INVESTIGATING THE IMPACT OF ENVIRONMENTAL FACTORS ON SURGICAL INFECTION RATES IN THE UNITED STATES

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On my honor as a University Student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments

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Introduction

Over the last several years, the number of infections associated with in-patient services has risen in the United States healthcare system. Surgical site infections (SSIs) are severe complications that occur in about 2% of surgeries in the United States and account for about 20% of healthcare-acquired infections (HAIs) (Johns Hopkins Medicine, 2009). Understanding the transmission of SSIs and HAIs is crucial for identifying effective preventive strategies. The most common ways a patient can become infected are if the germs are present before the surgery or through a contaminated caregiver or surgical instrument (Smith, 2010).

The anesthesiology department often comes under scrutiny during an HAI event since they operate across various patients and are involved in inserting catheters (Burns et al., 2022). Hand hygiene during anesthesia induction is an increasingly researched area, especially concerning HAIs. Patients are the most vulnerable during this procedure due to the intimate contact anesthesiologists have with the patient's blood and respiratory systems (Hailu et al., 2023). If proper sanitization practices are not followed, this can lead to germs entering a patient's body, thus an HAI. HAIs can result in grave consequences such as sepsis and death (Revelas, 2012). Proper infection control practices are expected to be in place; however, multiple people working simultaneously may be challenging (de Lissovoy et al., 2009). Moreover, anesthesia induction is a rapid procedure that may make it difficult for practitioners to sanitize their hands properly or remove gloves between steps (Biddle et al., 2018). Examining the social, technological, and institutional factors that impact a medical provider's ability to provide quality care is crucial to understanding the occurrence, progression, and impact of HAIs.

Both human and non-human entities are involved in a typical surgery. When drawing a surgery network, it is essential to consider both factors as their interplay leads to various benefits and consequences. In this paper, I used the Actor-Network Theory (ANT) framework to analyze the surgery network and the role of anesthesiologists within it. I focus on the heterogeneous networks and breakdown throughout this paper. I was interested in investigating what happens when a specific part of a system fails. It is essential to step back and examine the interplay between various forces when trying to understand a problem.

This paper will begin by providing some background on HAIs and SSIs and then proceed with a literature review on infections during healthcare procedures, the anesthesia induction process and environmental factors affecting practitioners. Subsequently, I will explain the methods used throughout the paper, specifically ANT. Lastly, this paper will delve into my analysis, explore future work, and summarize my findings.

Literature Review

Actor-Network Theory

An essential text for understanding network composition is *Some elements of a sociology of translation: domestication of the scallops and the fishermen of St Brieuc Bay* by Michael Callon (1984). Callon introduces Actor-Network Theory (ANT) as a framework for understanding the interactions between human and non-human actors in a network. The paper examines the relationships between scientists and fishermen in the bay of St Brieuc, France, concerning the scallop populations. Callon used this case study to illustrate ANT. This process has four steps: problematization, interessement, enrolment, and mobilization.

Problematization is the process of identifying a problem and one's contribution to solving it. This is the initial stage when the network begins to form. In Callon's case study, this is how researchers identified the declining scallop population. The researchers proposed studying the scallop larvae attachment process, as they felt that was crucial to understanding the decline and promoting stabilization. They also believed stabilizing the scallop population was crucial for the fishermen's livelihoods.

Interessement identifies the actors in the network. This is when the network starts to solidify, and actors are invited to participate. For this case study, the researchers collected scallop populations and observed their behavior in various controlled environments. By showing the scientific methods behind stabilizing the scallop population, the fishermen are more likely to be interested in the project.

Enrolment is when roles within the network are defined, and the actors formally accept these roles. In Callon's case study, the researchers need the fisherman and scallops to behave in certain ways for the network to be cohesive. Moreover, the researchers need this organization to validate their hypothesis.

Mobilization occurs when the network is operational, and all actors are engaged in their roles. This is the part of the process where a specific theory can be tested and its effects on the network observed. Fishermen in this stage followed scientists' advice regarding monitoring the scallop population. They agreed to the experiment and adhered to the new practices.

Healthcare Acquired Infections

Health care-associated infections – an overview by Mainul Haque, Massimo Sartelli, Judy McKimm, and Muhamad Abu Bakar provides an overview of HAIs (2018). As discussed before, HAIs are of growing importance due to their impact on patient morbidity, training protocols, safety standards, and financial burdens.

This text starts by introducing what HAIs are and where they occur. These infections mainly occur in hospital settings and can occur during any procedure. It is important to note the distinction between HAIs and SSIs. HAIs refer to an infection acquired in any healthcare setting; it does not necessarily need to be during surgery. SSIs, on the other hand, are infections acquired during a surgical procedure. HAIs can be bacterial, fungal, viral, etc.

Several risk factors elevate a patient's chance of contracting an HAI: medical history, safety standards, organizational issues, and type of procedure. If a patient is immunocompromised or has underlying health conditions, they are more prone to infection. Moreover, an invasive procedure is more likely to introduce bacteria into the body and cause trauma. HAIs have profound impacts not only on patient health but also in regards to hospital costs. They increase the patient's hospital stay, increase the number of additional medical tests, and may result in a malpractice case.

The paper emphasizes the need for education and proper training within healthcare settings to minimize HAIs and implement proper infection control practices. The paper also calls for more robust surveillance systems, international cooperation, and research into new infection control techniques.

Burnout

Environmental factors and their effects on healthcare workers are essential to consider when evaluating the quality of care being provided. Burnout, a very common result of the traditional hospital environment and practices, is explained in *Burnout and Doctors: Prevalence, Prevention and Intervention* by Shailesh Kumar (2016).

Published in MDPI, this source outlines the high levels of stress doctors face in their profession and eventual burnout. The paper highlights statistics showing that burnout is fairly common among doctors. Potential causes of burnout include workload, long hours, lack of control of work conditions, and absence of a community. Kumar discusses three dimensions of burnout: emotional exhaustion, cynicism, and a reduced sense of personal accomplishment. These dimensions can lead to lower quality of care for patients and a higher chance of medical errors.

Doctors can better deal with burnout by following effective prevention strategies. Individual-focused strategies include coping mechanisms, stress management techniques, and healthy work-life balance. Kumar also calls for organizational strategies to be implemented in healthcare institutions. These include providing better support systems to doctors, reducing working hours, and encouraging teamwork. Healthcare professionals are encouraged to recognize the symptoms of burnout early and seek help when needed.

Anesthesia Department's Role

Transmission of Pathogenic Bacterial Organisms in the Anesthesia Work Area by Randy Loftus, Matthew Koff, Corey Burchman, Joseph Schwartzman, Valerie Thorum, Megan Read, Tammara Wood, and Michael Beach discusses the transmission of bacteria during anesthesiology procedures (2008). The study's primary goal was to see how bacteria are transmitted within the anesthesia work area and to identify potential risk factors for this transmission. The study conducted a detailed observational and microbiological analysis within a random sample of 61 operative units across several hospitals.

The researchers found significant contamination within the anesthesia work area, particularly in MRSA and VRE. Key sources of contamination were direct contact with anesthesia providers, contaminated equipment, and improper disinfection. These findings suggest that stringent infection control practices must be in place to prevent the transmission of bacteria. Providers need to follow proper hand hygiene and disinfection protocols. One way institutions can ensure this is by providing enhanced training regarding the consequences of contamination during anesthesia. Standardized cleaning processes before and after a procedure must also be in place.

Methods and Framework

Research Questions

The overarching research question in this report is: how do social, technological, and institutional factors influence the practices used by medical professionals to understand and mitigate rising surgical infection rates? This question is then split into several sub-questions that are answered using various research methods.

The first sub-question is: How have social issues shaped surgical processes? It is important to consider the societal context in which surgery was developed and the various examples involving different patients. Historical case studies on past surgical practices and devices have been analyzed to answer this. Moreover, I reviewed articles and research reports on the impact of surgical innovations on safety standards. Most of these case studies revolve around the ethics of surgical innovations, safety standard issues in the past, and the impact of both things in the present day.

The second sub-question is: How does the hospital environment affect the practices adopted by medical professionals and their ability to provide quality care? Often, the safety standards set by the hospital and internal training significantly influence the quality of care given. Various methods were used to answer this question, including analyzing case studies, research reports, and interviews. More specifically, these sources focused on the impact of poor working conditions on the quality of care given. I analyzed research reports from the National Institutes of Health to study the impact of working conditions on human behavior.

The final sub-question is: What practices can be implemented to minimize the risk of infection? Analyzing what steps have worked in the past and what are currently working will help better shape future training protocols. Literature reviews were conducted to understand current practices and developments in this space. Most literature reviews focused on current STS research in the field and current practices in development.

Actor-Network Theory

Michael Callon's influential work, *Some elements of a sociology of translation: domestication of the scallops and the fishermen of St Brieuc Bay,* has been a cornerstone in developing the Actor-Network Theory (ANT) (Callon, 1984). The ANT framework explains how actors (both human and non-human) interact with each other in various systems. This theory has been instrumental in enabling scholars to delve into the networks in their research, what shapes and drives them, and the changes that can occur due to specific actors.

I analyzed the social and institutional factors affecting medical practitioners' work using ANT in this paper. The actors in my analysis were the various human and non-human entities that undergo a surgical procedure. The human entities include medical practitioners such as doctors, nurses, and patients. The non-human entities include surgical equipment, malpractice/safety guidelines, hospital capacity, and time constraints. These entities together form the surgery process shaped by the doctors and nurses performing the procedure and the patient undergoing it. Moreover, surgery is also affected by the quality of equipment in the hospital, safety guidelines that are followed, how understaffed the hospital is, and the criticality of the patient. In this project, we focused more on the impact of safety guidelines and medical equipment on the procedure.

This analysis extends to the impact of advanced sanitization equipment on surgical safety. The absence of advancements like contactless hand sanitizers can increase the risk of infection, as it is harder for practitioners to clean their hands between steps. Moreover, understanding the environmental stressors in the hospital as actors provided a more comprehensive view of what can impact a doctor's performance in the operating room.

The ANT study provided a holistic view of factors contributing to SSIs. The different actors in surgery unite to form a network of various steps taken during the procedure. This paper analyzed the heterogeneous networks and power dynamics between these actors. More specifically, I was interested in the chaos breakdown within the networks as that contributes to infections and mishaps.

Analysis

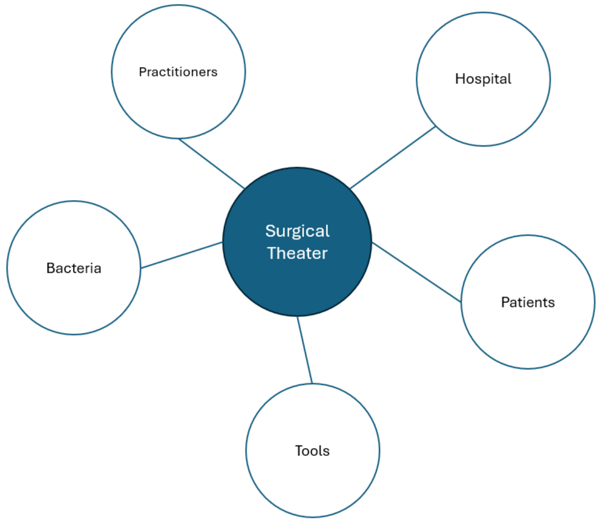

Figure 1: The Surgery Network

Key Actors

The surgery network shown in Figure 1 comprises six main actors with subnetworks: the surgical theater, patients, tools, bacteria, practitioners, and the hospital itself. ANT explains that none of these actors work independently but with each other, also known as *collaborative entanglement*.

The surgical theater is listed as the central actor because that is where the surgery occurs, and only specific individuals/objects are present. The network shown in Figure 1 is the surgical theater's network, which includes patients, surgery tools, bacteria, medical practitioners, and the hospital itself. Patients are whoever is undergoing surgery; surgery tools are any object that is used to perform the surgery; bacteria are pathogens that can enter the patient's body from human/non-human sources; medical practitioners include any licensed professional that is present during/assisting with the anesthesia induction process; and the hospital consists of management and medical lawyers who are responsible for overseeing legal issues and the reputation of the establishment.

During surgery, a patient is the most vulnerable and is undergoing treatment. A team of medical practitioners performs the surgery, which includes multiple steps such as sterilizing the tools used, patient prep, administering anesthesia, monitoring the patient's vitals, and performing the necessary surgery (Watson, 2023). The tools required for the surgery are sterilized and either discarded or cleaned after certain steps to prevent bacteria from entering the patient. However, the patient can get infected if tools are not properly sterilized, cleaned, or discarded. This can result in a multitude of complications and, sometimes, even death (Cui & Fang, 2015). If this happens, the hospital management and lawyers intervene to settle any malpractice lawsuits and revise the standards of the hospital.

These five actors have subnetworks of their own, which will be explored subsequently.

Medical Practitioners Sub-Network

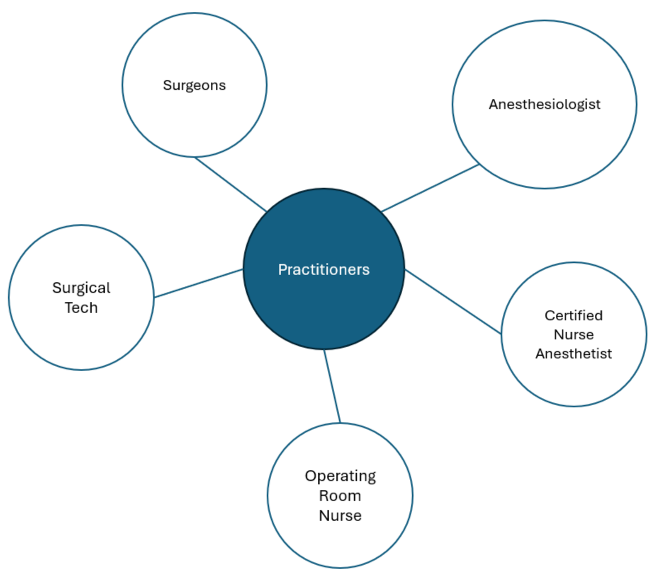

Figure 2: The Medical Practitioners Sub-Network

The medical practitioners subnetwork comprises surgeons, anesthesiologists, certified nurse anesthetists, operating room nurses, and surgical technologists. Surgeons lead the care team and perform the operation; anesthesiologists lead the anesthesia induction process and are responsible for administering sedatives and paralytics; certified nurse anesthetists assist the anesthesiologist during the anesthesia induction process and are also responsible for monitoring the patient during the procedure; operating room nurses assist the surgeon during the surgery; and surgical technologists are responsible for setting up and sterilizing the tools.

This sub-network can be prone to chaos breakdown, stemming from many root causes. For example, anesthesia induction is a rapid process involving multiple moving parts, making it difficult for the anesthesia care team to follow every hand hygiene step (Kamath et al., 2015). This can lead to bacteria entering the patient and infecting them. Moreover, anesthesiologists work across different operating rooms, which can also introduce the risk of SSIs and HAIs.

Surgeons are the leaders of the medical practitioner network. Their expertise in their field and judgment calls most directly affect the development of SSIs. If a surgeon makes the wrong decision during surgery, this can have grave consequences for the patient. Burnout, time constraints, and environmental limitations can all be determinantal to a surgeon's decision-making abilities.

Ultimately, the main desire of the medical practitioner network is to complete a successful surgery. This includes following proper safety/hygiene standards, following the appropriate steps, and maintaining clear communication within the care team. The medical practitioner network aims to carry the patient through surgery, uninfected safely.

Bacteria

Bacteria are crucial actors in the surgery network. Although bacteria do not have a subnetwork, exploring the relationships between bacteria and other actors in the surgery network is important.

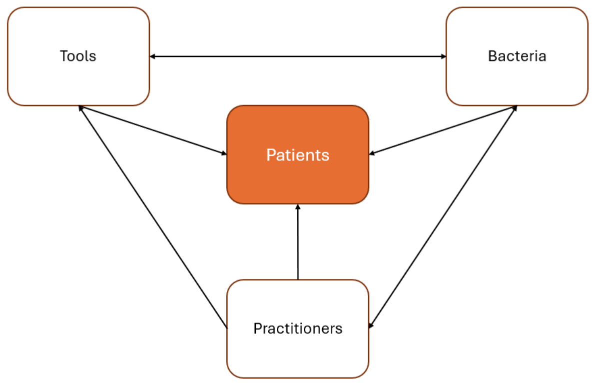

Figure 3: Relationships between Bacteria, Patients, and Tools

Figure 3 above shows the relationship between bacteria and the three actors they interact with: patients, practitioners, and tools. It also shows how bacteria can travel from one actor to another and how that affects the patient. It is important to note that bacteria are antagonists. Bacteria's goal in the surgery network is to infect the patient and travel via surgery tools and the practitioners.

The relationship between bacteria and surgery tools is two-fold, as they pull on each other. Bacteria manifest themselves in the surgery tools and can infect the patient when that tool is used. On the other hand, the surgery tools are sterilized so that bacteria are killed and do not infect the patient. Moreover, surgery tools are labeled dirty after surgery or discarded to prevent extra spread. The relationship between practitioners and bacteria is also very similar. Practitioners follow proper hand hygiene practices to prevent the spread of bacteria to tools and the patient. On the other hand, bacteria sit on the practitioners' gloves and hands after certain steps, hoping to infect the patient and the surgery tools.

The relationship between bacteria and the patient in a surgery network is one-way. During surgery, the patient is sedated and at their most vulnerable. Their immune system is often suppressed as their body is under great stress (*How Surgery Affects the Immune System*, 2024). Bacteria hope to enter the patient's body, but the patient's body has a hard time defending itself during surgery.

Patients

Patients are the most affected by SSIs, as they can lead to severe complications and even death. Like the Bacteria section, I will not explore the patient's subnetwork but instead focus on their interactions with other crucial actors in the surgery network, such as tools, bacteria, and practitioners. This network can be seen in Figure 3. This section will focus on understanding how the patient can get infected during surgery.

Starting with the relationship between bacteria and the patient, bacteria can enter the patient's body in multiple ways. As mentioned, patients are the most vulnerable during surgery and cannot adequately defend themselves against infection or respond to environmental cues. When surgery tools are improperly sterilized or improper hand hygiene is followed, bacteria can infect the patient.

In the relationship between practitioners and patients, medical practitioners are responsible for monitoring the patient, administering sedatives, and performing the surgery. If medical practitioners forget to remove their gloves or sanitize their hands between steps, bacteria will be introduced into the patient. Moreover, surgery technicians are responsible for sterilizing the tools. If this is not done correctly, SSIs can occur.

Tools

Much like the Bacteria and Patients sections, this section will explore the relationship between tools, patients, and bacteria, focusing on surgery tools. One of the goals of bacteria is to manifest themselves on the surgery tools and infect the patient during the procedure. Surgery technicians are responsible for sterilizing the tools, and if done improperly, it can lead to SSIs. Moreover, surgery tools should be appropriately discarded by practitioners during the procedure. When there are time constraints or after multiple long shifts, discarding every tool where it needs to be becomes difficult. When dirty tools are not labeled as such or placed in the correct room area, the patient is susceptible to SSIs.

Hospital Sub-Network

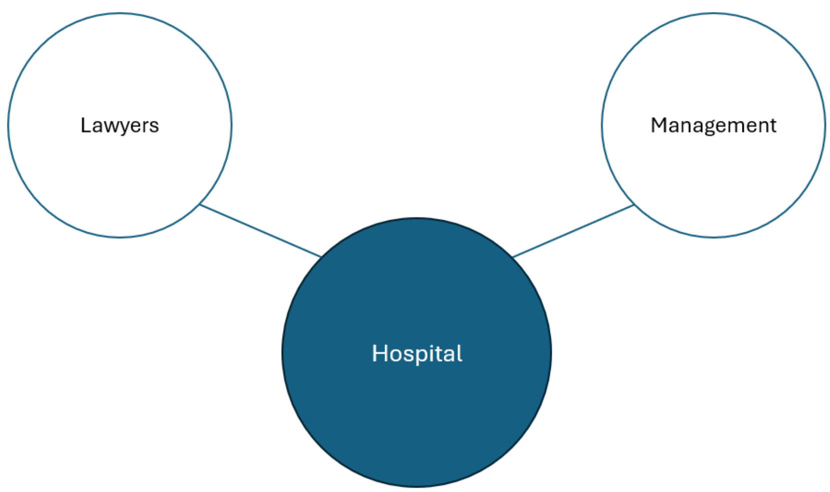

Figure 4: The Hospital Sub-Network

Another subnetwork I explored is the hospital subnetwork shown above in Figure 3. This subnetwork consists of two actors: management and lawyers. In a surgery network, the hospital's goal is to maintain proper safety standards, uphold the institution's reputation, and resolve legal issues. They also aim to minimize the institution's financial burden and streamline procedures.

Chaos breakdown in this network would occur when a patient gets infected during surgery and suffers severe complications. Oftentimes, this would result in a medical malpractice case. Hospital management would contact lawyers to resolve this issue and make executive decisions regarding monetary compensation and termination. Moreover, hospital management is responsible for reviewing safety practices and standards. Lawyers will negotiate the terms of the medical malpractice case and protect the practitioner/hospital.

Conclusion

This paper aims to understand how social, technological, and environmental factors affect the development and progression of SSIs and HAIs. Bacteria can enter the patient in multiple ways but often stem from improper hand hygiene or sterilization. I used the Actor-Network Theory to analyze the surgery network and the various subnetworks and relationships between actors. The overall surgery network consisted of the surgical theater, patients, tools, bacteria, practitioners, and the hospital itself. The surgical theater was listed as the central actor since it is a controlled environment.

Two subnetworks were analyzed: the hospital subnetwork and the medical practitioners subnetwork. The hospital subnetwork consisted of management and lawyers; the primary goal of this network is to reduce financial and legal burdens on the hospital and reinforce safety protocols. The medical practitioner subnetwork included surgeons, certified nurse anesthetists, anesthesiologists, operating room nurses, and surgical technicians. The main goal of this network was to perform the surgery successfully. Bacteria were identified as antagonists since they aim to infect the patient (which goes against what the other actors want). Medical practitioners must practice proper hand hygiene and sterilization when interacting with patients and using surgical tools to minimize the risk of SSIs. When a patient gets infected, chaos breakdown occurs within the network, and it would be the responsibility of the hospital subnetwork to address the consequences.

Based on my findings, I strongly recommend that medical practitioners adhere to proper hand hygiene practices. The process of cleansing hands should be thoroughly documented and implemented after almost every step in which the practitioner has contact with the surgical tools and the patient. Moreover, hospital training protocols should be regularly updated and reinforced; training videos should be accessible and presented periodically. Regular cleaning and disinfection should occur after surgical procedures in an operating room. All medical practitioners should have access to adequate protective personal equipment (PPE).

Organizations should also support the well-being of medical practitioners, especially doctors. SSIs can occur when there is a lapse in judgment, which can stem from various causes. Burnout is a common consequence of stressful environmental conditions. A burnt-out doctor may be more prone to making mistakes. Hospitals should provide more flexible work schedules, foster a collaborative environment, and provide a support system for practitioners to seek help.

Future work should expand the subnetworks shown above. There are many more actors that aren't included in the surgery network and the resulting subnetworks. Moreover, the surgery network shown above can be analyzed from different perspectives by rotating the central actors. For example, fleshing out a patient subnetwork to include various actors will show the depth of complexity when a patient gets infected. Future work should also emphasize the well-being of medical practioners and should aim to provide potential solutions for the harsh environmental conditions.

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