Building a ML-based Algorithm to Predict Patient Outcome for Focused Ultrasound Treatment
(Technical Topic)

The Factors Influencing Physician's Decisions on Adopting New Medical Technology
(STS Topic)

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By
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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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General Research Problem

How can computer algorithm-based technologies advance the field of medicine effectively?

Medical companies and biotechnology companies are constantly increasing the number of medical devices they produce, or providing updated versions of existing technologies. With a constant influx of new technologies, hospitals and physicians must decide which technologies to incorporate into their care, if any. New technologies can provide better outcomes to patients or make it easier for physicians. However, many factors affect the adoption of these technologies. My team is working to build a machine learning algorithm that can verify the eligibility of a focused ultrasound medical treatment for patients based on their CT scans. Focused ultrasound is a new non-invasive technology that can treat many disorders which otherwise require costly and high-risk surgeries. It works by using ultrasound beams to focus on a target in the brain, often tumors, and Expanding this current technology to include automated decisions will increase accuracy and efficiency with focused ultrasound.

There is no guarantee, however, that our project or projects similar to ours will be implemented in hospitals. It is frequently stated that it takes an average of 17 years for research evidence to reach clinical practice (Morris et al., 2011). In addition to the time and expense it takes to get FDA approval, there are many obstacles that prevent devices to be used as a standard of care within hospitals. This paper will research the individualistic qualities of physicians that affect their likelihood to adopt new technologies, and whether any trends occur in gender or socioeconomic status.

Technical Research Question: Building a ML-based Algorithm to Predict Patient Outcome for Focused Ultrasound Treatment

How can a machine learning algorithm be integrated into current focused ultrasound technologies to improve predictions of patient outcome?

Focused ultrasounds are gaining rapid clinical acceptance as a non-invasive treatment method that allows targeted brain heating and ablation. Applications of focused ultrasound are wide-ranging, spanning from neurological diseases such as Alzheimer's and Parkinson's to physical brain diseases such as brain tumors (ter Haar & Coussios, 2007). During a focused ultrasound treatment, ultrasound beams concentrate energy onto a target in the body without harming healthy tissue surrounding it. The goal of most treatments is to ablate the selected tissue, such as tumors. When the treatment is complete, physicians often check MRI scans to see if the ablation worked.

The success of ultrasound treatments can vary based on patient skull heterogeneity, location of target inside the brain, and other patient-specific factors. In 2006, a protocol was

created to use CT scans to predict the likelihood of focused ultrasound treatment success for individual patients. Physicians often use a metric called skull density ratio (SDR) that can be read from CT scans to determine patient treatment eligibility (Marquet et al., 2006). A low SDR score predicts that higher temperatures and energies will be required during the ultrasound treatment, which increases risk of overheating and tissue damage to the patient. Therefore, many physicians advise their patients with low SDR to not continue this treatment. However, studies show that despite this risk, many patients have had successful outcomes (Boutet et al., 2020). Due to the unique non-invasive nature of focused ultrasound, the development of an accurate treatment eligibility metric is necessary to ensure all truly eligible patients can benefit from the emerging technology.

To improve upon the current methodology of SDR scores, a new metric will be created using patient-specific anatomical details collected from CT scans. First, a neural network computer algorithm will be built to predict the maximum temperature reached by the brain during the ultrasound procedure. Then, a machine learning multiple regression model will be created to combine data of anatomical features of patients and the recently built model of temperature spread, to build a predictor of treatment eligibility for physicians. We have received 100+ anonymized patient data files from our advisor, and we plan to extract relevant features using principal component analysis (PCA). Our neural network algorithm will be guided by current models in literature for focused ultrasound eligibility predictions. By combining both of these, we aim to have a temperature model that will depict with at least 85% accuracy the maximum temperature reached will be within ± 1 ℃.

After the models are built, they will be implemented in the Focused Ultrasound Foundations's software, Kranion, which currently simulates how the treatment should be modified based on size and location of tumor/ablation. The preferred language of the software is Groovy, a Java-like computer language, so we will integrate our model from Python to Groovy. They will be made open source, and are intended to be used by current clinical researchers.

STS Research Question: A Comparative Analysis of Studies On Physician Factors Affecting Adoptions of New Medical Technologies

Are there any gender-based or socioeconomic trends in studies that explore the adoptions of medical technologies by physicians?

The global medical technology market was valued at $512.29 billion USD in 2022, and is projected to grow 5.9% every year (*Medical devices market share, growth, trends: Forecast [2030]* 2023). With an aging global population and the rise of chronic illnesses, the number of medical surgeries and diagnostic tests is also increasing every year, fueling the demand for greater medical technologies. There is no doubt that medical advancements have improved life

expectancy and quality of treatment over decades, such as increasing life expectancy by seven years from 1950 to 1990 (*U.S. life expectancy 1950-2023*). Despite the growing demand of medical technologies, the widespread adoption of these technologies is not at the same pace as the influx of medical devices.

The decision to adopt a new medical technology is one of the most important administrative decisions hospitals and its physicians can make. The process of adoption, however, is complex and can vary by field of specialty, location of hospital, as well as financial state of the hospital. Many studies of adoptions of medical technology are guided by a theoretical framework called the Technology-Organizational-Environmental (TOE) model. Through this model, a study can explore the relevant factors that affect adoption of one specific technology. Examples of factors within each category include: marginal benefits of technology, hospital size and other administrative constraints, and competition intensity by rivals, for technological, organizational and environmental factors respectively. Most literature primarily focuses on the organizational factors, and there is limited exploration of individual characteristics of physicians that affect adoption styles (Beier & Früh, 2020). However, many qualitative studies cite the personal motivations of physicians as a pivotal factor. Examples of personal characteristics may be the risk-aversion rate of a physician or other gender and socioeconomic trends among adopters. Understanding these factors is very important since these may help engineers who are targeting a specific type of practitioner, as well as for hospital systems when trying to increase implementation of a certain technology among its physicians.

There is a small amount of literature on the physician characteristics of early adopters of medical technologies. For example, one study exploring the adoption of a specific drug concluded that the youngest and oldest practitioners in their sample were least likely to adopt new drugs (Glass et al., 2004). In addition, a different study exploring the adoption of a new surgical procedure concluded that general practitioners were less likely to adopt new procedures than specialists, and that male specialists were more likely to adopt than female specialists (Artis et al., 2006). Because the type of medical technology varies between both of these studies, it is estimated that one general trend may not be concluded across different disciplines or types of technologies.

Theoretical Framework and Methods

To better explore the conclusions behind these studies, I would like to conduct a comparative analysis of studies exploring physician characteristics relevant to adoption of medical innovations. Many of these studies explore technologies that begin to be used by small samples of physicians and diffuse among more as they gain technological momentum. Therefore, not every physician in those studies will have decided to adopt the technology yet, or ever. This is crucial to understanding the trends among innovativeness, since we need technologies that are

not easily implemented. However, I will not be reviewing any technologies that are black-box based. This is most common among AI-based algorithms that provide statistical probabilities of diseases, such as an algorithm that automatically detects tumors on CT scans. Those technologies represent a dramatic change in a physician's work, and often have more characteristics such as political or environmental that may dominate the physician's decision to adopt, compared to the personal characteristics. In addition, there are not enough studies that range across many disciplines to be compared for trends.

Another criteria to determine which studies I will explore is whether a variety of physician characteristics are included in the study sample. This would include having physicians from rural and urban areas, small or private hospitals, and male and female. While not all of these criteria are strict, the study samples influence the type of conclusion a study will present, and I want to make sure to not confirm conclusions drawn from biased samples, although certain levels of bias will always exist.

Once I have researched and chosen 10-15 studies, I will make a note of the types of conclusions drawn and what sampling biases exist in each study. Then, I will conclude which physician characteristics have a consistent importance respective to their fields and technologies. This literature review will be able to shed light on how gender or socioeconomic norms may influence the adoption of medical technologies, thereby shaping the development of technologies.

Conclusion

Medical technologies will keep entering the field as the rate of chronic illnesses and procedures increase per year. Many of these medical technologies will not be adopted by physicians widely because it is a huge risk for many physicians to change their standard of care. However, patients will not receive the best level of care they can if the process of adoption is slow or difficult. To understand the process of medical device adoption, this STS project will look at one aspect: personal physician characteristics to determine if any trends exist among different disciplines or types of technologies. Other aspects such as environmental factors or cost-risk analysis can be researched in further studies, and the combination of all of these factors will impact whether a certain technology will be widely used. My technical report is building an algorithm to help neurologists determine if a focused ultrasound treatment will work for the patient. Because this is a type of technology that will ultimately be intended for physician use, I'm hoping my STS project can help me begin to understand the complexities behind the process of adoption in general.

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