Clean Your Hands: Using Computational Modeling to Improve Infection Rates in Anesthesia Induction

How Socioeconomic Factors of Telemedicine Influence the Healthcare Access Disparities in the US

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Bella Holloman

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Technical Team Members: Austin Campbell, Sergio Darquea, Gabriel Lawrence, Neha Pavuluru

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.

ADVISORS

Rider Foley, Department of Engineering and Society

Matthew Bolton, Department of Systems and Information Engineering

Introduction

The first medical procedure using anesthesia was performed in 1846 (Harrah, 2015). Since then, anesthesia has become widely used as millions of patients in the United States safely receive anesthesia for medical procedures every year (Cleveland Clinic, 2023). But the process has yet to be perfected as anesthesia comes with risks like infections, especially if hand hygiene is not prioritized. The anesthesiology process is a possible source of infection because it involves interactions between multiple people, hands, equipment, and the patient. Hand hygiene is important in anesthesia, as it is a major contributor to healthcare associated infections and can even lead to sepsis, which accounts for 270,000 annual deaths in the US (National Institute of General Medical Sciences, 2021). Proper sanitizing and following a specific procedure is therefore essential. There is not a standard procedure of exact steps for anesthesia processes across different hospitals and anesthesiologists. Anesthesiologists also may accidentally skip steps that affect the cleanliness of the entire process. The goal of standardizing the safest anesthesia procedure is to reduce the probability of infection, from hand hygiene or otherwise, and increase overall patient safety.

Anesthesia Induction

The process of anesthesia that the research team will be studying is the induction of anesthesia. The induction of anesthesia refers to "the transition from consciousness to unconsciousness at the outset of a general anesthetic" (Bowdle, 2011, p. 1007). It also includes the intubation process which is the insertion of the breathing tube through the patient's mouth. The research team will observe inductions where the anesthetic is administered through an intravenous line, an IV. The research team is also going to observe multiple induction processes at different hospitals, but a general process begins with pushing saline into the patient's IV and

attaching the vital monitors to the patient. Then, an oxygen mask is placed over the patient's mouth. The anesthetics are pushed through the IV, and the patient goes under. Next, the anesthesiologist removes the oxygen mask and uses a trach guide to gain access to the patient's throat and inserts a tube down the trachea. Once the tube is in place, it is taped down and a vent bag is attached to help with breathing during the rest of the procedure. The anesthesiologist uses a stethoscope and the monitor to watch the patient's vitals as the procedure continues. There is an anesthesia workstation that has the vital monitor and all the supplies needed for the anesthesia steps during the procedure (Barash, 2010).

The research team will be using PRISM, a probabilistic model checker, to model and review different processes of induction to determine when and if contamination occurs. PRISM will verify the cleanliness state of the different objects involved throughout the anesthesia process. One of the processes of anesthesia induction the team will observe will be at the UVA hospital. The research team will record each specific step of the different processes into an Excel sheet and give each object involved an initial state of clean or dirty. A clean object has been sanitized and has not since touched a dirty object. A dirty object is contaminated, so for example, the patient will always be classified as dirty. Then, the team will make note of which objects touch each other at each step as well as if they are clean or dirty. For example, at one step, the team will note which hand of the anesthesiologist touches the medical instrument, whether they have gloves on, and whether the hand, gloves, or instrument are dirty. If a dirty object touches a clean object, that clean object also becomes dirty in the model. Dirty objects can become clean once sanitized properly. The research team also plans to implement uncertainty in our model, such as what happens if the anesthesiologist skips a step or their hands touch each other between steps. By setting the assumed state at each step and end state of each object as a property, the

team can verify using PRISM. For example, the actual IV should be dirty at the end since it touched the patient, but the IV port to connect the medicines to should always be clean. By using PRISM, the team can compile a list of counter examples, when an object needed to be clean is dirty at the end or vice versa, to analyze. Our goal is to make a recommendation as to which induction process is the most effective or which specific steps to avoid. This capstone project works to completely standardize the anesthesia induction process across the world and in turn will reduce infection rates and improve patient safety in the future.

Telemedicine in the United States

Before a medical procedure, the patient usually must attend a pre-admission anesthesia consultation visit. These consultation meetings can be done virtually as of recent, which can be more convenient for all parties involved (Chatrath et al., 2010). These virtual meetings are an example of telemedicine usage in the US. Telemedicine is defined as "the delivery of medical care and provision of general health services from a distance" (Hyder, 2020, p. 1). This includes virtual visits and check-ups as well as remote health care like digital monitoring. Since the beginning of the COVID-19 pandemic, telemedicine has become a quickly growing field. The number of individual telehealth visits increased 154% among 4 large providers in the US after the COVID-19 pandemic began in 2020 (Neri, 2022). There are many benefits to telemedicine, such as cost savings, convenience, and reducing the spread of illnesses (Johns Hopkins Medicine, 2022). There are also disadvantages of telemedicine, including possible privacy concerns, ensuring security and confidentiality, as well as keeping up equality of care (Marin, 2020; Solimini et al., 2021). An aspect of telemedicine that may be both an advantage and disadvantage is access. Telemedicine can provide care to those farther away from more qualified doctors, but they are less likely to have access to the necessary technology. In 2022,

approximately 2.6 million people in the US did not have healthcare insurance (U.S. Census Bureau, 2023). There is already a healthcare disparity issue in the US, and it is a debate whether the socioeconomic influences of telemedicine will help or worsen the gap. Telemedicine is a quickly growing field that will have an impact on the structure of the United States' healthcare system.

Socioeconomic Factors of Telemedicine

As telemedicine becomes more popular, it is clear that there are many socioeconomic influences on its usage. There are several factors that influence telemedicine, including gender, age, race, education level, finances, and region and urbanization (Lucas, 2022). In 2021, more females used telemedicine than males and use increased as age increased. As age increases, generally income and insurance access increase as well, which is intuitive why older citizens may have more access to virtual health options. Non-Hispanic American Indian or Alaska Native adults were most likely to use telemedicine over Hispanic, non-Hispanic Black, and Non-Hispanic Asian adults. Adults with a college degree or higher as well as those well above the federal poverty level were also more likely to use telemedicine. Telemedicine requires access to video sharing technology and internet access, which those above the poverty line would be more likely to have (Health Resources and Services Administration, 2023). Urban areas had a higher percentage of population using telemedicine compared to more rural areas. This may be due to the fact that more urban areas have more access to the necessary technology. Telemedicine technology use is influenced by many socioeconomic factors and has an impact on its success as a technology. There are healthcare disparity gaps between different socioeconomic groups in the US, not only relating to telemedicine.

Infrastructure of Telemedicine

Infrastructure is a theory relating to how technology is built into the already existing environment in society (Star, 1999). Infrastructure by definition is invisible and exists everywhere. There are several properties to infrastructure, including transparency and visible when broken. Infrastructure is transparent in that it does not need to be remade for every task it completes. It will support these tasks without needing new changes to the current technology. Infrastructure becomes visible upon its breakdown. It works invisibly until there is an issue, and that is when the users become aware of the broken infrastructure around them. Telemedicine is made up of many technologies that fit into the current digital infrastructure of the US. Its infrastructure is transparent because much of the technology needed for telemedicine is the same technology that gets used on a daily basis in the US. These include laptops, tablets, and smartphones. These video sharing technologies do not need to be reinvented to complete the tasks necessary to telemedicine appointments. Telemedicine isn't clearly visible to the eye around the nation, it is within the already existing infrastructure of video accessible technology. Telemedicine becomes visible once the ideas behind the infrastructure is broken though. When people do not have access to these video sharing technologies and the internet, it is almost impossible to receive care virtually (Health Resources and Services Administration, 2023). This has a lot to do with why different socioeconomic groups are more or less likely to use telemedicine. The infrastructure of the telemedicine system leads to imperfections and outside social influences. Telemedicine has already "dramatically changed the administration and structure" of the United States' healthcare system (Drago, 2023). The continued increase in use of telemedicine has the potential to influence the infrastructure of the United State's existing healthcare system.

Research Question and Method

Access to healthcare is an ongoing issue in the United States. This disparity poses moral dilemmas because the US has great medical technology and capabilities, but they are not accessible to all divisions of the population (Riley, 2012). Since the growth of telemedicine began in the past couple years, my research question is how can the continued increase in use of telemedicine improve the healthcare disparity gap in the United States? I will analyze healthcare and telehealth access statistics a couple years before and after the COVID-19 pandemic in 2020. These statistics will be broken down into several socioeconomic categories, including race and ethnicity, age, education, household income, insurance, and region. Data from the Office of the Assistant Secretary for Planning and Evaluation within the US Department of Health and Human Services including the Household Pulse Survey produces telehealth use data broken down by socioeconomic factors from August 2021-August 2022 (Lee, 2023). I will also analyze data from the Agency for Healthcare Research and Quality in 2019, before the pandemic. It provides a detailed breakdown of statistics on healthcare disparities in the US in 2019 by many different factors (Agency for Healthcare Research and Quality, 2020). I will find trends in the gap from before the COVID-19 pandemic, to get a better understanding of what socioeconomic factors are an influence and to compare with trends in the gap in the couple years after 2020. If telemedicine statistics show more promising results where they were lacking in healthcare before the pandemic, telemedicine could be an infrastructure to help diminish that piece of the disparity gap.

Conclusion

As millions of surgeries with anesthesia are performed per year in the United States, the magnitude of this research becomes quite large. At the end of the project, the research team will have models of different anesthesia induction processes and recommendations for

anesthesiologists that may reduce the number of infections during anesthesia induction. This recommendation may be specific steps to follow or to avoid. Telemedicine is a newly growing sector, since the COVID-19 pandemic in 2020 began, and its true benefits and disadvantages are still uncertain. Also, there is uncertainty as to how telemedicine will change the overall structure of healthcare in the US. After the research, I will have an understanding of how socioeconomic factors influence telemedicine and can widen or close the gap of healthcare disparities in the United States.

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