Mobile Applications Utilization in the Healthcare Sector

James "Wes" Rhea and Max M. North
Information Systems & Security Department, Coles College of Business
Kennesaw State University, Kennesaw GA, U.S.A.

Ronny Richardson
Management, Entrepreneurship & Hospitality Department, Coles College of Business
Kennesaw State University, Kennesaw, GA 30144, U.S.A

Sarah M. North
Computer Science Department, College of Computing and Software Engineering
Kennesaw State University, Kennesaw GA, U.S.A.

Cyril Okhio
Department of Electrical & Computer Engineering, Southern Polytechnic College of Engineering&
Engineering Technology
Kennesaw State University, Kennesaw, GA, U.S.A.

David Garofalo
Department of Physics, College of Science and Mathematics
Kennesaw State University, Kennesaw GA, U.S.A.

Yeni Golias, Glenn Koch, Alejandra Lopez, Dani Mambobo, Kameron Patel, and Daniel Watson
Undergraduate Students [eclectic majors]: Kennesaw State University, Kennesaw GA, U.S.A.

[Abstract] The purpose of this report is to explore the impact of mobile applications on the healthcare industry, focusing on four main areas: improved access to healthcare, improved patient engagement, improved patient safety, and improved business models. This report also provides information regarding the security risks associated with the use of mobile applications as they pertain to the healthcare industry. Specific engineering applications of technology in healthcare are also presented, and we include concise examination of companies and corporations who utilize mobile applications to increase their efficiency.

[Keywords] healthcare, mobile application

Introduction

With patients' costs continuously rising under the Affordable Care Act, the number of patients in primary care is rapidly decreasing. Experts argue that a change in practice law is necessary to resolve the situation. Their argument is that these changes would give registered nurses, nurse practitioners, physician assistants, and pharmacists, the opportunity to gain more knowledge by taking more relevant classes to maximize their training programs. From 2011 to 2012, the National Conference of State Legislatures deliberated 349 bills related to decreasing nurse practitioner license restrictions. Kurt Mosley says, "We train them very well and sometimes either state legislation, federal legislation, or doctors limit their ability to take care of patients" (Sederstorm, 2017). Therefore, physicians should be the primary decision makers when it comes to delegating responsibilities. Experts also believe that a shared network of healthcare professionals would benefit the patients. An example of how this would work would be specialties working together, which would allow for researchers to collect data in order to reduce medical errors and increase patient safety across the board. Communication would also be improved, creating an even safer environment.

Improving Access to Healthcare

Technology has come a long way in the past few decades. With today's new technology, it has never been easier to have health care with telehealth. Not surprisingly, there has been worldwide demand due to its convenience. The way it works is by connecting with patients outside the traditional care systems, usually the ones that don't have insurance or live in an underserved area. Telehealth also specializes in delivering telemedicine care, nurse led telephone triage, awareness, and education. Another benefit is, improving clinical workflow by allowing medical staff to take each of the patient's request or visit instantly, suggest the best treatment, and find out more information. Going back to the patients that live in underserved areas, they may not even speak English. "That is where E-health comes in to translate the doctors and nurse reports into the patient's spoken language" (Thompson, 2016). The last benefit would be by keeping in touch and providing support to the patient. To continue patient support, it is imperative to store the patient's data in a secure database and use the information to improve medical decisions. Then, move the data to subsequent providers alongside the patient's field of care, leverage the data to improve their medical care, speed delivery up, and lower costs.

The World Health Organization defines mobile health, commonly referred to as mHealth, as "medical and public health practice supported by mobile devices, such as mobile phones, patient monitoring devices, personal digital assistants, and other wireless devices" (Leavy, 2019). mHealth is considered an innovator in healthcare technology. mHealth applications have doubled from 2015-2018. Many industry authorities predict this amazing rate of increase will continue for years to come. Globally, the mHealth marketplace could reach a value of $60 billion by 2022 (2020 and beyond).

Something that is becoming very popular are shared medical appointments. Shared medical appointments or group visits are when patients are put into a group to visit the doctor. However, it is only used when the group has chronic conditions, such as diabetes or asthma, so they won't spread germs. "The Cleveland Clinic has been offering group visits since 1999 which has increased in popularity" (Sopher, 2017). This type of setup lowers the wait time for patients and encourages patients to speak to their doctor in a face-to-face visit. In most cases, the groups can work with pharmacists, which can lead to a substantial savings in medication costs.

Due to the growth in the economy, coupled with the fact that many people have multiple jobs, the extended hours of operation will help working patients that need non-traditional doctor's hours. Bigby goes on to say, "Partnering with retail clinics like CVS, and Wal-Mart for afterhours help manages a link to the main care source, source consistency in care, and reduce unnecessary trips to the emergency department" (Sederstorm, 2017). These retail clinics (or pop-up clinics) staffed with physicians can help alleviate the burden on traditional doctor's offices. Bus transportation or the use of a ride share services such as Lyft or Uber would help elderly patients, teenagers, and the homeless. This transportation option could be funded by organizations in the community, as well as local doctors and nurses.

Since many baby boomers are retiring, the next course of action would be to invest in the medical work force. "According to the U.S. Department of Health and Human Services Health Resources and Service Administration, the demand for primary care physicians is probable to overtake physician supply, leaving a projected shortage of approximately 20,400 full-time equivalent primary care practitioners by 2020" (Sederstorm, 2017). Medical school enrollment is down due to the high cost of medical school, as well as a decrease in annual compensation and a high risk of liability.

To help increase professionals in the medical field, programs such as loan forgiveness are offered. According to the National Health Service Corps, there were 8,900 ACA supported clinicians in 2013. This doubled from 2008. Similarly, contributing to health promotion programs can help increase productivity among workers while reducing costs and saving money. "The program led to significant reductions in lost work time -- equivalent to about 10.3 hours in additional productive time per year. Savings averaged about $350 per participating employee, compared to similar workers who did not contribute in the wellness program" (News wise, 2013). Another way of doing this is to dedicate time to care for employees. An example would be by celebrating employee birthdays and work anniversaries. Also, you could encourage new employees to gain more knowledge of what to do and where to go for certain services by inspiring collaboration with current employees. Last, make sure to offer flexible scheduling along with

telecommuting. These are some of the easiest ways to invest in the health of your workers.

Another option is for medical students to work at student-run clinics. This gives students experience in delivering preventive care to vulnerable patients. Though they are often located in particularly underserved areas, they are providing free, easily accessible health care. Even with this opportunity for patients in need, student-run clinics are limited in the ways they can provide for their patients. An example would be students could help those with chronic diseases like high blood pressure or diabetes. Still, they are unable to provide more complex care that patients may need, such as performing surgeries or MRI scans.

The last topic would be for ways to assist underserved communities that have challenges accessing health care services. An urgent care center would allow for treatment without having to go to a hospital. Second, building a rural hospital health clinic. "By combining the care with rural hospitals and numerous health centers in the community to facilitate integration of primary, behavioral and oral health, and allow for economies of scale between those institutions" (Stempniak, 2016). Last, review the needs in rural areas for Native American health services to improve the quality of care.

Mobile health technology would enable services to be extended to areas that are underserved or have limited healthcare resources and professionals. "The ubiquity of smartphones and internet connectivity across the United States means there is an opportunity to improve health outcomes among those who live in remote regions with little access to medical information or care. The implementation of mHealth programs could provide a low-cost means of supporting a diverse range of healthcare functions in these regions" (Leavy, 2019).

Improving Patient Engagement

As technology evolves, society does, as well. Technology plays a huge role in society, whether it's in school, home, or industry. The healthcare industry has increased in both medical and technological advancements. Healthcare related resources have increased primarily due to the availability of healthcare-related information on the internet. Healthcare technology is massive, and ranges from health assessments to patient engagement. "As more technology developers focus on improving interoperability throughout the healthcare industry, medical providers are aligning their resources to better engage patients with their medical needs" (Gruessner, 2016).

Patient engagement has increasingly improved. Now, patients can use mobile apps to communicate with their doctors. Dr. Wayne Guerra, co-founder of iTriage, states that, "the patient's need for healthcare and medical information happens outside of the provider's office. What's more, patients increasingly want to be more involved in their healthcare and medical decisions, with greater access to information. And that's a good thing. Mobile healthcare applications can quickly provide information directly to the patient that's timely and relevant, and at their time of need. They are empowered to make better decisions about their symptoms, their condition, about procedures and tests…they provide decision support, access to the healthcare system, and some apps help an individual communicate with their doctor" (Gandolf, 2014). The healthcare industry is concentrated on improving the care for patients, as well as health related outcomes, by encouraging more patient engagement. Also, developing new technologies to trace medical conditions, decrease medical errors, and, hopefully, avert the more serious or potentially, life-threatening conditions. Mobile health applications and devices will play a huge role for increasing patient engagement across the healthcare continuum.

Another segment that mobile health can encourage engagement is in patient safety. "Protecting patients is an imperative goal of the FDA and federal agencies that regulate the healthcare industry. As the mobile health field continues to innovate new devices and applications, the federal regulatory associations including the FDA will likely only practice strong regulatory oversight on products that impact patient safety" (Gruessner, 2015). "Mobile technology is gradually being introduced in the field of health care, by allowing communication (effective, asynchronous, etc.), making reference material or information more accessible, acquiring critical thinking skills and even improving patient safety" (Casselman, et al., 2017; Roberts & Williams, 2017; Mira et al., 2016; O'Connor and Andrews, 2015; Pucer et al., 2014; Lee Ventola, 2014). For example, "SAMA (Safety Agenda Mobile App) is an iOS app for health managers that which would help them to manage interventions in relation to patient safety matters. SAMA includes a set of 37

predefined tasks that are the responsibility of health managers" (Mira et al., 2016). Also, another iOS application for healthcare professionals is PatientTouch, created by PatientSafe Solutions. Positive patient identification is a feature of the application that utilizes barcode verification. This lets users communicate with the network of healthcare professionals that can then carry and edit patient records at the patient's bedside.

When addressing the benefits of healthcare mobile applications, it's important to understand the positive course of why healthcare mobile apps are essential for patient engagement. For the patients, the outcomes are more detailed, individualized, and with the recent outbreak of the coronavirus it will make for a safer process. Patients can order prescriptions, verify test results, and have discussions with doctors. Also, patients can be remotely monitored, manage medical devices, and perform other healthcare related tasks from their smart phone, laptop, or tablet. According to Team Intrust, "As far as healthcare organizations, they can improve their bottom line of operating costs by the reduced costs of service delivery provided by the app. Just in the United States, preventative healthcare apps for diabetes, asthma care, cardiac rehabilitation, and pulmonary rehabilitation are estimated to save $7 billion a year in hospital admissions" (Team Intrust, et al., 2020).

Steinhubl et al. indicate "there are between 30,000 to more than 90,000 health care-related apps available for download" (Steinhubl et al, 2013). Now, patients have everything they need at their palm of their hand and have access to all their records faster than before. There are many resources and many companies that have increased technology in a way in which they can communicate with their patients faster than ever before. One great example is Kaiser Permanente. Kaiser uses mobile or web-based technology to help care for patients. You can create an account in which you have all your medical documents and doctors in your portal. You can access it anytime and anywhere. With the web-based portal, you can schedule appointments as well as view any lab results from your most recent visit with your doctor. With the increased use of mobile phones, Kaiser also has a mobile app. This is a great option for the patients that do not have access to the web portal. As Kaiser Permanente states, "You can view and cancel appointments easily, view prescription list, then order refills or check the status of an order, send messages to your doctor or Member Services" (Permanente, Kaiser). This allows for doctors to communicate with their patients easier. Although, this technology has allowed for more conveniences it still has its challenges, as well as advantages and disadvantages. A web portal and an app are two different things. One requires more research than the other. A web portal requires you to click and type more than an app making it a little harder to navigate. Applications are meant to make your life easier in many ways. Apps are designed to have fewer buttons and fewer navigation options while making it easier to get to your destination.

There are many ways in which the healthcare industry could help improve the mobile app industry. Rather than having web portals that make navigation hard, it may be more beneficial while increasing engagement to have an application that would make it easier to navigate. For example, if you want to schedule an appointment or view a lab result, you should be able to press a button and follow the prompts. This would make it easier for a patient to navigate or view lab results. Other ways to improve would be to include adding medication schedules and alerts. There could also be improvements, such as having doctors assign diets according to their patient's needs and conditions. Many times, there are unnecessary visits to the doctor's office; having rapid treatment on an app could help reduce health care costs. Live video would be a great improvement and would save the patient from having to go to the doctor's office for a minor illness. This could also eliminate unnecessary emergency room visits while still having access to a doctor. A check-in feature on the app would allow you to check in on your phone instead of having to wait in line for an available staff member.

Healthcare costs are rising; however, switching to mobile applications could help minimize the cost. Kern informs "The data demonstrates there is a potential savings of more than $23 billion through mobile apps by targeting patients with chronic diseases, bringing $2,000-3,000 per year in savings per patient" (Kern, 2014). As indicated earlier, they are thousands of mobile apps, but only some of the apps have been tested by the FDA. The mHealth apps that do not offer any medical advice are mainly the ones that have not been tested in clinical trials.

There are mHealth apps that are free, and for a fee. Free mobile apps have a risk of sharing personal

information with advertisers. Paid apps also have a similar problem of lacking data security that may lead to hackers trying to steal personal data. However, all this fear can change because the FDA will be increasing regulations on mobile health apps. iTriage is a mHealth app that is an example of patient engagement. This app provides multiple services. iTriage provides symptom checker, compares facilities visit cost, facilities hours, and wait times. Kern notifies "the potential cost savings of this app: $300 to $3000 per visit" (Kern, 2014). While patient engagement increases, so does the patient financial responsibility. Also, mHealth apps also have made it easier to manage their payment. More than half of patients now use mobile payment systems, mainly because they are convenient to use. A disadvantage about this is that patients must take responsibility and remember to pay on time so they can avoid paying extra fees. The healthcare industry can save billions of dollars by using mobile health apps. As more patients use mobile payment services, such as Paypal, Venmo, and Apple Pay, reducing paper communications will become a huge opportunity for savings. Healthcare providers could only send mail via the United States Postal Service ("USPS") to patients that are not using mobile apps or have opted out of email communications.

In conclusion, there are many options because of mHealth apps that are beneficial to patients and doctors that offer time savings and ease of use. Ricciardi1 et al. states that "In a recent national study, 72 percent of physicians reported that they had adopted some type of electronic health record system. Also, the percentage of hospitals with such systems more than doubled from 16 percent in 2009 to 35 percent in 2011" (2013) The healthcare industry will need to continue to advance the use of technology, so that the industry can improve patient engagement as its progresses.

Effects of Mobile Application Integration

The healthcare industry is a crucial part of society. Providing over 13 million jobs, healthcare is the country's largest industry. People are continuing to live longer, creating higher demand and strain on the specialist that work in the healthcare system. The demand for healthcare workers is expected to grow faster than the average rate for all occupations. This demand can be combatted by allowing the industry to have a tool to allow the current workers to handle more than what is possible while at the same time balancing their workload.

Through the process of integrating mobile applications to our healthcare system, it allows the whole industry to run smoother, save money, and stay organized as it continues to grow in the years to come. There have been many successful integrations of mobile applications into hospitals while the industry continues to become more digital. Whether the hospital is offering diagnostic, healing, rehabilitation, or preventive care services there will be continued opportunity for mobile applications (Leavy, 2019).

Patient safety is a key result of utilizing technology and mobile applications in the healthcare industry. One way in which technology and mobile applications improve patient safety is by removing an element of the human error that often results in patient harm. Whether the task at hand is assigning prescriptions to an individual at a pharmacy or if someone is getting spinal surgery, the amount of help that technology has to offer in this spectrum is unmatched by any other tool that could possibly be implemented in the healthcare industry. If a doctor were to accidentally prescribe a prescription in error, it could potentially be a fatal mistake.

Mobile applications can enhance and assist the healthcare industry by improving patient care experience, cost effective care, and operational effectiveness (Leavy, 2019). The improvement of the patient care experience is accomplished by allowing patients in underserved areas to access healthcare without having to travel long distances, especially if a patient is recuperating. Also, mobile applications allow patients to exchange information with a doctor or specialist in a timely manner. Mobile applications provide real-time management of critically ill patients by remotely locating a doctor or specialist while improving access to care.

Mobile applications in the healthcare industry provide more safety to their patients with financial security by providing cost-effective care by scaling resources and expertise with remote face-to-face conferencing on consultations with doctors or specialists. It also allows patients who have limited access to healthcare to reach the experts they need. Through the integration of mobile applications, it enhances physician efficiency by limiting the time between tasks. With these applications, doctors or specialists will

be more efficient than without the help of mobile applications. The mobile application in the healthcare industry will drive operational effectiveness. It accomplishes this by improving the collaboration between doctor and specialists via remote communication. This allows them to share ideas and information without having a formal meeting. By utilizing video conferencing, the distance barrier for formal meetings is removed.

Modern Business Models Integrating Mobile Applications

Affordable healthcare has been a hot topic in the United States for many years. With rising costs across the board from doctor visits to dental care, it appears that healthcare costs will continue to increase unless measures are taken to bring it under control. As the demand to control the cost of doctor visits and prescription drugs is on the rise, the elderly continue to witness the rising cost of their medications. In some cases, they are having to get separate policies just to cover their current prescribed medications. Citizens have begun to look to their elected officials for help. They are looking for relief in the form of price cuts or subsidies, anything to help offset the extreme prices.

With each election cycle comes a new champion for healthcare and the healthcare industry. Promises are made, strategies outlined, and plans put into place; at least, that is what was being propagated to the American people. However, these grandiose plans have been nothing more than elaborate sales tactics made by some politicians to get elected. They had grand excuses as to why they were not able to perform the duties that they had promised, but they were just excuses. It seems to be a hopeless battle with no end in sight. It appears that this would just be an issue that people across the country would have to live with.

The Patient Protection and Affordable Care Act, also known as the Affordable Care Act, was signed into law on March 23, 2010. This is by no means the savior of the healthcare industry. There are still costs that are far out of control and many of the promises made concerning the implementation of this new law have caused many families and business owners to incur costs that they were assured would not be passed on. And still, the public searches, looking for hope that costs will somehow be brought under control.

If there is a silver lining to be found in all this chaos it could be found in the business sector. Some have said that putting healthcare in the private sector would help keep prices in check while making sure that quality is also kept at a level above the normal standard. In 2013, this theory was put to a challenge. Michel Nischan made the statement, "health care systems often treat patients as numbers instead of as people who would live better with the right resources" (Apothecary, 2016). A group of entrepreneurs, philanthropists, and many others were given the challenge to make healthcare not only a more viable option, but a more affordable option as well.

Companies Utilizing Mobile Applications [Selected]

MeraDoctor, an India based company, utilizes technology, specifically telephones, to contact and diagnose patients across India. These specialists directly target families in low-income areas that would normally not have access to medical facilities. Their physicians undergo a strenuous training program to help them diagnose different ailments over the phone. This service is available twenty-four hours a day, seven days a week. Once a diagnosis is made, the patient is put in touch with a local facility to be seen by a medical professional or to pick up any needed medications. When medications are needed, the doctor on the phone can simply send the prescription by SMS to the specialist that will be working with the patient. If a patient calls and the doctor happens to miss the call, it automatically gets transferred to the next available doctor. MeraDoctor offers this service for a membership fee of less than five cents a day. If, for some reason, things do not go as advertised, then the patient is refunded for the service. (Apothecary, 2016)

Access Afya, a US based company, working in the low-income areas of Kenya, has found a way to reduce clinic visits while staying in touch with the patients on a personal level. The company has developed health kiosks or "mini-clinics" in poverty-stricken areas. The interesting point about these areas is that most of the patients own cell phones. The nurses that operate these kiosks use cell phone technology to keep in contact with the patients, update medical records and files, and prescribe medications. Their motto is, "We bring care directly to the doorsteps of the people that need is most." This approach appears to be working well; to date they have helped more than five hundred patients (Apothecary, 2016).

Another India based company, Healthpoint Services, has found a way to use a clean water initiative to help fund their idea for affordable healthcare. The company is out to provide clean drinking water to rural villages in India. By doing this, the company has also been able to provide medications through local licensed pharmacies, as well. It has also been able to add eighty comprehensive diagnostic tools and access to qualified medical professionals. Because of their business model, Healthpoint Services has been able to offer many other services, as well, ranging from vaccinations to eye care, and management for diabetes and many other chronic diseases (Apothecary, 2016).

Heal, a telehealth and doctor house calls company that seeks to deliver a reduced-cost option to hospitals and urgent care centers, utilizes a mobile application to provide telemedicine treatment via a one-touch platform with the choice of using a web browser or the Heal mobile application. The Heal platform will send the patient a text message with their appointment link. The advantage in using the Heal application is that anyone involved in the individual's care, from family members to pharmacists to any type of specialist, can enter the session. This should result in better engagement, as well as a continuum of care for the patient and more efficiencies for the healthcare professionals involved in the treatment of the patient.

Ortholive, the world's leading orthopedic virtual care platform, provides convenient, secure entrance to patient care while increasing proficiency and returns, as well as user satisfaction without an expensive or challenging learning curve to use the application. Ortholive's focus is to simplify orthopedic care so doctors and employers can treat patients quickly, safely, and, effectively. According to Ortholive, treating injuries at the workplace using telemedicine can save up to 80% of on-the-job-related costs for injuries. For employers, the application can help employees get back to work faster, improve morale, and reduce Occupational Safety and Health Administration (OSHA) events that need to be recorded. For doctor practices, the application can help efficiency, increase practice revenue, and improve overall patient satisfaction. Ortholive promotes convenient and secure access to sensitive patient information. Other features include the Health Insurance Portability and Accountability Act of 1996 ("HIPAA") compliance, virtual appointments, integrated scheduling, and secure messaging.

Here in the US, the nonprofit organization, Sarrell Dental, has found a way to bring much needed dental and eye care to children in underserved areas. However, the organization has struggled to keep the clinic doors open. The company tried two days a week until they finally decided to give up. In 2005, a retired businessman and former CEO stepped in and helped the group re-structure and re-organize. Since that time, they have expanded to fourteen clinics, several of which offer optical services. A mobile dental bus is another service the company has been able to offer. This service reaches out to areas in rural Alabama and has an estimated impact of more than sixty percent of children that do not normally have access to such services (Apothecary, 2016).

These are only a few of the many stories of local business stepping in to help with an industry that is struggling and having a very difficult time keeping up with the demand that is facing them. So, is privatized healthcare the path to success? Maybe, maybe not. The path that is currently in place has its limitations and challenges. If these stories and the many others like them are indicative of what can be done when ambitious entrepreneurs get involved, then maybe it is worth taking notice. Maybe, they can "offer the right resources" (Apothecary, 2016).

Security Risks Associated with Mobile Applications

Mobile applications are playing a vital role in the healthcare industry. Doctors utilize medical apps that monitor heart rate, oscillation, the oxygen level in blood vessels, and blood pressure. It is essential that these apps function properly, particularly in an event that shows a change in the patient's data that could signal a potential health issue. Apps used in the healthcare industry must meet FDA requirements. According to Daniela Hernandez, many medical specialists have been reluctant to adopt the notion of patient-generated data notably because many are doubtful of the information.

Apps that require private network settings might be liable for security breaches. Dr. Eric Topol, a cardiologist at the Scripps Clinic in San Diego, stated that patients are showing concern with internet-based systems because of the personal information that could be hacked, whether intentionally or not. Also, clues indicating the intransigence against patient-generated data systems is collapsing because the healthcare

institutions are shifting their focus toward web-based solutions that will implement effective results and save money. Practice Fusion is collaborating with the software industry to find better ways to keep patient information safe from hackers.

"A recent study conducted by the University of Piraeus published in the *Institute of Electrical and Electronics Engineering Access Journal* (29 January 2018) indicates that many popular mobile health apps fall down when it comes to adequate privacy and cyber security protections. Many of these apps do not follow standard practices or do not comply with the impending General Data Protection Regulation (GDPR). Consequently, the privacy risk to millions of healthcare consumers and related healthcare institutions is significant." (Hoyme, 2018)

AliveCor, Inc., a producer of heart monitors for smartphones, and Diasend, an online diabetes management system, want to improve their security firewalls to prevent intruders from hacking into patients' personal accounts. When patients agree to share information, the information gathered will appear instantly on the Practice Fusion medical records. This organization is developing more devices that help consumers stay updated with their health status. This implementation is going to help doctors and hospitals stay current with their patients and notify them of treatments. Hence, the company will require FDA clearance for medical use because they provide diagnostic services.

With the increased use of mobile applications, privacy advocates are growing in the healthcare industry. The federal privacy law does not apply to the increasing quantity of data generated by many health consumer apps and devices, making it easy for advertising companies to access health data to target patients. A company such as Practice Fusion must adhere to federal regulations that govern patient-to- doctor confidentiality under the Health Insurance Portability and Accountability Act ("HIPAA"). Any unapproved gathering or loss of patient data could cause the firm to be deprived of its credibility. The privacy question with the most concern is among patients on who can have permission to inspect their medical data, and to whom should medical information be revealed without the patient's consent? The main concern is that personal information or healthcare information could be linked to financial records, potentially causing financial or reputational harm to an individual. Furthermore, insurance and electronic medical record companies are spending more and joining with tech organizations, such as RedBrick Health and Audax Health, to create health tracking mechanisms that inspire users to stay active daily and sync their results to their platforms.

Providing new ways to keep personal medical records safe will help the healthcare industry prosper because it will allow for more convenience for patients and doctors to stay updated with current medical information. "With greater volumes of patient data on mobile devices, there is greater responsibility on healthcare professionals to keep these devices very safe. If a device gets lost or stolen, very sensitive patient data could find its way into the wrong hands" (Leavy, 2019).

Blockchain technology is increasing in popularity in the healthcare sector, especially in mobile applications. Blockchain technology has been a huge success in cryptocurrency. Blockchain utilizes a peer-to-peer database to save authenticate healthcare records for all transactions. Blockchain technology stores patient records in a secure and encrypted format that gives a potential higher level of protection over the more traditional encryption methods such as the Advance Encryption Standard ("AES") that is 256 bit.

Security and privacy issues are the primary concern for many advocates, but mobile applications are making it simpler for people to stay current with their health status and maintain a healthy living lifestyle. Employing advanced security protections such as blockchain technology to mitigate privacy and security risks with healthcare mobile applications will encourage people to utilize mobile applications while increasing user engagement.

Engineering Aspects of Applications of Technology in Healthcare

The burgeoning value of technology applications in healthcare cannot be underestimated. While there are incredible technology applications in healthcare, a specific disease management application, for example, focuses on lymphedema.

Lymphedema is the build-up of lymph fluids within the soft body tissues within the body's lymphatic system (Suarez, Huaroto, Reymundo, Holland, Walsh, & Vela, 2018). The lymph system is the network of

vessels, tissues, and organs that carries lymph fluids to aid in fighting infections throughout the body. This chronic disease is characterized in two ways: primary, which is affected by abnormal development, and secondary, which is caused by directing trauma, such as infection, cancer growth, radiation, or removal surgery. Swelling is also classified into four categories (Zhao, Liu & Guan, 2019).

Swelling can cause discomfort and undesirable deformities to the limbs, as lymphedema can occur in any part of the human body. Treatment commonly consists of manual lymphatic drainage (MLD) to promote lymphatic fluid movement from light massage techniques. However, while MLD has proven successful, the World Health Organization (WHO) estimates approximately 300 million cases of lymphedema worldwide, of which there exists an insufficient number of therapists and accessibility for this extensive cohort of patients (Horvat, 2012). Another promising method is intermittent pneumatic compression (IPC), which mechanizes the drainage of lymph nodes through a pneumatic compressive sleeve.

Lymphedema pump devices work by using the pneumatic compression in a limb cuff to force the fluid away from the swollen area. These pumps are not fully effective because patients may experience pain and discomfort from the pump treatment because of the compression level and the severity of swollen lymph nodes. Others may have continuous high blood pressure, which may affect the compression treatment as lymph fluid could flow into the bloodstream. This side effect often causes blood pressure changes that could be undesirable and harmful to the patient. Last and most important for the article, available data suggests that user compliance of this mobile technology is a factor in determining the effectiveness of the device. Users may give inaccurate feedback or inconsistently follow through with regulated treatments, causing unreliable data readings for effectiveness.

By implementing remote and accessible sensors to read analog data and blood pressure, compression cuffs can be monitored and regulated for user comfort and vital sign detection. Using the data, treatment can be taken safely. Treatment results can then be further analyzed through a network system that is remotely accessible to users, health care providers, caretakers, or other medical personnel for review. The authors of "Development of a Soft Pneumatic Actuator System Based on Flexible Force Sensor for Lower Limb Compression Therapy" proposed a soft pneumatic-polymer-based actuator (SPFPA) is supposed to mimic manual lymphatic drainage. The actuator performs two simultaneous movements that exert compression and lateral tractional force (Qiu, Zhang, & Liu, 2016). It comprises two materials, a fabric-based element and a soft hyperplastic compliant element attached by silicone rubber. As air is pumped into the fabric element, the actuator starts unfolding to find its original curved shape. When the air is removed, the fabric element folds back by the action of the soft hyperplastic compliant element, which leaves the SPFPA to recover its initial position. The SPFPA is intended to work in contact with the skin by having several actuators in series on a split to be personalized and easy to wear. Overall, this study offers alternative methods for treating lymphedema with medical devices.

In a pioneering article, "Development of an Intelligent Digital Monitoring and Biofeedback System for Intermittent Pneumatic Compression Therapy Device," the authors focus on developing a newly designed intelligent digital monitoring and biofeedback system. Existing intermittent pneumatic compression devices only involve control or an analog input system, incapable of timely monitoring and obtaining real-time feedback of pressure dosages delivered to the human body. This study was unable to visualize pressure variations with inflation time (Berger, 2001). This new design allows the senior design of a lymphedema device to have a base structure on how to implement a better monitoring and biofeedback system. To have a successful system, four major units are required: an input unit (limb and IPC device), a monitoring unit (sensors), a data acquisition unit, and an output unit (display or APP). This would allow physicians or end-users to timely learn the pressure magnitudes and variations in the proactive compression treatment, and to obtain timely biofeedback on dynamics of pressure delivery to the limbs. Altogether, this improves the efficacy of this technology in the treatment of adverse blood circulation disorders.

When it comes to medical compression devices, there are two cuff types that can be used, which are the single chamber or sequential chamber cuffs, as seen in the patent "Sequential Lymphedema Pump." The single chamber is the most common, but for this lymphedema pump application, a sequential cuff can be effective in several ways. One possible idea is for variable chamber compressions (Olszewski & Waldemar, 2014). Not all patients have the same lymphedema condition as the shape, affected area, and degree of

swelling varies (Olszewski & Waldemar, 2014). Having a sequential cuff allows more control on comfort levels for personalization. Patients would be able to adjust the compression in each chamber for their comfort and to aid in swelling reduction. Another benefit to sequential pumps is the capability to direct the fluid flow for drainage. It is possible that the compression force can determine where the fluid will exit the lymphatic system.

The research article "Control Strategies for Intelligent Adjustment of Pressure in Intermittent Pneumatic Compression Systems" concentrated on design algorithms to control cuff pressures in real time. Patients of deep vein thrombosis (DVT) must lay in bed facing upward for extended periods of time (Kuo, Wu, Chou, Chen, & Kuo, 2017). Like lymphedema patients, those afflicted with DVT benefit from the usage of intermittent pneumatic compression treatment. Three methods were compared and tested to control the pump's speed to adjust the pressure. The first was proportional integration differentiation, which needed two cycles to reach stability but required the most time of calibration with maximum variance with the poorest stability. The second was the ideal gas law, which required two cycles to reach stability and was the easiest to realize, as all calculation processes could run automatically. The last approach was the look-up table, which took three cycles to reach stability and had the lowest efficiency. From this research, using the calculations from the ideal gas law would be best suited for potential real-time control of the pneumatic cuff pressure because of its accuracy and stability.

Abi Berger explains how blood pressure is measured, the instruments utilized, and the logic behind it in the article, "Oscillatory Blood Pressure Monitoring Devices." Oscillatory devices produce a digital readout and work on the principle that blood flowing through an artery between systolic and diastolic pressures causes vibrations in the arterial wall, which can be detected and transduced into electrical signals (Berger, 2001). Modern technology used today to measure blood pressure is called "fuzzy logic," which inflates the blood pressure to 20 mmHg about any individual's systolic pressure. The bladders within the upper arm cuffs must encircle 80% of the arm's circumference. The cuff used will inflate to this pressure and no blood flow will occur in the individual's artery. After the cuff starts deflating, the blood pressure will drop down below the systolic level. This process causes blood flow through the artery to not have any vibrations in the arterial wall. Vibrations can occur at any point where the cuff pressure is high. The vibrations are then transferred from the arterial wall, which travel through the air inside the cuff, into a monitor's transducer. These vibrations, at the end, convert the measurements into electrical signals. This article will help guide the lymphedema device project in understanding how blood pressure is being measured with oscillatory devices and the logic needed for application.

To validate the daily high pressure requires a long inflation time intermittent pneumatic treatment, "The Effectiveness of Intermittent Pneumatic Compression in Long-Term Therapy of Lymphedema of Lower Limbs" reports the effects from a three-year treatment of lymphedema patients. The effectiveness was measured in terms of decrease of limb circumference and volume, tissue elasticity, histological changes, and incidental complications. Intermittent pneumatic compression takes over permanently missing function of obliterated lymphatics by squeezing edema tissue fluid to the regions with normal lymphatic drainage (Patents.google.com, 2020). The highest flow of 220-120 mL/1 hr. cycle was obtained with compression pressures between 80-120 mmHg with inflation timing of six to seven minutes. The results were permanent decrease of limb circumference and increased, or at least, maintained elasticity of tissues. From this publication, a pressure of 100-120 mmHg applied at 50 seconds intervals for a total of 400 seconds with a sequential inflation may be best used in creation of a lymphedema compression sleeve.

In the article "Development of a Blood Pressure Measurement Instrument with Active Cuff Pressure Control Schemes," the author details an oscillo-metric blood pressure (BP) approach based on the cuff pressure (Kuo, Wu, Chou, Chen, & Kuo, 2017). A variable volume chamber was utilized to alter the cuff pressure actively and stably during the inflating and deflating cycles. The control system used in this research was a closed-loop pressure control system. The system was then activated by controlling the piston position of a single-acting cylinder. A screw motor drove this cylinder. Consequently, the variable volume chamber could significantly eliminate the air turbulence disturbance during the air injection stage compared to an air pump mechanism (Brennan & Miller, 1998). The oscillo-metric method is the most common approach that is being used to measure BP. This approach requires no professional skills; this is the most

crucial fact in this article, since people with no background or knowledge in the medical field can operate this blood pressure instrument. This increases patient confidence in the usage and enables patients to use it more accurately with minimal usage error. This will enable BP to be monitored daily and make long-term measurements for patients with lymphedema.

Medical personnel and manufacturers have trouble with validating the effectiveness of lymphedema pump devices. User compliance is a factor in determining the usage and effectiveness of these devices. In "User Friendly Lymphedema Pump," user compliance is discussed to find whether the devices are user friendly, economically advantageous, and effective for reducing swelling. Data can potentially demonstrate insight as to whether the patient experiences pain during treatment and if the treatment really works. The disadvantages of user compliance are patients not complying with treatment schedules, procrastination, and discouragement from treatment pain (Nguyen, Mirza, Naeem, & Nguyen, 2017). These reasons lead to inconsistent and unreliable data.

A recent article, "Overview of Treatment Options and Review of The Current Role and Use of Compression Garments, Intermittent Pumps, and Exercise in the Management of Lymphedema" discusses the compression pathway for lymphedema pumps. Determining the type and number of motor pumps needed for a lymphedema device depends on the type of cuff in usage (Okui, Nagura, Yamada, & Nakamura, 2018). Using a single chambered cuff allows the design to use on motor pump. A sequential cuff will either need one or multiple motor pumps. The idea of using one motor pump for a sequential cuff compression can be cost effective, but the timing it takes to compress is longer due to the pressure build-up needed for each chamber (Pecht, (1991). Utilizing a motor pump for each sequential chamber can greatly reduce the timing needed for compression and treatment.

In "A Review on IoT Healthcare Monitoring Applications and a Vision for Transforming Sensor Data into Real-time Clinical Feedback," the author investigated the use of internet of things (IoT) based on applications in the medical field. A proposal was written of an IoT tiered architecture (IoTTA) towards an approach for transforming sensor data into real-time clinical feedback (Vasava & Deshpande, 2016). The internet of things can be implemented in the lymphedema device by integrating wireless communication, sensor networks, data processing, and cloud computing. Remote healthcare monitoring systems based on IoT technology have tremendous potential. They can decrease pressure on hospital systems and healthcare providers, increase effective self-care, and potentially reduce healthcare costs.

The article "Hybrid Pneumatic Source Based on Evaluation of Air Compression Methods for Portability" proposes hybrid pneumatic power sources to optimize portability. Comparisons of six different compressed gas generation methods were evaluated as follows: battery-driven small compressor, air tank, the chemical reaction mixture of citric acid and sodium bicarbonate, sublimation of dry ice, liquid-gas phase change of liquid carbon dioxide, the gas-liquid phase change of dimethyl ether. The portability of each was determined by maximum supplied pressure (MPa), flow density (NL/g), a mass of additional systems (g), and flow density considering a vessel {NL/g} (Degada & Savani, 2015). There was no best method, as each had its advantage and disadvantage. Using a lithium-ion battery as a power source to produce compressed air generated by driving a motor seems the most feasible for a pneumatic compression sleeve within the study. This method is generally stable; however, the energy efficiency is low when it generates high pressure.

The design for the structure of the device is taken into consideration when designing it for durability. "Handbook of Electronic Package Design" details the electronic packaging design strategies and process used for electronic packaging. Electronic devices are built to have durable casings to protect the electrical components (Johnson, Smith, Smith, Kight, & Harrop, 2003). To build a structurally sound lymphedema device, the device must be able to withstand daily activity and portability. Not only is structural integrity needed, but thermal regulation is a must for electrical functionality (Johnson, Smith, Smith, Kight, & Harrop, 2003). Building a device based on thermal regulation can determine the compactness of the device. When incorporating physical design features, including buttons, screens, and handles, structure and usability must be determined in the design.

The blood pressure monitor should be able to travel with the patient. This device will make it manageable for appointments and an everyday lifestyle for patients with lymphedema. The article "Design and implementation of low cost, portable telemedicine system: An embedded technology and ICT

approach," explains the importance of a portable health monitoring device (Degada & Savani, 2015). There have been many advancements with technologies and circuits becoming smaller and denser. This is possible due to the integration of analog components on a chip itself. Furthermore, the large amount of general-purpose input/output (GPIO) makes sensor interfacing easier. The inbuilt Debian is almost a full-fledged OS having a complete wiring library for direct terminal access, sophisticated compiler collection (GCC) which makes building, installing, and running of any module easier and a full network stack, which allows programmers to exploit any kind of connectivity desired in the form of wired (Ethernet, SPI, etc.) or wireless protocols (Degada & Savani, 2015). There is a built-in flash that will allow the portability of such a device.

The built-in flash makes the communication between the BeagleBlack micro-controller secure and fast. A Wi-Fi module was used as the primary communication source.

Amit Degada and Vijay Savani cover the design and implementation of a portable telemedicine system using embedded technology in "Design and Implementation of Low Cost, Portable Telemedicine System: An Embedded Technology and ICT Approach." This benefit provides the advantages of being low cost and low weight. The use of embedded technology makes for easy design and implementation of biomedical sensors and storage with ease of access to the central patient clinical database (Degada & Savani, 2015). Its purpose is to extend monitoring of patients through their body temperature, blood pressure, glucose level measurement, low-cost ECG monitoring, and possible remote consultation. The design between the hardware and software can be implemented for the lymphedema pump device to optimize patient compliance and caretaker monitoring. For this design, a TI-Beagle Bone Black serves as the computing unit with attached sensors. The software environment is configured on Ubuntu OS with a dynamic database is created in MYSQL. Apache is a web server application, and the webpages are designed in PHP. The system permits building computer-based patient records that provide easy and fast access to large databases and will yield diagnostic links from doctor to patient.

The article "Smart Remote Monitoring System and Method" discusses a remote monitoring system that includes transducers, a transducer control module, a communications device, a monitoring system, and an end-user display terminal. The monitoring system receives, stores, and analyzes information received from the transducer control module. Furthermore, it reports the information to the end-user terminals via a wide area network, such as the Internet, in response to user requests (Johnson, Smith, Smith, Kight, & Harrop, 2003). For the lymphedema device, there are advantages of using pressure sensors as the transducer of choice. While pressure transducers are high-level output signals, pressure sensors are low output signals as millivolts. The millivolt output signals can typically be used up to twenty feet away from the electronic device without a significant signal loss and can reduce the package size and costs.

Conclusion

As the world continues to modernize, so too will the technology that shapes the healthcare industry. Organizations such as RedBrick Health and Audax Health are incorporating mobile applications to ensure their consumers receive the best possible healthcare experience, while companies such as Access Afya and Healthpoint Services utilize mobile applications to help the underserved areas so they can receive proper healthcare attention. While there are security risks that may occur due to the utilization of mobile applications, companies such as Diasend are actively conducting research and experimentation in order to create the safest and most efficient business model possible to protect patient data. While the mobilization of healthcare is new, it is the future, and it will be the companies that begin utilizing mobile applications today that will drive the healthcare industry of the future.

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