On Socioeconomic Impacts of Technological Advancements in Healthcare

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Abstract

US healthcare has made huge progress in technological advancements and regulatory standards over the last century. Despite this, healthcare as an industry has many challenges which are experienced by many patients on a daily basis and has also become a hot topic for politicians to debate in recent years. This study aims to identify technological advancements in healthcare and their socioeconomic impacts. In order to precisely pin down the opportunities related to technology in healthcare, researchers seek to find answers to questions related to technological advancements in healthcare over the past century to present day, make comparisons of advances in healthcare with the manufacturing industry, and observe technology's relationship with socioeconomic status of today's society and healthcare. The research was conducted through an extensive literature review using online resources available through the university and public databases. Findings of this research study suggest that healthcare is nimble in its overall advancement but in regards to technology, it is still catching up compared with other industries like manufacturing. Technology is definitely a boon to society from a healthcare perspective but it can also be a disadvantage at times due to its poor management and system wide applications.

Keywords
Technology, socioeconomic, technological advancement, healthcare, manufacturing.

1. Introduction
According to Bureau of Labor Statistics (BLS), US Department of Labor, the Healthcare and Social Assistance sector covers institutions providing healthcare and social assistance for people. The reason both are under the same group is because sometimes it is difficult to distinguish between the boundaries of these two groups. The services provided by establishments in this sector are carried out by trained professionals. Many of the industries in this sector are defined based on the academic degree held by the practitioners included in the industry (BLS, 2019).

Just about a hundred years ago, healthcare was not regulated and the concept of health insurance was also not in existence. Doctors provided care to patients in their homes. Hospitals that existed at that time provided limited services. When patients were seen, doctors were paid direct out-of-pocket fees which still exist in many parts of the world, especially in developing and underdeveloped countries. Medical science and technology were primitive and there was little that doctors could do to treat most illnesses. One of the most common medical devices, the modern thermometer was invented in 1709 by Daniel Fahrenheit. It first contained alcohol and eventually, it was improvised with liquid mercury (Rubin, 2018). A French physician named Rene Theophile Hyacinthe Laennec invented the stethoscope in 1816 (Roguin, 2006). Even the X-ray technology that looks so common today was invented only about three decades ago (Moseley III, 2008).

Today, since healthcare involves people's lives and health, it is considered as one of the complex and highly

regulated industries in existence. Healthcare regulations are developed and enforced by all levels of government – federal, state and local – and also by a large assortment of private organizations. There are times they work in conjunction and there are times they work in silos (Field, 2008). However, according to Johns Hopkins Medicine (2016), death due to medical errors is the third leading cause of death in the USA which was calculated to be more than 250,000 deaths per year. This number is not only alarming but is also pushing policy makers and people in the USA to question about the quality of care they are receiving despite being one of the few countries in the world with highly expensive healthcare. According to Byrnes (2019), the USA spends $8,047 per capita and 14% of the GDP on public health, and provider to patient ratio is 2.6:1,000. As a patient, what is more alarming is that despite a very expensive healthcare system, according to the Commonwealth Fund: a non-profit organization, the USA ranks last for health outcomes, equity and quality when compared to most developed countries in the world (Cook, 2018).

Healthcare as an industry has many challenges which are experienced by many patients day to day but it has also become a hot topic for politicians to debate. The Patient Protection and Affordable Care Act was enacted in March 2010 but is being proposed for repeal by many republican politicians who are against the reform (Health Reform, 2019). Today more than 90% of the Americans have health insurance yet some policymakers believe that current insurance programs offered through the government are too generous and inappropriately burdening taxpayers (Fiedler & Young, 2019).

Statement of the Problem

This study is focused on identifying technological advancements in healthcare and how these are impacting people's lives i.e. socioeconomic consequences of such advancements. In order to precisely pin down the opportunities related to technology in healthcare, the following research questions were proposed.

Research Questions

1. What are some of the technological advancements in healthcare?
2. How does technological advancement in healthcare compare with other industries like manufacturing?
3. How is technology contributing to the socioeconomic status of today's society in relation to healthcare?

2. Methodology

This study is based on the literature search that was conducted by using available online databases (Google and Mendeley) and university libraries (North Carolina Agricultural & Technical State University and Indiana State University). Hence, the study is an unstructured and qualitative meta-analysis of the literature search. Articles were first short-listed based on the key words and then a select list of articles was identified based on the relevance to the current topic for final analysis.

3. Findings

Findings in terms of responses to the three research questions have been summarized in this section.

Technological Advancements in Healthcare

Thimbleby (2013) highlights the fact that medical culture, in relation to patients being treated as helpless, has hierarchies, strict cultures, etc., and has been that way since the beginning of the 19th century. However, there has been a dramatic technological advancement in medicine, and this is hard to even explain. For example, most people may not know how an infusion pump works. In the past, they used clockwork mechanisms, and before that they were gravity fed. Today, almost everything contains some computer function and has a colorful screen and a lot of buttons and functionalities. Implanted defibrillators that use telephone networks and internet to keep cardiologists informed just-in-time about the status of the patients work like magic. New inventions in drugs, vaccines, and treatment methodologies are all modern magic. It is amazing to note how healthcare has changed in the last 150 years. It is amazing to think – how it will proceed in the future.

Medieval Islamic physicians led the advancement of case histories for educational use. A forerunner of modern medical records first appeared in Europe by the early 19th century. Development of the clinical record in the USA was pioneered in the 19th century in major teaching hospitals. Use for direct patient care only started in the 20th century. In the first decades of the twenty-first century, most hospitals started moving from paper medical records to electronic medical records (EMR) for direct patient care. This is one technology that is mostly used across the board

due to the financial incentives stimulated by the regulatory bodies as well as the ease of providing care to the patients conveniently (Gillum, 2013). In today's era of Industrial Revolution 4.0, the Electronic Health Record (EHR), which is also used synonymously as EMR, is considered one of the top technological advancements in the recent time. Besides, EHR/EMR, below is a list of some other technological advancements, which are said to have reshaped and transformed modern healthcare (Jayanthi, 2014):

- Mobile health (mHealth) is enabling providers as well as patients to receive and provide care at the ease of their fingertips without needing devices connected with wires and cords.
- Telemedicine/telehealth is another technology that many hospitals and clinics are using today to provide care to patients from a remote location during emergencies and where there is a lack of resources or expertise.
- Online patient portal is the patient facing technology platform where patients are becoming actively engaged with the healthcare provider as well as interacting when needed, shortening the time to commute as well as time to move through complex healthcare systems.
- Self-service kiosks similar to what is seen at airports and in many retail stores today are becoming the norm at clinics throughout the country. Many hospitals still check in patients in a traditional way, i.e. with the help of a front desk clerk, but many hospitals are also moving to patients checking in themselves online or through self-service kiosks.
- Remote monitoring tools such as temperature monitoring systems (for vaccines and temperate controlled medications and tissue samples and sensors of movement or other modern technologies) alert care givers and provide a great way to leverage technology to enhance patient care, reducing cost and risks to both healthcare providers and patients.
- Wearable technology is no more a surprise for many patients. Pacemakers, glucose monitors, hearing aids, etc. are just a few examples of wearable technologies that are not only connected to patients' bodies but are also connected to the internet providing just-in-time notification to care givers in case of failure or emergencies.
- Wireless communication as well as iPads to communicate between care givers (nurses and doctors) is an example of wireless communication technology that is widely used throughout all private and public hospitals.
- Real-time locating services for devices (for example, the location of a missing infusion pump on a floor that is in use or not used) or even to locate the patients, depend on technologies like RFID and scan. These services are helping hospitals and clinics be more efficient, and response time has decreased significantly in case of a need.
- Genome sequencing/pharmacogenomics is another cutting edge technology where a care plan is tailored based on a patient's need. One medicine may not work for all patients who have a similar diagnosis so individualized medicine is just a common practice today.

Advancements in imaging technologies, particularly cardiac ultrasound imaging such as Doppler imaging, contrast echocardiography, point-of-care echocardiography, etc. have helped tremendously in dealing with cardiovascular diseases (Dave et al., 2018). Because of these advancements real-time imaging, bed-side imaging, ionizing-radiation-free imaging, etc. have become possible at reasonable costs.

Because of technological advancements, the healthcare industry has grown up from the 1.0 to the 4.0 generation (Kumari, et al., 2018). Healthcare 3.0 was hospital centric, where patients with chronic diseases had to make several hospital visits for routine checkups and treatments, a time-consuming and expensive approach. Advancement in information and communication technologies (ICTs) and following the *Industry 4.0* paradigm, more and more *integrated* application of ICTs pillars has enabled providers to collect large data from different sources in easier ways (Aceto et al., 2018). Therefore, Healthcare 3.0 problems are mitigated as patients' data can be stored and retrieved with the latest fog and cloud computing technologies at low costs (Kumari, et al., 2018). In the Internet of Things (IoT) era and Healthcare 4.0, uninterrupted services can be provided to the end users when required (Kumari et al., 2018).

These technological advancements are just the beginning of a new era and are setting up a foundation for the healthcare industry to step into Industrial Revolution 5.0, which is characterized by full scale coordination between human and machine (Robotic Industries Association, 2018). Robotics was not even mentioned on the list above which is also a technology that is widely used in today's operating rooms. There are still debates and adjustments

being made about Robotic Surgeries but many hospitals in the USA are increasingly using Robotic Surgeries day by day (Schwitzer, 2018). Although quality of care in the US is not as effective in comparison to other developed nations, with rapidly changing and progressing technological advancement in healthcare, especially in the USA, there is hope and desire from both the customers i.e. patients and providers (hospitals/clinics/nursing homes) that technology will help improve cost, care, and quality of care.

Technological Advancements in Healthcare versus Manufacturing Industry

A case example of the manufacturing industry (goods producing industry) can be used in comparison with the healthcare industry, which is considered a service industry. In the case of healthcare, the service provided to its customers i.e. patients is the *care* and *treatment* (Pondhe et al., 2006).

Many experts argue that manufacturing and healthcare cannot be compared. However, as the healthcare delivery system is moving from volume based incentives to value based incentives through government agencies and regulatory bodies, many hospitals today are looking for new ways to cut costs and improve quality (Toussaint et al., 2010). One way hospitals are doing so is by hiring experts in lean manufacturing principles who have been in the manufacturing industry for many years to help streamline the process and improve efficiencies by reducing waste. The main purpose of lean thinking is to identify and minimize waste (Womack and Jones, 2003; Dahlgaard and Dahlgaard-Park, 2006; Khan et al., 2020; Bader, et al., 2020; Douglas et al,, 2015; Taylor et al., 2015; Suarez-Barraza et al., 2016; Badar, 2014). Several researchers have applied lean concepts in healthcare (Dahlgaard et al., 2011; Gonzalez-Aleu et al., 2018; Grove et al., 2010; Pondhe et al., 2006; Robinson et al., 2012).

The biggest hurdle in entertaining the idea of reducing waste in healthcare is the culture (Becker's Hospital Review, 2012). Healthcare and many other service industries kept themselves away from best practices that are used in manufacturing for decades. Today, as mentioned in the previous section of this study, most technologies used by healthcare are either invented in the manufacturing setting or are direct adoptions from manufacturing or other settings like independent research and academia. One example of such practice is robotic surgery. Robinson (2014) mentions that the use of robotic technology in manufacturing goes back to the 1950s, whereas the first use of a robot in the theater of surgery was in the 1980s. It took 30 years for robotic technology to join the healthcare sector (Shah, Vyas & Vyas, 2014).

In the 1750s, people, cargo, and information moved no faster than ox, horse or wind could carry them. There was no electricity. The vast majority of people worked for basic needs: food, clothing and shelter (Hendrickson, 2015). The time period between 1750 and 1914 is known as the time period of industrial revolution. The first industrial revolution happened between 1750 and 1850, and the second industrial revolution happened between 1850 and 1914 (Brooks, 2018).

The healthcare industry, on the other hand, has a long history of existence. The first evidence of a surgical procedure dates back to 3000 BC. It continued through the Middle Ages and into the Renaissance. At that time and for a long period of time, anesthesia was not used at all. Patients were strapped to a bed (Clunie, 2014). An early form of anesthesia was first used towards the end of first industrial revolution in October, 1846 (Medical Milestones, 2017). This clearly shows that healthcare has a long history of existence but the advancement in technology did not take off until the late 19th century, similar to the manufacturing industry. Table 1 presents a summary of some technological advancements in both the manufacturing and healthcare industries, and how they relate to each other.

Table 1. Summary of technological advancements in manufacturing and healthcare industries

	Pre-Industrial Revolution Era	Industrial Revolution 1.0 *(1750 to 1850)*	Industrial Revolution 2.0 *(1850 to 1904)*	Industrial Revolution 3.0 *(1904 to 1969)*	Industrial Revolution 4.0 *(1969 to present)*
Technology initiation in manufacturing	-Earliest forms of welding dates back to 3800 BCE[4]	-First circular saw machine was patented in 1777[13]	Need something here	-First Robot was used in 1954[1]	Need something here

Technology initiation in healthcare		-First successful cesarean in the US took place in 1794[9]	-First anesthesia was used in 1846[3]	-Tuberculosis vaccine was invented in 1921[8] - Penicillin was invented in 1928[10] - First successful organ to be transplanted was in 1954[11]	-First Robot was used to assist surgery in 1989[2]
Other, complementary technological initiation	-Oldest wheel discovered was from 3500BC[12]	-Michael Faraday discovered electricity in 1831[6]	-Automobile was first invented and perfected in Europe in the later 1800s[7]	-First commercial computer produced in 1950[5]	-Internet was opened for public in 1991[14]

[1](Robinson, 2014)
[2](Shah, Vyas & Vyas, 2014)
[3](Medical Milestones, 2017)
[4](The History of Welding from the Middle Ages to Modern Technology, n.d.)
[5](1950 | Timeline of Computer History | Computer History Museum, 2019)
[6](History of Electricity, 2014)
[7](Automobile History, 2010)
[8](History | World TB Day | TB | CDC, 2018)
[9](Long, 2011)
[10](Discovery and Development of Penicillin, n.d.)
[11](History, n.d.)
[12](Ancient Mesopotamia: Science, Inventions, and Technology, n.d.)
[13](History of the Circular Saw, 2019)
[14](Bryant, 2016)

Table 1 simply illustrates that both industries made advancements in parallel, but of course the true number of technologies that could be added to such a timeline is immense and difficult to amass to completion. The examples above provide a snapshot of how young the technological advancement really is in both manufacturing and healthcare. It also makes researchers and readers think about where it is heading. In this brief synopsis, it is clear that the manufacturing industry along with other industries compliment the healthcare industry, which is just starting to catch up with the technological advancements around it (e.g., 3D printed organs are starting to revolutionize healthcare) as well as within it (e.g., cures for AIDS and cancer have yet to be discovered). Trenfield et al. (2018) has explained how 3-D printing can reshape the design, production and usage of medicine from large batch processes to customized printlets with a tailored dose, that can be produced on-demand.

Technology in Healthcare and Its Role in Socioeconomic Factors of the Society
Technology is seen as a driving force behind improvements in healthcare. Just by looking at the technological advancements in the last few decades, it is hard not to agree with this statement. The University of Illinois at Chicago (UIC, 2019) lists three ways technology has changed healthcare:
- Better and more accessible treatment
- Improved care and efficiency
- Improvement in healthcare and disease control through the use of software

Most paper billing processes have been replaced by wireless systems and online platforms. People's lives are becoming better due to the fact that technology is helping patients schedule, cancel or reschedule their appointments as well as receive care when and where they need it. Society has become better and efficient through the use of technology enabled healthcare. However, society is also faced with tradeoffs in many ways due to the use of technology. For example, only in a single month, September 2019, 1.5 million patients' data was breached, as was reported to federal government. For that month, only the reported and documented data breach is known. No one

really knows how many other patients are unknowingly compromising their records (Cohen, 2019). When one goes to receive healthcare to a hospital or clinic, a patient's crucial information such as social security number, date of birth, address, etc. are asked and documented. Similar to other information technology systems, all the data has to be stored somewhere on the server(s). If someone from inside the institution or outside the institution with bad intentions wants to expose the data to 'bad' authorities, it is not difficult to do so. Despite being highly regulated and it being a criminal offense, history shows that people are doing that. Ellison (2019) lists 12 recent lawsuits in healthcare of which one of the lawsuits was related to a data breach of 7.7 million people through a medical diagnostic company dealing with lab tests. Earlier in 2019, another lawsuit was filed related to DNA sequencing. Technology is moving faster than the laws are made for such advancement in technology (Couzin-Frankel, 2019). These are only a few examples of how society is reacting to and is impacted by the technology that is advancing day and night.

Technological advancement in healthcare is definitely helping societies and people to live better lives, but at the same time there are tradeoffs to its rewards that society is reaping. For example, progress in information technologies has benefitted with rendering remote services to improve efficiency and economic convenience of healthcare systems (Botrugno, 2019). However, remote services decrease the intimacy and humanity intrinsic to face-to-face medical practice. Another example, with machine learning and artificial intelligence, researchers are able to narrow down types of diseases and individualize forms of treatment to target groups of the population. This is definitely very inspiring and has a long headway to make, but its future is bright. With the multi-billion dollars investing in technology in healthcare, that day may not be far away when technology will allow us to live forever as it is increasing life expectancy relative to that of a decade or two ago. However, ethical questions are always on the rise with technologies; such as clinical trials done on someone who is sure to die. There have been lawsuits where ethics is always a priority over technological tests and clinical trials (Saraf, 2018).

4. Conclusion and Discussion

Regardless of type and size of technological advancement in healthcare and many other changes in the last century, healthcare is a very sensitive industry because it involves human beings. Horton (2017) stated that hospital staff took pictures of patient's genitals, and care givers including physicians were suspended for using phones during their work as well as taking pictures of patient's private parts. Whether technology is involved or not, there are things that are pure black and white like should a staff really take a picture of patient's genitals? Now, having that said, could that be part of the process of providing care to the patients? The answers could be both 'yes' and 'no' depending on the situation, but can patients say no to picture taking in general? There are also cases where patients and visitors are violent while receiving care and is that ok to be violent or are they excused because they were under stress? These questions are heard day and night at the healthcare institutions. There is always something going on and sometimes it is involving technology and sometimes it is not. There are things that are black and white, and there are things that are not so much black and white. There are laws governing some technology and there are no laws covering other technological practices in healthcare.

To sum up, technology is a boon to society and it has helped society in tremendous ways culturally, economically, socially, and ethically, but it is also a curse because technology is becoming a platform for "bad minds" that is actually harming the patients. It has become easier for hackers to intrude into the systems than it was before a decade a two ago. If Apple and Google can be hacked by the hackers and if Microsoft's platforms can be compromised by the hackers, they can easily hack any systems we can think of. The biggest question is, how do we use technology to our benefit and at the same time carefully manage it in such a way that internal employees or external intruders do not misuse technology to their benefit or to harm others.

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