Causal Impacts of Climate Change on Public Health Outcomes
(Technical Paper)

Impacts of Electronic Health Records on Patient Health Outcomes
(STS Paper)

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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

Introduction

With a market size of over $67 billion, big data in healthcare has risen over the past few decades in the United States by utilizing sources ranging from electronic health records (EHRs) to population health studies in order to improve the overall quality of life (*Healthcare IT Market Size, Share & Growth Report, 2020-2027*, n.d.). Big data refers to large, complex data sets that can be analyzed computationally and then be converted into critical insight to provide better clinical care (Catalyst, 2018). Given that public-health issues, such as climate change, are projected to cause 250,000 additional deaths per year from 2030 to 2050 due to air pollution, it is of the utmost importance to incorporate this vast data into technological solutions that can improve overall health (*Climate Change and Health*, n.d.). With the lack of a national healthcare system in the US, technologies such as the EHR will need to be implemented in order to uphold standards of care balancing privacy and accessibility when handling this data.

For the STS research project portion of this proposal, the impacts of the EHR system on patient health outcomes in the US will be analyzed. Recent studies have shown that medical errors account for approximately 251,000 deaths per year in the US making medical errors the third leading cause of death (Anderson & Abrahamson, 2017). Prior to 2009, only 10% of hospitals had adopted EHRs. In order to improve care coordination and reduce the number of patients that died from medical errors, the Health Information Technology for Economic and Clinical Health (HITECH) Act federally mandated that all primary care providers adopt a meaningful EHR system by 2014 (Balestra, 2017). A meaningful EHR system is broadly defined as a digital repository of patient data that contains medical history, medications, immunizations, and laboratory test results. Using this data, the EHR system's primary purpose is to support efficient and integrated healthcare (Häyrinen et al., 2008). Since the implementation of the EHR

system, research has shown a reduced number of medical errors for patients (Campanella et al., 2016).

On a different note of big data in healthcare, the capstone team will develop a computational model to investigate the causal impacts of climate change on population health outcomes. More specifically, the team will research the effects of a climate change variable, such as air pollution, on the number of respiratory-related mortalities in a specific geographical region over a set time period. The rationale for the project is to elucidate the impacts of climate change and to highlight which climate change variables have a direct causal impact on particular health outcomes. In terms of significance, this project will foster the implementation of adaptive resilience programs to mitigate climate change. Overall, both projects will aim to use big data and manipulate it into clinical insight to improve human health.

Causal Impacts of Climate Change on Public Health Outcomes

Climate change is the largest global health threat of the 21st century. Climate change is defined as the long-term alteration of temperature and typical weather patterns in a given place and includes events such as average increases in the frequency of natural disasters, global temperatures, and exposure to vector-, food-, and water-borne infectious diseases.

One of the many contributing factors to climate change is air pollution. Air pollution causes an estimated seven million deaths worldwide every year, a statistic that has been on the rise since 2016. From 2030 to 2050, climate change is estimated to cause 250,000 additional deaths due to air pollution, malaria, and heat stress (*Climate Change and Health*, n.d.). When specifically referring to air quality, the annual average levels of fine particulate matter (PM 2.5) declined by 24% between 2009 to 2016, and then experienced a 5% increase between 2016 and 2018 which can be attributed to the rollbacks of the Clean Air Act (*Harder To Breathe: Air*

Quality Has Worsened Since 2016, n.d.). Fine particulate matter (PM) is a term that describes the mixture of solid and liquid particles found in the air such as dirt and soot. PM 2.5 specifically refers to fine inhalable particles with a diameter 2.5 micrometers or less (US EPA, 2016). Changes in the quality of air, water, and food affect our health through multiple pathways including increases in respiratory and cardiovascular disease, injuries and premature deaths, as well as threats to mental health. Due to the complex processes involved in climate change, the exact extent to which human health outcomes may be influenced by the changing climate remains unclear. In fact, several different interpretations of the severity of climate change exist.

To elucidate the impacts of climate change, the capstone team will develop a computational causal model between climate change drivers and human health outcomes. A primary objective is to identify causal versus correlational links of air particulate matter to the number of mortalities that occur due to respiratory complications in a certain geographical region over a set time period. The rationale for developing a causal model is that it can help answer questions on what climate variables need to be prioritized without the need for an interventional study that would require randomized controlled trials, which in this case, is increasingly difficult due to the complexity of climate change.

There are three main objectives that will be accomplished in this project. First, the project will aim to collect, process, and integrate historical climate and public health time series data, with a focus on monthly or seasonal time series data. Health outcome time series data will be gathered for the same time period and at equivalent time intervals (monthly, seasonal, or yearly) as the climate time series data in order to compare the two variables. Second, after leveraging information in temporal data, a causal model between a factor of climate change (i.e. PM2.5) and a public health outcome metric (i.e. number of mortalities due to respiratory complications) will

be developed using computational software such as R and MATLAB. Third, the model will be validated against data using time-series cross-validation techniques. In cross-validation, certain subsets of the data are used to predict subsequent data as well as to measure the statistical error between the predicted model and the actual data (Bronshtein, 2020).

Overall, this study is novel because although literature has implied correlations between climate change and public health outcomes, the two have not been combined in a causal model thus far (Davoodabadi et al., 2019). With this project, the increased understanding of climate change will transform how the boundaries and determinants of human health are viewed universally. As a long-term goal, this model will help support the prioritization of climate change preventative programs and adaptive resilience plans. Understanding the implications of climate change now will help foster the development of proactive and responsive policies and predictive models to reduce future risks and impacts of climate change.

Impacts of EHRs on Patient Health Outcomes

Prior to 2009, medical errors in the US were estimated to harm 1.5 million patients per year, with about 400,000 preventable adverse events (Agrawal, 2009). In addition, medical errors imposed a heavy financial cost totaling up to $20 billion per year (Rodziewicz et al., 2020). As a result, prevention of medical errors has become a top priority recently for clinicians and patients. With the rise of information technology and as part of the HITECH Act of 2009, the US federal government mandated that all clinicians adopt electronic health records (EHRs) by the year 2014 in order to foster an integrated healthcare environment (Menachemi & Collum, 2011). A meaningful EHR is described as a digitalized form of patient data that contains information such as medical history, medications, immunizations, laboratory data, and more. Clinicians are

required to adopt an EHR system with certain functionalities associated with medical error reduction and cost-containment.

Given that patient care is the number one priority in healthcare, one of the most important stakeholders of the EHR system is the patient. To improve the quality of care for the patient, EHR systems are required to have clinical decision support (CDS) tools, computerized physician order entry (CPOE) systems, and health information exchange (HIE) interfaces. When these tools are collectively integrated, several past studies have shown that medical errors can be reduced by as much as 83% (Menachemi & Collum, 2011). These tools are also associated with lower patient mortality rates, but unfortunately, EHR systems continue to be slowly integrated into mainstream clinical workflows due to personal biases (Amarasingham et al., 2009).

Considering that doctors are another major stakeholder in the EHR system, it will be important to look at the EHR system's impact on the doctor-patient relationship (DPR). While some studies have shown that it took less time for doctors to retrieve information using EHRs, other studies noted that patients expressed concern about losing eye-contact with doctors using EHRs (Alkureishi et al., 2016). Additional studies noted that improving the DPR can lead to fewer medical malpractice lawsuits and increased patient satisfaction (Afsar-manesh et al., 2014). Therefore, it will be vital to look at multiple before and after experiments of EHR implementation to understand the full implications of the EHR on the DPR.

To promote patient-centered healthcare, EHR systems give patients digital access to their personal EHR through a web-based portal. This portal allows a patient to serve as a disciplined assistant to the clinician where a patient can improve health outcomes through patient-discovered errors in medical data (Dendere et al., 2019). However, there is uncertainty regarding the level of patient access that should be granted to EHRs (Lucivero, 2017). Giving patient access to EHRs

has multifaceted psychosocial impacts on a patient's anxiety such as reducing waiting time when accessing records but also allowing a patient to misinterpret sensitive information online without proper clinical guidance (Wiljer et al., 2010). Furthermore, by providing patient access to critically sensitive information, this may raise additional concerns about privacy and security of medical data. Overall, the uncertainty of EHRs with respect to aspects such as clinical outcomes, the patient experience, and logistics such as security of data, may explain why there is a slow adoption of fully-integrated EHR systems in clinical practice.

With substantial evidence describing the advantages and disadvantages of EHR systems, a comprehensive literature review will be conducted to understand the full implications of the EHR system on health outcomes from a patient perspective. The first STS theory that will be utilized is technological momentum. Technological momentum postulates that a technological system, such as the EHR system, shapes and is shaped by society (Smith et al., 1994). As a young technological system becomes larger and complex, the system becomes more of a shaper of its environment rather than being shaped by it. This time-dependence behavior is due to the fact that the mature system acquires political, economical, and value components that are harder to influence by society (Smith et al., 1994). The EHR system is time-dependent, because when the new EHR system is first adopted, initial social interests govern how and to what extent the EHR system will be integrated into the clinical workflow. As the EHR system matures over time and becomes widely adopted, the EHR system itself will influence clinical practices and become the standard to improve the quality of care in the US.

The second STS theory that will be utilized is Actor-Network Theory (ANT) which considers human and non-human elements as actors within a heterogeneous network (Cressman, 2009). ANT posits that social effects are generated as a result of the constantly evolving

relationships between actors in which one actor gives a role to others. ANT also demonstrates that social reality is complex and dynamic due to the addition or removal of actors to a network (Cresswell et al., 2010). The integration of a new EHR system in a clinical setting requires the formation of new connections and for pre-established actors to reorganize around this new non-human actor. ANT will help to gain a deeper insight into the process involved in forming the new network and therefore, help to facilitate effective integration of EHR systems into the healthcare environment (Cresswell et al., 2010). The main actors that will be focused on will be the EHR system and the patient. However, the perspectives of clinicians and health-insurance companies will be brought in to provide a comprehensive view on the impact of EHRs. Without proper intervention in healthcare, medical errors will continue to have detrimental effects on the health of individuals. Understanding the impacts of EHRs from a patient perspective through the technological momentum and ANT framework will lead to new insights on the role of EHRs in improving the quality of care and enhancing population health.

Research Question and Methods

Research Question: How does the implementation of the electronic health record (EHR) system in healthcare impact patient health outcomes in the US?

To answer the research question, the documentary research method will be utilized incorporating various sources related to EHR implementation and associated patient health outcomes. Beginning with the background, context regarding the history of EHRs in the US as well as the lack of clear EHR data and interoperability standards in the US will be examined. The documentary research method is optimal, because it will create a comprehensive narrative of EHRs through the study (and cross-verification) of multiple documents and will highlight the sociotechnical and clinical value of EHRs. Given the current uncertainty of whether EHRs

should be implemented in the US, this approach will encapsulate the perspective of multiple patients and address any gaps in knowledge in order to promote faster integration of EHRs into American healthcare.

Keywords such as “EHR implementation,” “patient health outcomes,” and “health information technology” will be used to gather pertinent, well-grounded resources. The literature search will consist of sources such as research articles, review articles, empirical studies, and patient-based data that pertain to before, during, and after implementation of the EHR system in a clinical setting. The research will be organized by theme where it will first examine the impact of the EHR system on patient clinical outcomes such as medical errors and mortality rates. Second, it will observe the impact of the EHR system on patient experiences with a focus on the doctor-patient relationship, particularly through patient responses and experimental studies. Third, it will focus on the impact of the EHR system on logistical and financial aspects associated with healthcare such as security of data, duration of a patient’s clinical visit, and costs for patient care. Through this approach, connections between EHR implementation and improved health outcomes will be established.

Conclusion

This proposal covers the causal impacts of climate change on population health outcomes as well as the sociotechnical impacts of EHR implementation on patient health outcomes in the US. The capstone team will develop a computational causal model between a climate change variable (i.e. PM2.5) and a population health outcome metric (i.e. number of mortalities due to respiratory complications) in a specific geographical region over a set time period. The team expects to establish a strong causal link between the two variables to show through statistical validation that higher air pollution causes an increase in the number of respiratory-related

mortalities. As a long-term goal, the novel model will help to predict, adapt, and eventually mitigate climate change effects on public health as well as foster proactive planning to fight climate change.

On a similar note of big data in healthcare, this proposal also examines the impacts of EHR implementation on patient health outcomes in the US, specifically focusing on clinical outcomes, patient experiences, and the logistical and economical aspects associated with patient care. Currently, uncertainty regarding the effects of EHRs may explain why there is a slow rate of integration of EHRs into clinical workflows across the country. Through the STS research approach, connections between EHR implementation and improved patient health outcomes will be elucidated. An improved understanding of EHRs will foster faster EHR implementation into the clinical setting in order to build the foundations for an integrated and interoperable healthcare system that keeps patients its number one priority.

Together, these two projects highlight the benefits that big data will bring in healthcare. By incorporating this vast data into healthcare technology, society will be able to appreciate the insights it brings and benefit from improved health outcomes.

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