Prior to live interviews regarding this issue, researchers must be familiar with the current CDC standards for SP. In turn, allowing the researcher to determine the efficacy of different SP described in interviews. Additionally, it will create a baseline for adequate comparisons to be made between Gross National Income (GNI), which is the factor identifying low and middle income countries (LMICs) in this study, and SP capability.

There are a few key guidelines SP units can realistically adhere to in order to ensure satisfactory sterility in LMIC hospitals. These include the following: 1) the use of biological, mechanical or chemical tests called "indicators" to indicate a steam sterilizer's (often times these are called autoclave machines) efficacy before, during and after use, 2) physical separations within the sterilization room into at least three separate areas to "minimize the flow of contaminants" to sterile regions of the facility, 3) proper cleaning to decontaminate instruments of visual debris before they are sterilized, and 4) modern methods of wrapping and packaging soon to be sterile items.

The most accurate form of sterility surveillance of autoclaves is performed by biological indicators. The most common biological indicator used is a spore test, sometimes known as a Self-Contained Biological Indicator (SCBI). This is "because they assess the sterilization process directly by killing known highly resistant microorganisms" as stated by the CDC. However, it is strongly encouraged to perform additional mechanical and chemical efficacy tests with each cycle of the autoclave (a type of steam sterilizing machine), since biological testing is only completed on a weekly basis (CDC).

Mechanical indicators are often built into an autoclave in order to monitor each cycle the machine undergoes. This often appears in the form of temperature and pressure gauges as well as exposure time monitors which alert the operator that there is a mechanical failure in the machine prohibiting it from meeting manufacturer standards of sterility (CDC).

Finally, chemical indicators have properties which provoke them to change color when an ideal "temperatures or combinations of time and temperature" are met (CDC). They can be applied to the outside of a package of instruments in the form of tape or be incorporated into the packaging itself. Tab or strip forms of indicators can be placed within a package to ensure the contents meet sterility requirements. The color changes are seen immediately after each autoclave cycle if performed adequately and therefore make this a necessity in effective sterile processing (SP) units (CDC). All three of these indicators are commonly used in high income countries (HICs) to uphold the recommended standards of sterility previously mentioned.

Realistically, these standards can be achieved by low resource countries with sufficient aid and innovative solutions. If the correlations between SP, GNI and SSI rates are demonstrated by this study, these standards can be applied to reduce SSI rates worldwide.

Methods

To reveal the correlation between surgical instrument sterilization processes in low and middle income (LMIC) hospitals and surgical site infection (SSI) rates, a multifaceted research approach was employed. To narrow the scope of the sample studied, a low to middle income gross national income (GNI) range was established. Gross national income

is the yearly income earned by a country's citizens divided by the total population (World Health Organization). The list provided by the World Bank of GNI per country was applied to the research to distinguish qualifying LMICs within the GNI range of $683 to $10,358 (The World Bank). Gross national income (GNI) was applied as opposed to the more common measure of economic wellbeing, gross domestic product (GDP). This is because GNI serves as a direct indicator of average population income while GDP indicates the average production rates of a country. The relevance of national production rates to the ability of a hospital's sterilization procedures is almost non-existent. On the contrary, gross national income is more representative of a hospital's probable financial status and therefore sterilization resources. As a result, it was determined that GNI was more aligned with the goals of the study than GDP. After the research pool of LMICs was generated, research analysis was conducted relating to the state of SP in LMICs and the prevalence of SSI.

To support the research analysis data, interviews were conducted to include recent, first hand observations of sterile processing (SP) status in low and middle income countries (LMICs). For this portion of data collection, 17 surgeons and organizations who lead surgical projects in LMICs were contacted by email. Of those 17, five responses were obtained and provided contact information for medical professionals who practiced in LMICs through a snowball networking effect. Virtual meetings through the phone app were scheduled with those five medical professionals. The vocations varied from surgeons to surgical technologists. The subjects studied had commonly practiced in the U.S. but traveled abroad to a LMIC either for volunteering or employment purposes after the year 2016.

During the interview, the inquiries posed were extracted from a set of prewritten questions. These questions were carefully developed after analysis of existing research, which described the conditions of an inadequate sterilization environment versus what the ideal environment would be (Robertson et al., 2021; Panta et al., 2019). The questions aimed to reveal the experience of these medical professionals concerning the state of surgical instrument sterilization in the operating rooms (OR) and hospitals they worked in. The answers disclosed as a result of these inquiries were then compared to the CDC guidelines of sterilization to identify any divergences which would render the SP inadequate. Occasionally, prewritten, supplementary questions were administered to gather further information from the subjects. The interviews were recorded on the voice memos app and later transcribed into a document containing all the questions asked as well as the responses.

Prior to the interview, verbal consent was obtained and the subjects were informed on the risks of the interview as well as the future publication of their responses. Additionally, the subjects were notified that their identities would be fully protected. This privacy was executed by the omission of their names and the hospital's names or specific locations in any section of the results or publicized paper. For the data collection of the interviews, their names were forsaken altogether, and they were identified by number (ex. "Interviewee 1"). This eliminated the opportunity for bias by the researcher and it ensured subject anonymity. To further deter bias and safeguard identities, no interviews were conducted in person or through video call.

The main risk for participants was the loss of employment or future volunteer opportunities. By exposing the inner workings of SP units abroad, they risk deteriorating their reputation with such hospitals. Certain hospitals may be aware of their own breaches of sterility requirements, but simply don't have the means to modernize. If an ex-employee or volunteer were to expose the flaws the subject may not be welcomed back. To prevent this, the identity protection methods were put in place. In order to further avoid this, no specific hospital names were publicized and only generic descriptions of the locations were included. This way hospitals would be incapable of recognizing themselves in the responses.

A small-scale research analysis was conducted to gather public data including Gross National Income (GNI) and rates of Surgical Site Infection (SSI) per LMIC. GNIs were published through The World Bank for all the countries studied, and SSI rates were gathered from a variety of digital sources. This data was then entered into google sheets.

Interview data was quantified through scoring to identify the trends mentioned in the table below. All the questions were written in a yes or no format in order to facilitate this quantification. All of the yes responses were

entered as a value of one in google sheets and all no responses were entered as a value of zero. Several sterile processing (SP) factors were studied such as visible contamination, availability of biological indicators, mechanical indicators, chemical indicators or even functioning autoclaves (steam sterilizers) (CDC) in order to determine adequacy.

Questions:

1. Where did you work abroad, when and for how long?
2. Was the hospital you worked at well-funded compared to its counterparts?
3. Was the employee who completed the sterile processing (SP) of surgical instruments trained in surgical technology and sterilization?
4. Was there no use of contaminated instruments or expectation to use such instruments?
5. Were the instruments wrapped in sterile packaging? Did that packaging include chemical tape, color changing tabs, strips, or color changing regions of packaging?
6. Was there a functioning autoclave in your hospital? Did that autoclave include mechanical indicators such as a pressure, temperature and/or cycle time gauges?
7. Were weekly spore tests or SCBI's completed weekly as biological indicators?
8. Were there designated areas for different parts of the sterilization process?
9. Were instruments decontaminated before sterilization?

Follow-Up Questions:

1. Could you tell me a bit more about that experience?
2. Do you have any additional details regarding that situation?
3. Would you mind further describing that?
4. Can you please elaborate on that response?

Table 1. Adherence to CDC Guidelines Scoring Table

Questions	Affirmative Response	Negative Response	Notes
1. Length of travel to LMIC >1 week, after 2016			
2. Well funded?			
3. Trained SP Operator?			
4. Plenty of SP witnessed?			
5. No use of contaminated instruments?			
6. Wrapped with chemical indicators?			
7. Autoclave with mechanical indicators?			
8. Biological indicators used?			
9. Separated areas?			
10. Decontamination part of SP?			

Results

In order to correlate gross national income (GNI) to inadequate sterile processing (SP) as a result of insufficient funding for such SP, the audience must be familiar with the GNIs (Gross National Incomes) of the countries studied. In order to be classified as a low and middle income country (LMIC), said country's GNI must lie between $683 to $10,358 U.S. dollars (The World Bank). The following chart (Figure 1) demonstrates the GNIs per country in 2021.

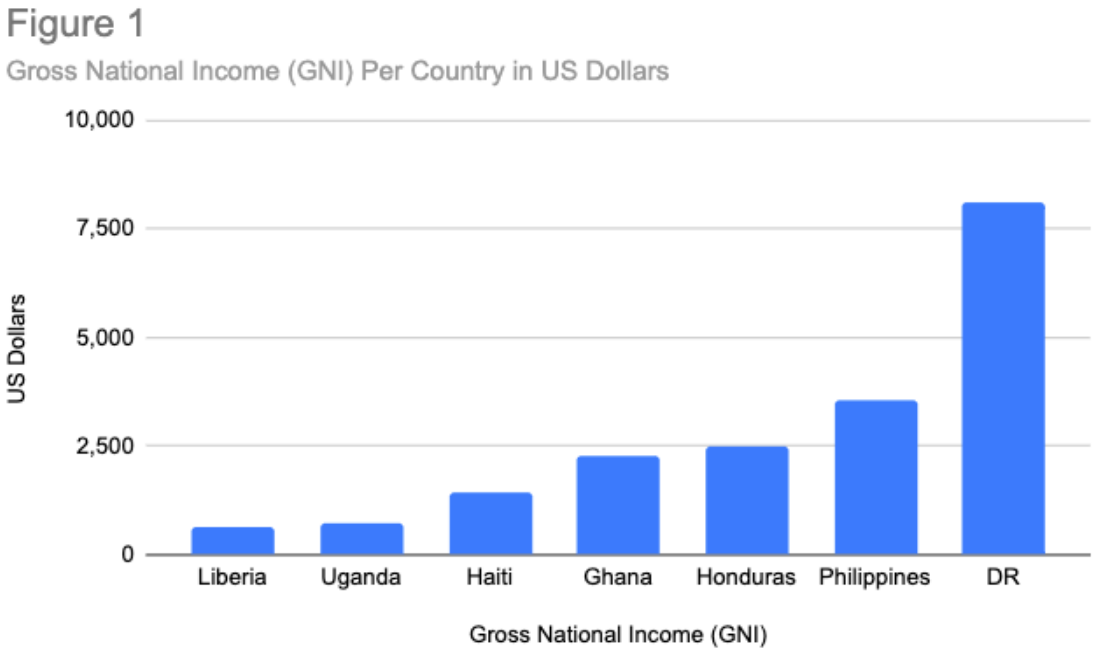

Figure 1. Gross National Income Per Country in US Dollars. The bar graph demonstrates the seven low and middle income countries studied and their respective gross national incomes. Liberia will be excluded from the following figures due to unreliable data.

As seen above, Liberia has the lowest GNI at $630 per year. However, during interviews it scored with 100% adherence to CDC standards in surgical instrument sterility. This is a direct result of the organization who the interviewee traveled with. The responses recorded for Liberia were describing Liberian hospitals taken over by the multi-million dollar organization: Medicine Without Borders. Respondents stated that the majority of sterilization equipment was brought “from France” and that “Medicine Without Borders is a very organized NGO”. For this reason, all the responses from Liberia were omitted from the data. This goes to show the inherent risk of data inaccuracies depending on the state of the organization sponsoring the surgical trip. Luckily, all the other respondents traveled with smaller, less affluent groups which allows for more accurate depictions of local SP.

The following charts depict a country’s average response or adherence to each question regarding SP. Questions 1 and 4 were omitted from the graphs because they do not provide any information regarding adherence to CDC guidelines. Instead, they serve to establish preliminary requirements for the respondents. These requirements are that they reside in the country for a week or longer and that they must have witnessed or been a part of the SP in the hospital. Originally, Question 2 was included as a way to avoid inaccurate representation of the country described. By asking if the hospital the interviewee worked in was particularly well-funded compared to local counterparts, it ensured that the responses are representative of other healthcare facilities in the area. For Ghana, Uganda, the Dominican Republic (DR) and Honduras, respondents considered their hospital to have more financial resources than others in the region. This is important to note when analyzing the rest of the responses for those four countries. However, the

rest of the responses were unsure of the financial status of their hospital let alone neighboring ones. For that reason as well as the fact that it does not play a direct role in SP, it was also omitted from the following chart.

In the following questions, an affirmative response is quantified as 100%. If a country does not appear on a question, it means that 100% of the responses for that country were negative or 0% and there was no adherence to CDC sterile processing guidelines.

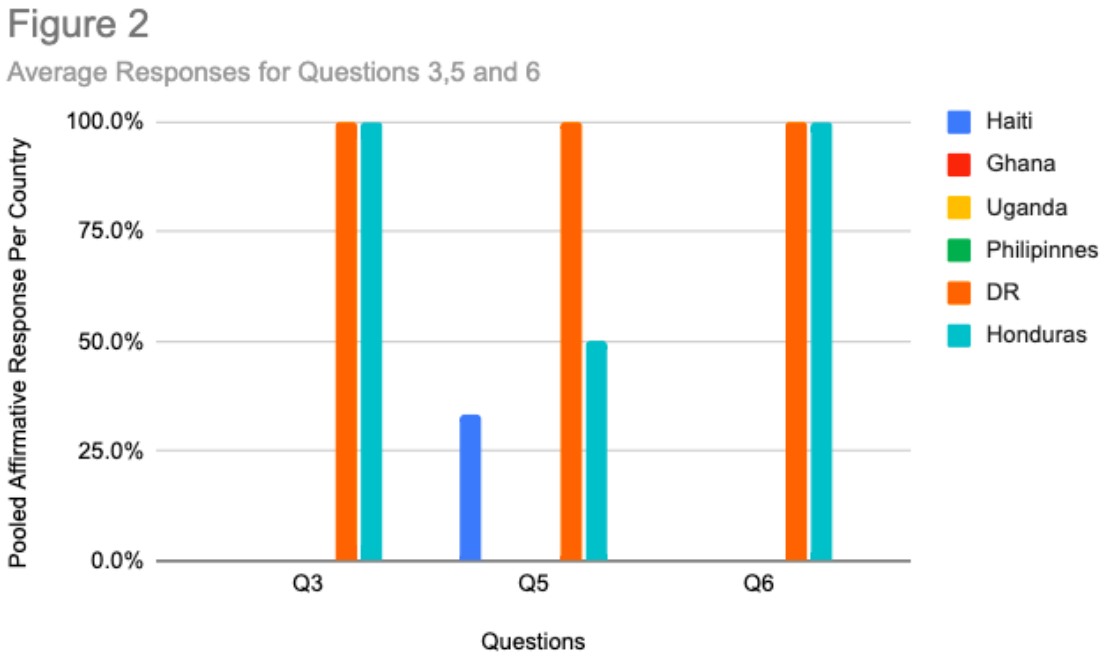

Figure 2. Average Responses for Questions 3,5, and 6. This demonstrates the positive responses for questions 3, 5 and 6 during interviews. The responses in adherence to CDC guidelines for sterile processing are affirmative and scored as 100%. The countries represented in the legend but not the bar graph signify an average response of 0% or no adherence.

Question 3 (Q3) reveals that only 2 of the 7 countries studied stated that those operating the sterile processing (SP) of surgical instruments were previously trained in sterilization or surgical technology. All countries other than the Dominican Republic and Honduras had uninformed employees handling the most crucial element of sterility in the operating room. In fact, one respondent from Ghana stated that the sterilization nurses "barely finished high school." Another respondent from the Philippines stated that "they don't train staff in proper technique" and she mentioned that "a teenager… with no training" was responsible for the hospital's SP.

The fifth question determined whether or not respondents were expected to or used contaminated instruments. Respondents in Ghana, Uganda and the Philippines had to use contaminated instruments in surgery, while Haiti and Honduras only used them some of the time. This contamination isn't necessarily visual, it's usually present at the microscopic level in the form of bacteria and viruses. This can be attributed to instruments being dried in open air where they're vulnerable to passing microbes or inadequate autoclaves which fail to eliminate those microbes. However, in the case of the Philippines the contamination was so abundant that it was visible to the naked eye. A respondent stated that when they walked into the filipino hospital's supply room which was filled with surgical instruments, they found "that rodents had been in there eating the supplies" and defecating throughout the room and on the instruments. The respondent mentioned that to solve this issue, local staff would "wash [the instruments] with soap and water" and hang them to dry "outside on trees or bushes". They made it clear that "things did not get sterilized."

The bars on question 6 (Q6) demonstrate that out of the 6 countries studied only the Dominican Republic and Honduras use chemical indicators. These indicators could be in the form of strips or tape which are critical to determine whether or not an instrument has been adequately sterilized. According to the CDC, each instrument should be accompanied by a chemical indicator which changes color when sufficiently sterilized. This ensures that when surgeons open a pack of instruments, they can be certain that each instrument is sterile. Hence, when countries don't use such indicators, they have no way of knowing whether the specific instrument is safe for use.

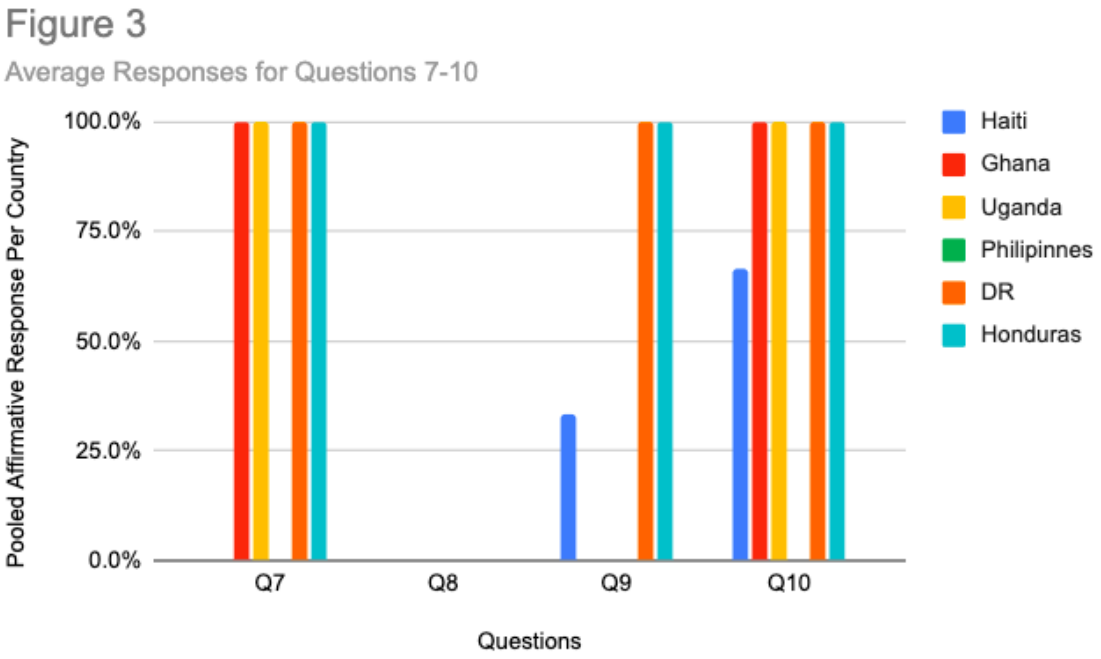

Figure 3. Average Responses for Questions 7-10. This demonstrates the positive responses for questions 7-10 during interviews. The responses in adherence to CDC guidelines for sterile processing are affirmative and scored as 100%. The countries represented in the legend but not the bar graph signify an average response of 0% or no adherence. For example, no country used biological indicators as seen in question 8.

All countries except Haiti and the Philippines use mechanical indicators. These measure pressure levels and ensure proper length of exposure as well as indicating mechanical failure of the autoclave. Respondents from Haiti did not use autoclaves but instead dysfunctional "crock pot" like steam sterilization. In the Philippines they had no steam sterilization altogether but attempted to compensate by soaking instruments in harmful ethylene chloride and bleach which is strongly discouraged by the CDC. None of the countries use biological indicators, another of the CDC's recommendations, which monitors autoclave function weekly. Honduras and the Dominican Republic had separated areas for different parts of the SP process in order to maintain flow from dirty to clean. Only some respondents from Haiti stated that separation of areas was present.

Once all this information was gathered, averages were calculated from each country to determine the adherence to CDC guidelines. Since affirmative responses were quantified at 100% and negative responses were quantified as 0%, a higher percentage of adherence is ideal.

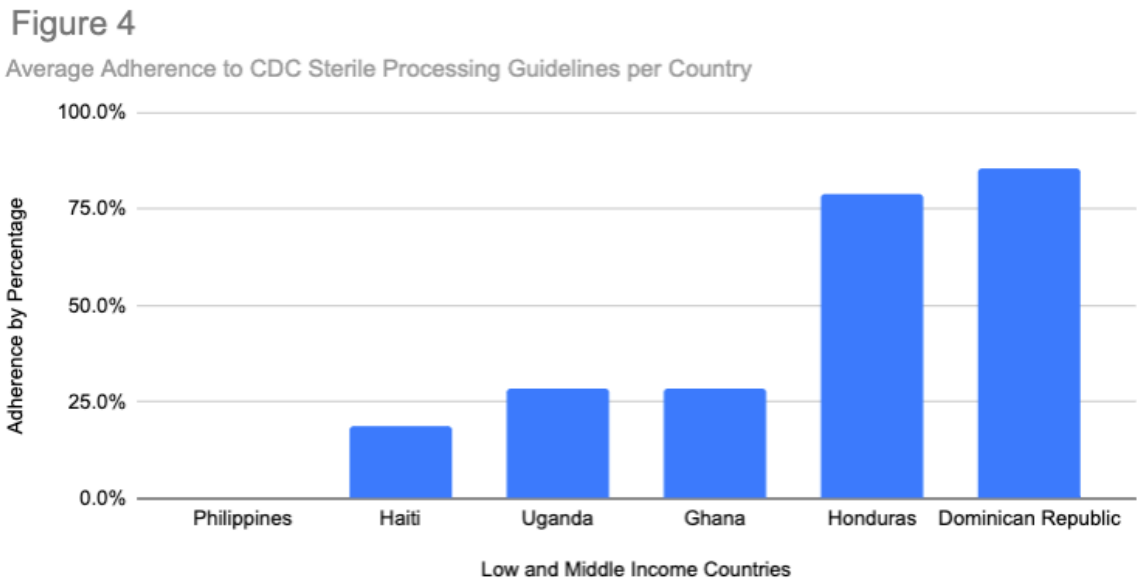

Figure 4. Average Adherence to CDC Sterile Processing Guidelines per Country. Averages of all the responses from interviews per country. The larger the percentage, the greater the adherence to CDC sterile processing guidelines.

It is clear that the Philippines falls far behind the rest of the countries and the Dominican Republic has the most adequate SP. The researcher predicts that this adherence is a result of low GNIs and causes high SSI rates in its respective country.

Data Analysis

A multifaceted approach to data analysis was completed by studying the effects of gross national income (GNI) on sterile processing (SP) adherence and said adherence on surgical site infection (SSI) rates per country. Average SP adherence to CDC guidelines was later correlated to SSIs and GNIs respectively.

The data collected describing the state of SP within a nation was inspected for credibility and later scored for adherence to CDC guidelines or inadequacy. Additionally, GNIs per country were included courtesy of The World Bank and national SSI rates were gathered from various online sources.

A one tailed test was conducted to determine a correlation of R squared = 0.277 between GNI per country and SP adherence. The following scatter plot demonstrates the weak correlation with a flow of GNI influencing SP adherence.

Figure 5

Correlation of Gross National Income to Sterile Processing (SP) Adherence

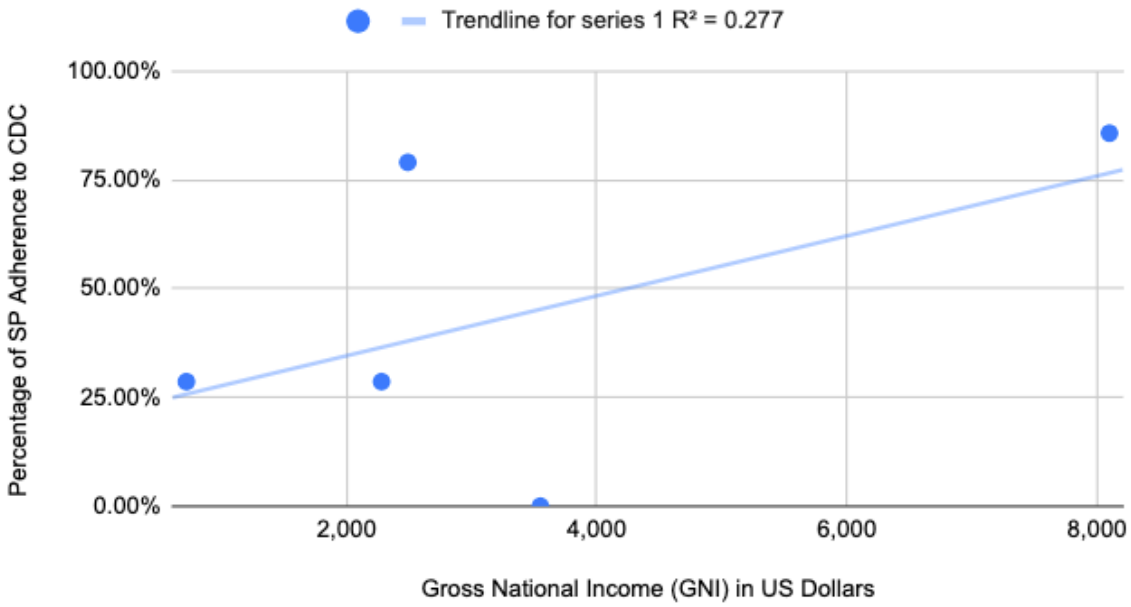

Figure 5. Correlation of Gross National Income to Sterile Processing Adherence. A weak correlation can be observed between the gross national income of a country and its corresponding sterile processing adequacy.

The unilateral flow of GNI to SP adherence can be inferred from several studies stating that a lack of financial resources is the main hindrance to proper SP (Robertson et al., 2021; Panta et al., 2019; Fast et al., 2019; Fast et al., 2017; O'Hara et al., 2015). This same sentiment is shared by respondents who state that in Haiti "they didn't always" have chemical tape. Or worse, another respondent stated that Haitian hospitals "didn't have enough water to run [autoclaves]" let alone the power source to support the machines.

However, the results calculated demonstrate a weaker than expected correlation as a result of unreliable data. A possible explanation for the previous result is that GNI is incredibly general and there's no way to know exactly how much of a country's wealth is invested in healthcare. For example, a country may have the highest GNI of all but receives a low SP adequacy score if their government pours the country's wealth into infrastructure rather than healthcare. Another justification for this result is that the SP adequacy is overgeneralized. Since this research couldn't be conducted for every hospital in every country, the scores for one hospital in a country were forced to represent the whole country. It is acknowledged that this leaves unwanted room for misrepresentation of a country's SP adequacy.

Next, the correlation between SP adherence and SSI rates per country was calculated using the same statistical test. The adequacy of surgical instrument sterilization processes in hospitals is directly correlated to surgical site infection rates in low and middle income countries. A one tailed test with a flow of SP adherence to SSI prevalence rendered the following strong correlation of R squared = 0.772.

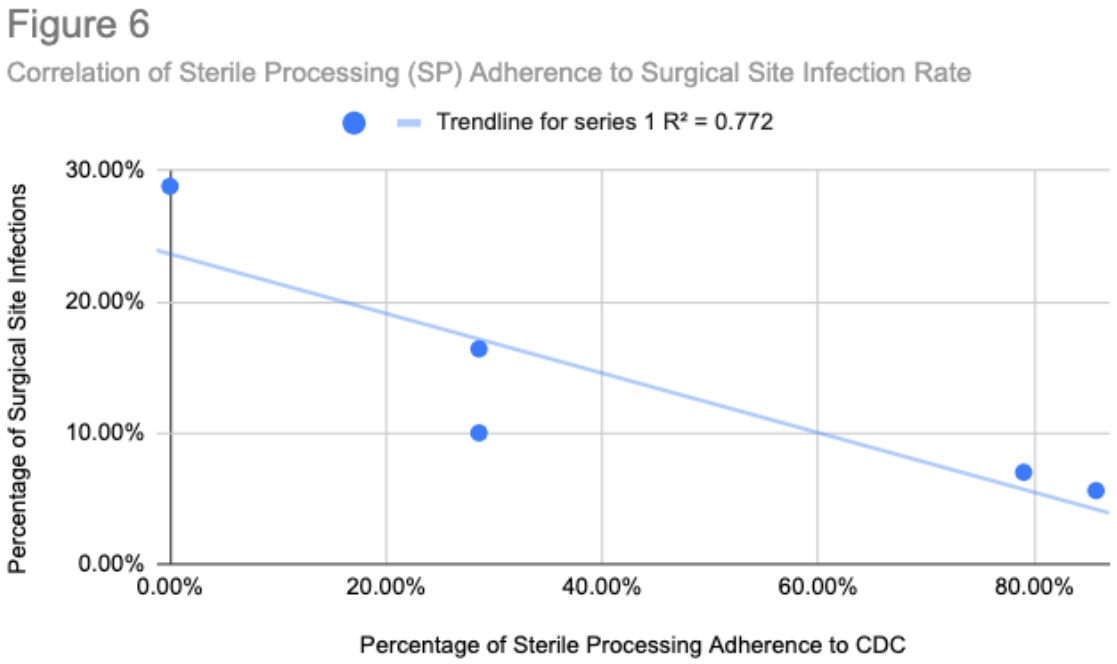

Figure 6. Correlation of Sterile Processing Adherence to Surgical Site Infection Rate. A strong correlation can be observed between the sterile processing adequacy of a country and its corresponding surgical site infection rate.

As stated throughout the study, this is likely a result of insufficient indicators of sterility, dysfunctional autoclaves and other contaminating factors reaching the instruments that work beneath vulnerable layers of skin, fascia and muscle. With reference to the question, what is the impact of surgical instrument sterilization processes in hospitals, on surgical site infection rates in low and middle income countries? The correlation illustrates that the inadequacy of sterile processing is directly responsible for the prevalence of possibly fatal surgical site infections.

Conclusion

Current research reveals that LMICs have rates of SSI up to 64.8% higher than HICs (Fast et al., 2017). These infections commonly invade the bloodstream, spread throughout the body and transform into fatal sepsis. Nowadays, reversing these conditions can be especially troublesome as a result of bacterial resistance most commonly found in hospitals or medical facilities. When the bacteria that infects a patient gets treated with antibiotics, it will eventually evolve to resist the antibiotic and can spread throughout the hospital untamed (CDC, 2019). However, the correlation between those infections and sterile processing had yet to be explored. Rather studies explain the effects of such rates on the economy or focus on rates after a specific procedure instead of the bigger picture (Ayala et al., 2021; Monahan et al., 2020). These studies ignore the root of the problem: the instruments entering the surgical site.

In order to address the impact of instrument sterilization processes in hospitals on surgical site incision infection rates in low and middle income countries, research analysis and phone interviews were conducted. It was crucial to interview medical professionals who had supervised or witnessed the SP in LMICs due to their valuable firsthand descriptions. The most reliable way to conduct this research would be to inspect hospitals in person, but as a result of obvious financial and time restrictions, that research has yet to be completed. However, this study captures that perspective, employing a comprehensive approach in order to collect first hand data globally. These responses were later scored and compared to researched SSI rates per country to reveal a strong one tailed correlation between SSI and SP. A secondary analysis was completed between GNI and adequacy of SP per country resulting in a weak

one tailed correlation. The salience of this connection cannot be forsaken when the lives of patients are at stake. When inadequately sterilized instruments are used on a patient, the compromised, recovering patient is placed in direct danger of infection and possible death. In future, these results serve to pinpoint which countries require more financial support and SP training over others.

Alas, this study was not without its own set of limitations including geographic, financial and data restrictions. To begin, results of sterile processing (SP) adequacy per country would be far more accurate if the researcher was able to travel to various LMIC countries and collect unbiased data. This way the data from one hospital would not be used to generalize data for the country as a whole. It would be presumptuous to state that data from one hospital can accurately depict the SP adequacy of all the hospitals nationwide, but unfortunately the researcher had no other option as a result of these financial and geographic barriers. Furthermore, sample size proved to be another challenge. The researcher contacted 17 surgical travel organizations world wide by email and heard back from only five. That less-than-ideal sample size made it impossible to assume that these five interviewees knew the SP adequacy of the whole country. Even with geographic and financial limitations in place, a large sample size could diversify the data enough to paint a more precise picture of SP adequacy in LMICs.

Additionally, since traditional surgical trips keep their professionals in one hospital that they've built connections with, the interviewees had no idea how the hospital they worked in compared to others in the area or even the country. This made question 2 (“Was the hospital you worked at well-funded compared to its counterparts?”) especially hard to answer since subjects were unsure if the hospital’s counterparts in the area were equally as well funded. As a result of this inconsistent data point, it was given less priority and excluded from the factors that measured SP adequacy.

As previously stated, yet another issue appeared when it was revealed that Liberia, the country in the study with the lowest GNI, was ranked with 100% adherence to CDC standards in surgical instrument sterility. This came as a result of the financial fortitude of the organization the interviewee traveled with allowing them to import the latest in sterilization technology from France. For this reason, Liberia was excused from the data. None of the other respondents directly mentioned this hindrance to data but there's no way to know if some smaller sterilization resources like chemical indicators were imported by other organizations therefore making the hospital appear to have better than usual SP.

Another complication presented itself during research analysis of global SSIs. Since counting each infection after each surgery in every hospital within a country is incredibly tedious research to collect and is constantly fluctuating, SSI data was sparse and often unavailable. This led the researcher to resort to various, inconsistent sources for such data. Future researchers with greater financial capabilities could travel to a hospital in one of these countries, monitor the rate of SSIs over a period of time and compare that to the hospital’s SP adequacy in accordance with the list of questions previously provided.

Risk of bias from various aspects was also present. A researcher could potentially discriminate against subjects of different backgrounds or social standing. To prevent this, the research was conducted solely on phone calls without any video. The responses were then analyzed under pseudonyms like respondent 1 or 2 in order to avoid name-based bias.

Future researchers should consider employing these results to pinpoint which countries require more financial support and SP training over others. For example, from the data collected, it can be concluded that the Philippines would benefit more from financial support on this issue than the Dominican Republic. In fact, the strong correlation between sterile processing (SP) adequacy and surgical site infections (SSIs) can be used in the argument to demand that funding. It can be used as proof that SP directly influences SSI prevalence and consequently sepsis. By stating that SP inadequacy can result in sepsis, an urgency is created for donors to invest in the health of these underprivileged countries. In addition, by disclosing what the specific responses were for each question per country, donors and organizations receive more specific information regarding which parts of the SP lags behind. Such as the WHO donating biological indicators to Uganda rather than autoclaves which the study shows they are already in possession of on question 7. Research to follow should expand the sample size and use more reliable SSI rates to confirm these findings.

More opportunities in research are now possible regarding how the targeted funding or donations affect the respective communities positively.

As previously emphasized, improving sterile processing (SP) in low and middle income countries (LMICs) will greatly decrease morbidity and mortality. Aside from that crucial implication, this improvement will also increase surgical tourism and surgical research. Surgical Tourism is the act of traveling to other countries for a better price on a surgical procedure. However, at the moment, only a few countries are world renowned for this industry including the Dominican Republic. As seen in the data, the Dominican Republic ranked with impressive SP adequacy and low SSI rates. This gains a tourist's trust and makes them more likely to travel for that surgery and in turn boost that country's economy. Additionally, safer surgeries will attract more researchers to study the industry and develop cutting edge research or innovation within the country's own borders.

To let LMIC populations rot away from sepsis after simple surgical procedures is no longer acceptable. The research presented provides the information necessary to target specific points in SP which could be lifesaving. Not to mention, keeping patients out of the hospital after surgery has tremendous financial benefit (Monahan et al., 2020). The surefire way to prevent blood poisoning bacteria from ending the lives of women, children and surgical patients of all ages is proper sterilization of surgical instruments. Low and Middle Income Countries are in dire need of a sterilization transformation in order to eradicate such infections from the operating room. Improving the state of surgical care globally renders countless benefits including an increase in surgical tourism, surgical research and lower postoperative morbidity and mortality.

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