Integration of Algorithms in Healthcare: How Artificial Intelligence and Machine Learning May Restructure the Patient-Physician Relationship

A Research Paper in STS 4600

Presented to the Faculty of the School of Engineering and Applied Sciences
University of Virginia • Charlottesville, Virginia

In Partial Fulfillment of the Requirements for the Degree
Bachelor of Science in Engineering

Author
Saurav Pandey
Spring 2020

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

Signature _____ Date _____

Approved _____ Date _____
Rider Foley, Department of Engineering and Society

Introduction

Hospitals are traditionally spaces dedicated to the diagnosis and treatment of ailed individuals. Since the establishment of such facilities, patients have depended on hospitals and its various clinicians for medical consultation and expertise. Likewise, clinicians also hope to provide patients with accurate diagnoses and effective treatment options (Helli´n, 2002). However, successful clinical patient outcomes and quality standard of care greatly hinges on an effective "patient-physician relationship," an often-misunderstood concept, despite being as fundamental to the field as the practice of medicine itself.

The patient-physician relationship can legally be defined as a consensual association, where the patient *knowingly* seeks the physician's assistance and the physician *knowingly* accepts the individual as a patient (QT, Inc. v. Mayo Clinic Jacksonville, 2006). Despite its invaluable importance in the clinic, this shared relationship frequently undergoes transformations, shifting as rapidly as the health systems surrounding it. The changes in the patient-physician relationship is best highlighted by Szasz and Hollender (1956), who have defined three models best encapsulating this dynamic interaction over time: a) active-passivity, b) guidance-co-operation, and c) mutual participation.

Under the active-passivity model, the patient is often in a state of helplessness and unable to contribute, requiring immediate treatment, regardless of outcomes. Similarly, the model of guidance-co-operation expects patients to be willing to cooperate and listen to doctors' orders, once again placing the clinician in a position of power. Both of these models are paternalistic and predominantly doctor-centered. However, there exists a new form of alliance between doctors and their patients, where the physician must treat and respect each patient as a unique human being (Kaba & Sooriakumaran, 2006). This has led to the formation of the mutual-participation

relationship, and ushered in an era of patient-centered care. This observed shift in the healthcare landscape can be attributed to various factors, but the impact of medical technologies in particular must not be ignored. The open-source nature of the internet alone has promoted unprecedent levels of patient agency by providing them boundless information on topics ranging from symptoms and prognosis to recommended course of action and home remedies (Kelly & Eisenberg, 2019). Medical technologies, endogenous to the hospital setting, can have similar effects, and leading this charge are the novel health-based machineries that integrate artificial intelligence (AI) and machine learning (ML) processes. Although AI's impact in medicine remains to be seen, many believe that the medical field has obligations in overseeing the integration of this technology towards patient care. Therefore, this sociotechnical study is hoping to uncover not only the current state of clinical AI technologies, but its impending role in reshaping, or potentially transforming, the long-standing patient-physician relationship.

Case Context: AI and ML Integration into Healthcare

The field of artificial intelligence has rapidly expanded from simple checkers-playing computer programs to intricate systems capable of outperforming humans in various complex activities, such as image and object recognition, predictive models, and artistic imitations. Indeed, the assumption that machines may displace humans is a fear that has existed since the initial days of industrialization. Currently, the medical field is seemingly susceptible to these technological pressures because the diagnosis and prevention of diseases are progressively reliant on artificial intelligence and machine learning algorithms.

Artificial intelligence can generally be defined as the imitation or simulation of human cognition by machines (Fogel & Kvedar, 2018). Within healthcare, AI is already being implemented for numerous roles as it is anticipated to replace major surgical procedures by 2053

(Grace et al., 2018). Medical specialties that rely on pattern-recognitions such as radiology and pathology are also liable of being replaced by developing AI methods. Fogel and Kvedar (2018) further note that the data available in the form of clinical and pathological images are ideally suited to power computer algorithms that lead to AI-generated predictions. With access to hundreds of biomarker data, imaging results from millions of patients, as well as thousands of physicians' notes, AI similarly possesses significant advantages in quick and accurate patient diagnosis (Krittanawong, 2018). In these regards, AI technology has already begun infiltrating and influencing the healthcare landscape. As these technologies continually build and improve on their designs, their exerted effect will be difficult to dismiss. AI technology, therefore, will challenge the roles traditionally ascribed to hospitals and the long-standing relationships established between patients and physicians will also be called into question.

However, despite the rapid developments in this field, it is imperative to realize that successful implementation of AI is equally dependent on societal factors and the willingness of numerous groups to adopt these machineries. Various agents ranging from patients, clinicians, healthcare administrators, and governmental organizations will have some degree of control in limiting AI's function within medicine. Governmental regulation will be forced to keep pace with the advancements observed in healthcare-based AI technologies due to both safety and privacy concerns. Therefore, many improved technologies observed in research and development may purposely face delay as a result of rigorous testing and cumbersome governmental red-taping. The framing of this research is thus best aligned with theories of *soft technological determinism*, where the presence of particular technology such as clinical AI tools is only a "facilitating factor leading to potential opportunities that may or may not be taken up by society because of other mediating influences" (Swearengen, 2007, p. 228-230).

Sociotechnical Exploration: Theories on Technological Determinism

Technological determinism is a prevailing sociotechnical theory that suggests a society's technology is the most influential factor in driving human actions and behaviors (Smith & Marx, 1994). This theory operates under the notion that technological developments are unstoppable once in progress (Krishna-Hensel, 2016, p.). Theories of technological determinism, however, are best described under two differing school of thoughts classified as either "soft" or "hard" determinism.

Under the hard determinist view, there exists an optimistic belief in technological progress. An *invisible hand* of some form will perpetually guide the technology onward and upward, using individuals and organizations as vessels for its driven purpose. Hard determinist would thus argue that the transformation of the patient-physician relationship would become entirely dependent on the technological advancements observed in the artificial intelligence industry. These invented artifacts would primarily fulfil the interest of scientists and researchers developing the emergent technologies, while effectively ignoring its consequential effects on broader society. The researchers interested in developing AI algorithms are unlikely to even consider how physicians' relations with their patients will shift if transformative AI systems were to take hold of hospitals. If AI technologies continually make headway, possessing perfect diagnosing and interpretive capabilities, hard determinists would suggest that it is no longer inconceivable to imagine a healthcare system where machines—not humans—serve as clinicians. Such beliefs are espoused by both historian Yuval Harari and business tycoon Vinod Khosla, who argue that AI technology already reveals deterministic capabilities in the healthcare setting, further suggesting that this grip will only strengthen over time (Harari, 2017; Kocher and Emanuel, 2019). Although AI systems are currently incapable of displacing doctors and their assigned roles entirely, Harari contends that

the current obstacles within AI machines only need to be solved once. If *and* when this quandary is resolved, an infinite number of doctors would theoretically be made available.

While proponents of hard determinism argue that the force exerted by technology is inflexible, those in support of soft determinism assert that various social, economic, and political factors also impart some influence against these designed artifacts (Smith & Marx, 1994). Despite Harari's far-reaching theories, it is difficult to suggest that hard determinism and AI technology will drastically subvert the physician's role. Factors such as the patient concern for privacy as well as the government's domineering involvement in regulating medical advancements certainly cannot go ignored. Unleashing AI technology to its full capacity requires the AI system have complete access to patient data, which raises numerous questions regarding patient confidentiality as protected by laws under Health Insurance Portability and Accountability Act (HIPPA). Furthermore, Cutcliffe's (2001) exploration of scientific accountability demonstrates the power among governmental agencies in establishing regulations that mandate scientific compliance. With the passing of the Government Performance and Results Act (GPRA) in 1993, governmental agencies have begun inquiring scientific and medical institutions with questions along the lines of *"what kind of results are being achieved?"* From Cutcliffe's viewpoint, governmental regulations will not be eradicated anytime soon, and thus the implementation of AI within healthcare will be substantially controlled. Agencies such as Centers for Medicare and Medicaid Services (CMS) and Food and Drug Administration (FDA) would similarly play a heavy role in ensuring that any form of AI-powered medical devices is both reliable and rigorously tested before they are placed near a hospital setting. Due to stringent political regulations within healthcare, the extent to which technology can impact patient-physician relation may purposely be curtailed, thus favoring a sociotechnical framework of soft technological determinism.

Research Question and Methods

In this study, I explore the impact of emerging clinical technologies through my research question: How will technological advancements in machine learning and artificial intelligence algorithms play a role in reshaping, or even disrupting, the patient-physician relationship?

This question is motivated by current conversations among data scientists, clinicians, and health regulators with many of them sharing polarizing thoughts and opinions regarding clinical AI tools and devices. To better encapsulate these differing opinions, this study addresses the research question primarily through *discourse analysis* and *literature review*. As part of the discourse, newspaper articles, interviews, magazines, and scientific dialogues were identified by Google and Microsoft Academic. Papers relating to scientific applications were found through exhaustive searches in Google Scholar and PubMed utilizing key phrases such as "artificial intelligence" or "AI-based healthcare." Among the sources identified, particular attention was given in understanding the perspectives of actors most impacted by clinical AI technology: patients, doctors, and biomedical engineers. The various responses and positions provided by scientists, physicians, and media was gathered, and sorted in two categories: those who believed AI will either a) *positively* or b) *negatively* affect the patient-physician relationship. A similar model was generated in arguing the long-term employability of the medical profession by identifying two positions: those who believed AI tools will either a) replace doctors entirely or b) facilitate doctors by solely serving as helpful clinical tools. As part of the discourse, patient advocacy groups and clinical studies were consulted to better characterize themes and significance of a positive patient-physician relationship. The main factors that emerged from these dialogues were then utilized as key metrics in assessing whether AI-based technology will enhance or hinder future patient-physician relationships.

Results

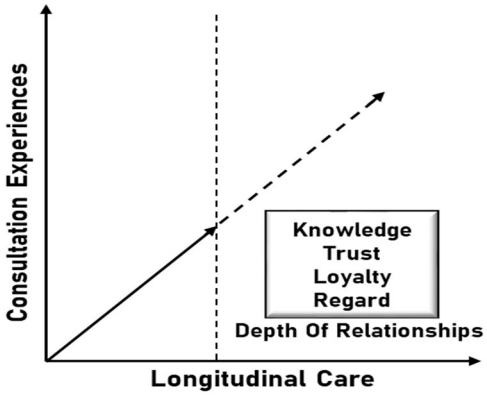
The findings describe components characterizing healthy patient-physician relationships as well as factors promoting such bonds. Negative aspects that hinder the relationship are also explored, followed by how AI technologies may serve to address those sources of hindrance. In keeping with the discourse, this study also provides counterpoints suggesting AI may hurt the longstanding patient-physician bond. Furthermore, deterministic capabilities of clinical AI tools are considered by addressing the susceptibility of physicians being displaced by these devices. However, the framing of soft determinism provides evidence that this may be an unlikely outcome.

A. Conceptualizing the Patient-Physician Relationship

The patient-physician relationship is an important but often misunderstood idea. Any attempts at analyzing the potential impacts of AI on this sacred relationship must therefore begin by a clear understanding of the shared bond from the perspectives of patients and medical professionals. Studies have attempted to clarify how patients experience and evaluate their relationship with healthcare providers by identifying factors that characterize a positive network. Through exhaustive review and thematic analysis of more than 1900 papers, Ridd (2009) and his colleagues demonstrated that patients found longitudinal care and positive consultation experiences—active listening, clear diagnosis, as well as humanized communications—as the key process in developing and maintaining a healthy patient-physician relationship (Figure 1).

Figure 1. Conceptualizing Patient-Physician Relationship

The study identified two major elements (longitudinal care and consultation experiences) contributing to the initial development of a patient–physician relationship. Longitudinal care is achieved through repeated communication and positive consultations with health professionals. Facilitating this dynamic relationship are the thematic elements that emerged in content analysis of 1900+ papers: knowledge, trust, loyalty, and regard, which enhance and deepen the relationship, further pushing the curve positively.



Ridd also synthesized four main elements that emerged from his literature review that helps further deepen the relationship: knowledge, trust, loyalty, and regard, described in Table 1.

Factors	Description
Knowledge	Doctors' knowledge of patients and level of familiarity with their doctor.
Trust	Patients' faith in doctors' competence, and doctors' trust in patients and their report of symptoms.
Loyalty	Patients' will to forgive doctors for inconvenience and doctors' pledge not to abandon patients.
Regard	Patients feeling that doctors likes them as individuals and are "on their side."

Table 1. Critical Factors on the Patient-Physician Relationship

Additional attempts in understanding the ideal patient-physician relationships was conducted by surveying media content recommended by patient advocacy groups (Supplemental Table 1). The premier eight advocacy groups echoed much of the same themes—trust, knowledge, loyalty, and regard—identified in Ridd's initial analysis. Furthermore, these groups were able to identify concepts of autonomy and open communications as equally vital in building a strong relationship. Despite most of these criteria being subjective, qualitative studies are well-suited in investigating poorly understood topics like patient–physician relationships. Therefore, the four tenets highlighted above should be effective in conceptualizing how AI technology will impact the shared relationships between doctors and their respective patients.

Building upon this framework, studies have similarly attempted to identify indicators that adversely affect patient-physician relationships. A comprehensive study by Chipidza and her colleagues (2015) at Harvard Medical School amassed series of research papers, articulating four key categories that severely disrupt the previously identified elements (Table 1) that are essential in promoting a desirable patient-physician relationship. These four disruptive categories were classified as either: patient factors, provider factors, patient-provider mismatches, or systemic factors. Patient factors stem from the individual seeking care and include issues such as a "difficult

patient," where the patient dislikes the physician, resulting in a lack of regard between the two actors. Similarly, the study includes provider factors such as physician burnout or systemic factors such as time constraints that limit patient-physician interactions, leaving relations vulnerable to mistrust and contempt. An abridged table from the study is shown below with factors most relevant to issues that artificial intelligence technology may be able to address (Table 2).

B. Discourse Review: Exploring the Varying Viewpoints

Table 2: Relevant Factors Severely Hindering Patient-Physician Relationships (Source: Chipidza et al, 2015)

Factor	Category	Strain on Relationships	
Physician Burnout; Detachment	Provider Factor	*Trust:*	Burnout jeopardizes trust in physicians' competence
		Knowledge:	Burnout hinders attentiveness; physicians fail to recognize patient needs
		Regard:	Emotionally exhausted physicians cannot show affection
		Loyalty:	Patients unlikely to return to physician who cannot recognize their needs
Cultural Barriers	Patient/Provider Mismatches	*Trust:*	Physicians less likely to share important medical information
		Knowledge:	Doctors/patients have difficulty getting to know one another
		Regard:	Doctors are less empathetic towards patients who lack proficiency in English
Time Constraints	Systemic	*Trust:*	Doctors don't make time to explain, diminishing trust
		Knowledge:	Less time for the physician/patient to get to know one another
		Regard:	Less time for rapport if doctors lack time to communicate
		Loyalty:	Patients less likely to be loyal towards doctor that don't show positive regard
High Patient Ratio	Systemic	*Knowledge*:	Patients cannot get familiarity with their care team
		Regard:	Too many patients limits opportunities for proper rapport
Documentation Burden	Systemic	*Knowledge*:	Physicians spend visitation making sure boxes get checked, while patient feels that the doctor is unknown to him/her
		Regard:	Required paperwork and documentation enhances physician burnout, making it harder for the physician to show empathy

Having conceptualized the patient-physician network and identifying factors that promote and hinder this relation, it then begs the question: How does AI exactly fit into this relationship? What do the chief experts leading both the medical and engineering forefront of AI technology have to express regarding healthcare powered by AI? Although the speculation that AI tools will replace physicians is debated, the profession of medicine nevertheless has incredible opportunities in overseeing the application of AI technology in patient care (Darcy, Louie & Roberts, 2016).

Analysis of the existing literature and dialogue has demonstrated various positions among researchers regarding the impact of clinical AI applications on patient-physician relationships. Although intricate, these viewpoints can be broadly characterized into two distinct groups: a) the group I will term *techno-optimists*, who undoubtedly hold the belief that AI will improve the patient-physician relationship and b) the group I will term *techno-pessimists*, who are increasingly wary of AI technologies, citing inaccurate results and privacy as a cause for concern.

The techno-optimists reference many of the factors identified by Chipidza that currently strain physician-patient relationships. Chief among these are the belief that implementation of AI tools will enable physicians to spend an increased amount time with their patients, relieving them from the "time constraints" and "documentation burdens" acknowledged in Table 2. Fogel and Kvedar (2018) expressed confidence that AI tools will strengthen the physician-patient relationship by automating many monotonous tasks such as electronic health record (EHR) documentation, giving physicians more time to "humanize" with their patients. French researchers expressed similar sentiments by demonstrating the automation of mundane tasks through AI technologies frees up more time for physicians to invest in improving their relationships with patients, citing the astronomical amount of time physicians currently spend searching through medical histories, laboratory results, and other clinical data (Lerner et al., 2018). It is the belief of

these researchers that more time spent interacting with patients will lead to better development of *trust* and *knowledge*, and will help doctors better empathize with their patients, further resulting in an improved sense of *regard*. Consequently, patients are also more likely to develop a sense of *loyalty* towards health professionals that show more compassion and understanding towards their ailment, ultimately enhancing the shared relationship between a doctor and his/her clients. Other proponents of AI technology hold the belief that physicians will be more effective in their ability to provide treatments once healthcare-based AI is fully commercialized. In the field of breast imaging, Aminololama-Shakeri and Lopez (2019) argue that AI-enabled technology in tasks such as breast density assessments, screening, examination reporting, and protocoling will open up boundless opportunities for radiologists to play a more active role in disease management. Renowned businessman Vinod Khosla shares a similar viewpoint, arguing that there will no longer be a need for humans to read MRI chart or an X-ray (Farr, 2017). Instead, he argues that the focus should be geared towards helping physicians better utilize the outputs generated from algorithms, so that doctors can effectively work with their patients in providing a better course of treatment.

Countering the sentiments expressed by the techno-optimists are researchers that believe patient-physician relations will be disrupted as a consequence of AI technology. LaRosa & Danks (2018) argue that much of the progress in AI-drive healthcare are in fact overstated. If AI tools and computer-aided software continually hold value within doctors' offices, despite their current shortcomings, the trusting relationship between doctors and patients will face severe disruptions. The belief that AI tools can aid the patient-physician relationship implicitly holds the assumption that AI tools will fare as well, if not better, than current standards of care. However, the AI algorithms consistently outperforming human doctors in critical clinical procedures is not certain as demonstrated by IBM's Watson—one of the few AI systems ever to be fully integrated within

a healthcare setting. In 2012, IBM partnered with Memorial Sloan Kettering to train Watson, a one-of-a-kind AI system, in interpreting patients' clinical data (Strickland, 2019). However, reports failed to impress as studies have found Watson's Oncology system frequently generating inaccurate treatment recommendations and suboptimal diagnostic rate—as low as 49 percent at Gachon University Medical Center in China. Reports in 2018 further revealed that Watson, despite several software updates, was continually making inaccurate treatment recommendations, which placed severe doubts among even the most optimistic scientists regarding AI-driven tools. Ajay Royyuru, IBM's own vice president of healthcare, suggested that the utilization of Watson for "diagnosis is not the place to go…No matter how well you do it with AI, it is not going to displace the expert practitioner" (Strickland, 2019). Watson's inability to correctly perform its intended use, despite the involvement of premier medical and technological institutions, serves to highlight AI as a rudimentary technological system still in its infancy. If physicians today were to thoughtlessly trust the recommendations made by AI systems like Watson, these tools will disrupt the entire foundation of trust the patient-physician relationship is based upon. Increased compassion and socialization from doctors will not hold clinical significance or improve the patient-physician relationships if wrongful suggestions from AI tools are blindly followed.

Other critics similarly express that increased involvement in AI technology will do nothing more than further distance doctors from their patients because of our current healthcare practices. This is especially true in the United States, where physicians spend more time interacting with the EHR systems than with patients directly (Young, 2018). A study surveying doctors found that physicians realistically spend only between 13 to 24 minutes with each patient (Statista, 2019). What is especially concerning are the incentive-based payment systems since many physicians are compensated based on the number of patients observed (Rabin, 2014). This often incentivizes

physicians to see as many patients as possible, often compromising in the quality of care they provide. To many critics of AI and the healthcare system, it is naïve to assume that physicians will be utilizing the additional allotted time in solidarity with their patients. A fundamental change in the organization of our healthcare system would be necessary in promoting the more sustained and impactful patient-physician interactions that the techno-optimists prefer to envision.

C. Future of AI Technology: Are Doctors Vulnerable?

Layered within the arguments proposed by both the techno-optimists and techno-pessimists lies yet another contentious discussion: If AI tools continue to develop at their current rate, to what degree will they influence the healthcare landscape? As digital health transforms the doctor-patient hierarchy into an equal level partnership, what happens with the unquestioned autonomy that doctors previously used to enjoy? In evaluating this framing, I will once again introduce two differing viewpoints: a) the group I will term *determinists* who believe AI technologies hold severe consequential capabilities that will transform the patient-physician relationship into a patient-algorithm one and b) the group I will term *constructionist*, who see AI technologies as nothing more than devices empowering existing doctors in their treatment duties.

The determinists' viewpoints are best espoused by Yuval Harari (2018), who has conceptualized a healthcare system driven by AI technology. Harari shows value in AI-based physician systems in instances where new diseases, such as COVID-19, might be detected. Rather than having human physicians who are not immediately updated, utilization of AI doctors enables instant information transfer to all systems with each unit communicating to one another regarding their assessments of the novel disease. To Harari, the potential advantages of connectivity and updatability are so grand that it is justifiable "to replace humans with computers, even if…some humans do a better job than the machines." (Harari, 2018). These words certainly echo with truth

in midst of an ongoing pandemic, where a centralized system has better capabilities in assessing, tracking, and limiting the transmission of a disease. The determinist argument is further legitimized by current AI systems that are already implemented in areas lacking proper healthcare access. Countries such as China and Japan are applying AI technology to push back against physician shortages, especially in rural areas ("Hospitals are using AI to slash wait times and solve doctor shortages", 2019). A study published by the American Academy of Ophthalmology found that a Google algorithm improved doctors' ability to diagnose diabetic retinopathy (Source). The algorithm was tested in India, exactly the type of country that could benefit from AI screenings, since it particularly suffers from a shortage of ophthalmologists (Sayres et al., 2019). Therefore, it can be argued that these machineries are already in the process of replacing doctors, especially in areas where there were none to begin with.

On the contrary, the constructionist often minimizes the roles of clinical AI technology, merely viewing them as tools disposable to physicians. The constructionist viewpoints are primarily buttressed on the assumption that AI tools are neither capable of performing the full functionalities of a human physician, nor will they effectively replicate the trust and the human connection shared between patients and their doctors. When the British Medical Journal (2002) inquired, "What makes a good doctor," the primary qualities highlighted by readers included compassion, understanding, empathy, competence, and humanity (Rizo, 2002). Despite the study being released during the initial integration of AI technologies, it remains clear that patients expect profoundly human qualities in their acquainted healthcare professionals. In situations like end-of-life care, constructionist would similarly argue that that it is impossible to imagine compassionate services being delivered in hospices staffed by algorithms. Journals and current medical professionals cite that treatment methods progresses non-linearly, much different than how

algorithms process and make decisions. Cures are often serendipitous "miracles" that come as a result of doctors attempting several treatment programs, consulting various specialists, and openly communicating with patients and their families (Miller, 2020). The notion that AI tools will perfectly recapitulate these factors remains unlikely. Even if these skills were somehow endowed into an AI system, issues of privacy still remain a concern. The refusal to disclose information by either the patient or the doctor into electronic health records can affect the clinical recommendations made by AI systems. This is especially worrying because the AI tools depend on reliable data to make effective and accurate predictions. Therefore, under the constructionist viewpoint, doctors still possess great value in the clinic and their role is unlikely to diminish anytime soon.

Based on these findings, it seems that clinical AI applications' ability to influence the patient-physician relationship will depend largely in the capabilities of the technology itself. It still remains to be seen whether AI systems develop the integral competencies necessary for both patients and physicians to begin trusting them. Although current models such as IBM's Watson are limited, AI's ability to positively address many of the constraints that currently hinder the patient-physician relationship indicates the need for more development in this frontier. There remains a boundless amount of hope that AI systems can positively transform the patient-physician relationship, but changes in the structure of our healthcare and health practices are also vital in facilitating this transformation.

Discussion

This research thus far has evaluated not only the potential impacts of emerging AI tools on the patient-physician relationship, but also its likelihood in threatening the ascribed role of a physician. From my discourse analysis, I introduced several different positions voiced by experts

regarding this complex topic and categorized them into four distinct groups. In answering the question of AI tools' impact on the patient-physician relationship, I presented the arguments made by both the *techno-optimists* as well as the *techno-pessimists*. In addressing if doctors should feel threatened by emerging AI and ML technologies, I similarly presented the arguments made by the so-called *determinists* and the *constructionists*.

Although the techno-optimist and determinist viewpoints offer several alternatives that clinical AI technologies can provide in ameliorating the patient-physician relationship, it remains clear that AI tools currently lack the capabilities of entirely dominating the healthcare frontier. However, this is not to suggest the AI tools are completely powerless against human actors because their need is increasingly becoming apparent. The viewpoints expressed by the constructionists are somewhat dismissive towards the advancements observed in the AI industry. For example, the notion that AI tools are incapable of recapitulating human emotions are shortsighted claims that ignore the dramatic improvements made by contemporary chat bots, some of which will soon pass the Turing test, exhibiting intelligent behavior equivalent to humans. If the pace of development is sustained over the years, AI tools will certainly push back with some deterministic capabilities.

The theories espoused from the four groups each hold varying degrees of credibility, but a more thorough and accurate evaluation of the research question is best understood through *soft technological determinism.* Irrespective of technological advancements in health AI products, there are external factors that will forever limit the degree of AI tools integration into the clinic. These tools are designed for human diagnosis and treatments, interacting at an extremely personal level with a patient. Developing a system that enough individuals can trust for medical use is an incredible hurdle that AI tools are struggling to overcome. Once again, theories of soft determinism help us understand AI's future role because its clinical success is dependent on sociopolitical

factors such as: *societal acceptance, patient and physician trust, governmental regulation, and healthcare implementations*. In fact, it can be argued that AI technologies will consistently fall vulnerable to these factors. If clinical AI systems were integrated into the healthcare environment and performed poorly, these tools will undoubtedly face scrutiny, making it more difficult for them to resurface as commercial products. These findings also confirm that the physician's role within the hospital is immune to disruptions as proposed by overzealous hard determinists.

Having said that, a major limitation in fully addressing the depth of this question is primarily due to the lack of successful clinical AI tools available. Most of the developments are still purely in early stages of development and in pre-clinical markets. Any attempts to fully integrate AI systems have been largely unsuccessful as demonstrated by IBM's Watson. Therefore, most of the viewpoints expressed in AI's ability to transform patient-physician relationship is purely conceptualized. Many of the arguments that favor AI may be constrained, being viewed as heavy rhetoric, instead of empirical documentation of this technology's progression.

As part of the discourse analysis, I had planned to conduct interviews with some of the patient-advocacy groups to gain more patient perspective on AI technology. The lack of awareness regarding current AI technology among the patient advocacy representatives suggested that I should have broadened my pool of potential interviewees. Their unfamiliarity with AI technology further indicates that clinical AI tools are still under development, and that their potency has yet to be realized by individual agents in the healthcare environment. My list of expanded interviewees would have included experts in the field of healthcare and AI technology—many of whom would have been available at Charlottesville. However, the on-going outbreak of COVID-19 made securing these interviews more challenging. In the future, I would like to be more proactive in recruiting as many individuals that could speak more on this topic. Although there is a wealth of

information made available online, in-depth one-on-one conversations with more qualified subjects would have added a significant amount of value to this study. This research was intended to be a discourse analysis, but it also lacks the opinions and inputs of the general public as well as personal discussions among individual patients. While securing patient interviews might have proven difficult, a broad survey could have been designed and released for the community to provide their thoughts and feeling about AI technology in relation to healthcare.

As part of this research, I wanted to combine both my current studies in BME as well as my future aspirations to work clinically as a doctor. Thus, I was curious to investigate a topic that considered both of these distinct but related fields. My research in AI technology was driven by my particular interest in emerging imaging technologies, an area where clinically based AI tools have made significant amount of progress. Since AI technologies have yet to fully be unleashed in healthcare, it was also interesting to read varying positions provided by the experts in the field. I also gained a significant insight in what encompasses a holistic form of treatment through my explorations in understanding patient-physician relationships. This research has further strengthened my desire to enter the medical field because I recognize the lack of medical professionals that see value in understanding technical devices and their broader social impacts.

Conclusion

This sociotechnical study focused on clinical applications of artificial intelligence and machine learning algorithms to better understand how developments of these emerging technologies will come to impact the patient-physician relationships. The study also sought to evaluate whether these technologies pose a significant risk towards the current role of the physician, ultimately coming to the conclusion that AI tools are more suited as supplementary components in physicians treating their respective patients. Through the lens of soft determinism,

the study also demonstrated that implementation of clinical AI technology is imminent, but its success depends on numerous external influences. The developed algorithms must not only perform with high accuracy, but also willingly be adopted by several groups including patients, physicians, health care administrators, and regulating governmental bodies. Although clinical AI and predictive analysis are quickly becoming the norm, it is vital to recognize that collaboration between the human (doctor) and non-human (clinical AI technology) actors is the most obvious path in promoting positive clinical outcomes—artificial intelligence and humans are most potent when cooperating together with a unified purpose.

This study only explored the potential consequences of AI and ML tools on a specific niche within the healthcare sector: the patient-physician relationship. Future studies should broaden these discussions by attempting to understand how AI tools may impact some of the more complex aspects of the healthcare industry. Therefore, interesting questions for further exploration include (but are not limited to): *1) Who bears responsibility if an AI-assisted medical decision causes harm to a patient? 2) Will AI increase the cost of care and how will AI change the current standing structures of insurance policies? 3) Will doctors and medical professionals really be more efficient if AI handles some of the time-consuming tasks?*

References

Aminololama-Shakeri, S., & López, J. E. (2019). The Doctor-Patient Relationship With Artificial Intelligence. *AJR. American Journal of Roentgenology*, *212*(2), 308–310. https://doi.org/10.2214/AJR.18.20509

Chipidza, F. E., Wallwork, R. S., & Stern, T. A. (2015). Impact of the Doctor-Patient Relationship. *The Primary Care Companion for CNS Disorders*, *17*(5). https://doi.org/10.4088/PCC.15f01840

Cutcliffe, S. H., & Mitcham, C. (2001). Visions of STS: counterpoints in science, technology, and society studies. (pp. 99-107). Albany, NY: State University of New York Press.

Darcy, A. M., Louie, A. K., & Roberts, L. W. (2016). Machine Learning and the Profession of Medicine. *JAMA*, *315*(6), 551–552. https://doi.org/10.1001/jama.2015.18421

Farr, C. (2017). Here's why one tech investor thinks some doctors will be 'obsolete' in five years. Retrieved 22 April 2020, from https://www.cnbc.com/2017/04/07/vinod-khosla-radiologists-obsolete-five-years.html

Fogel, A. L., & Kvedar, J. C. (2018). Artificial intelligence powers digital medicine. *Nature Partner Journals Digital Medicine*, *1*(1), 5. https://doi.org/10.1038/s41746-017-0012-2

HellÍn, T. (2002). The physician–patient relationship: Recent developments and changes. *Haemophilia*, *8*(3), 450–454. https://doi.org/10.1046/j.1365-2516.2002.00636.x

Hospitals are using AI to slash wait times and solve doctor shortages. (2019). Retrieved 23 April 2020, from https://apolitical.co/en/solution_article/hospitals-are-using-ai-to-slash-wait-times-and-solve-doctor-shortages

Grace, K., Salvatier, J., Dafoe, A., Zhang, B., & Evans, O. (2017). When Will AI Exceed Human Performance? Evidence from AI Experts. *ArXiv:1705.08807*. Retrieved from http://arxiv.org/abs/1705.08807

Kaba, R., & Sooriakumaran, P. (2007). The evolution of the doctor-patient relationship. *International Journal of Surgery*, *5*(1), 57–65. https://doi.org/10.1016/j.ijsu.2006.01.005

Kelly, C., & Eisenberg, M. (2019, February 27). The precautions you should take before consulting 'Dr. Google.' *Washington Post*, 3–4.

Kocher, B., & Emanuel, Z. (2019). Will robots replace doctors? Retrieved 20 April 2020, from https://www.brookings.edu/blog/usc-brookings-schaeffer-on-health-policy/2019/03/05/will-robots-replace-doctors/

Krishna-HenseL, S. (2016). The Resurgence of the State: Trends and Processes in Cyberspace Governance (1st ed., pp. 153-154). New York, New York: Routledge Publishing.

Krittanawong, C. (2018). The rise of artificial intelligence and the uncertain future for physicians. *European Journal of Internal Medicine*, *48*, e13–e14. https://doi.org/10.1016/j.ejim.2017.06.017

LaRosa, E., & Danks, D. (2018). Impacts on Trust of Healthcare AI. *AIES '18*. https://doi.org/10.1145/3278721.3278771

Lerner, I., Veil, R., Nguyen, D.-P., Luu, V. P., & Jantzen, R. (2018). Revolution in Health Care: How Will Data Science Impact Doctor–Patient Relationships? *Frontiers in Public Health*, *6*. https://doi.org/10.3389/fpubh.2018.00099

Miller, T. (2020). 5 Reasons Why Artificial Intelligence Won't Replace Physicians - Dolbey Systems, Inc. Retrieved 25 April 2020, from https://www.dolbey.com/5-reasons-why-artificial-intelligence-wont-replace-physicians/

QT, Inc. v. Mayo Clinic Jacksonville, No. 05 C 6387 (N.D. Ill. May 15, 2006)

Rabin, R. C. (2014, April 21). 15-Minute Visits Take A Toll On The Doctor-Patient Relationship. *Kaiser Health News*. https://khn.org/news/15-minute-doctor-visits/

Ridd, M., Shaw, A., Lewis, G., & Salisbury, C. (2009). The patient–doctor relationship: A synthesis of the qualitative literature on patients' perspectives. *The British Journal of General Practice*, *59*(561), e116–e133. https://doi.org/10.3399/bjgp09X420248

Rizo, C. (2002). What's a good doctor and how do you make one? *BMJ*, *325*(7366), 711. https://doi.org/10.1136/bmj.325.7366.711

Statista. (2018). Retrieved March 30, 2020, from https://www.statista.com/statistics/250219/us-physicians-opinion-about-their-compensation/

Sayres, R., Taly, A., Rahimy, E., Blumer, K., Coz, D., Hammel, N., Krause, J., Narayanaswamy, A., Rastegar, Z., Wu, D., Xu, S., Barb, S., Joseph, A., Shumski, M., Smith, J., Sood, A. B., Corrado, G. S., Peng, L., & Webster, D. R. (2019). Using a Deep Learning Algorithm and Integrated Gradients Explanation to Assist Grading for Diabetic Retinopathy. *Ophthalmology*, *126*(4), 552–564. https://doi.org/10.1016/j.ophtha.2018.11.016

Smith, Merritt Roe & Leo Marx (eds) (1994) Does Technology Drive History? The Dilemma of Technological Determinism (Cambridge, MA: MIT Press).

Swearengen, J. (2007). Beyond Paradise: Technology and the Kingdom of God (pp. 228-230). Eugene, Oregon: Wipf & Stock Publishers.

Young, R. A., Burge, S. K., Kumar, K. A., Wilson, J. M., & Ortiz, D. F. (2018). A Time-Motion Study of Primary Care Physicians' Work in the Electronic Health Record Era. *Family Medicine*, *50*(2), 91–99. https://doi.org/10.22454/FamMed.2018.184803

Yuval Harari. (2017, July 20). Homo Deus and the Impact of Digitalization on Society. Retrieved October 18, 2019, from Yuval Noah Harari website: https://www.ynharari.com/homo-deus-impact-digitalization-society/

Harari, Y. (2018). Why Technology Favors Tyranny. Retrieved 22 April 2020, from https://www.theatlantic.com/magazine/archive/2018/10/yuval-noah-harari-technology-tyranny/568330/

Supplemental Material

Supplemental Table 1: Key Themes Identified by Patient-Advocacy Groups That Characterize Positive Patient-Physician Relationship

Advocacy Group	Disease	Discussion of Patient-Physician Relationship	Key Themes
American Cancer Society	Cancer	Honesty, active and clear communications always leads to better outcomes and is the ideal form of relation. It is important to find hospitals that has experience treating type of cancer. Larger hospitals may have more experience with different kinds of cancers and offer more services.	**Trust Honesty Communication Knowledge**
American Diabetes Association	Diabetes	Diabetes care team depends on patients to tell the truth about how they feel. Two components of successful teamwork are physician-patient communication and shared decision-making, both of which have been shown to improve patient satisfaction, adherence to treatment plans, and health outcomes.	**Trust Regard Knowledge Autonomy**
American Heart Association	Cardiovascular	Communication is the thing, but chemistry is also key. A good doctor will spend time with a patient to answer all of their questions and concerns. Although receiving a heart disease diagnosis can be frightful and unnerving, a trusting, positive relationship with a cardiologist will make the experience a bit easier to handle.	**Communication Chemistry Regard Loyalty**
American Lung Association	Pulmonary	The integrity of the provider– patient relationship must be protected; medical decisions are not influenced by inappropriate economic considerations. Health care providers must provide appropriate care and also advocate for their patient. The unique, trusting nature of the health care provider– patient relationship, which includes advocacy and confidentiality, must not be jeopardized. Physicians and other health care providers have a responsibility to respect patient autonomy.	**Knowledge Loyalty Trust Regard Autonomy**
Cystic Fibrosis Foundation	Cystic Fibrosis	Strong relationships take time and trust to build, and are possible when the other person open. Patients and care teams can build deeper relationships by seeing the person behind the title. Care team members must communicate freely and building relationships has to be longitudinal. Clinicians must understand where the patient is each time they come into the clinic, hold them accountable and adjust to fit their needs and to understand more about them as they go.	**Trust Communication Loyalty Knowledge Regard**
March of Dimes	Maternity Pediatrics	When choosing a pediatrician, it is vital to finding someone with whom patients feel comfortable and trust. Patients may need to call the practice in the middle of the night with a question; thus, is it important that they feel confident that the person on the other end of the phone can address any concerns. A patient-physician relationship must also be based on face-to-face visits. Relationships cannot be established solely by a phone call, online questionnaire, or Internet discussion.	**Trust Communication Knowledge**
National Organization of Rare Disorders	Rare Diseases	Physicians' professional credibility and competence, as well as the appropriateness of communication, significantly determine patients' status, symptoms and outcomes. A dedicated rare disease patient organization has the potential to function as a catalyst for moving from a paternalistic to a power-sharing model of the patient-physician relationship. It can act as a transformative resource for all key actors. Patient-involvement is equally key in the advocating for drug development of rare diseases.	**Communication Trust Regard Accountability**