



Leveraging Telemedicine to Improve Healthcare Access in Sierra Leone

By Josephine A. Samura

Abstract

This paper aims to answer the question of how telemedicine can be used to expand healthcare access in Sierra Leone. The research was conducted utilizing literature review methodology with 22 publications pertaining to the topic of telemedicine in general as well as various projects implemented in developing nations, particularly those in Africa and Sierra Leone. The study showed that telemedicine is effective in expanding healthcare to underserved and hard to reach populations while providing outcomes comparable to those of the traditional face to face model. However, the number of such projects implemented in Africa is rather small, which is the main limitation of this study. Additionally, the available body of research is inconclusive when it comes to the long-term sustainability of telemedicine initiatives without significant financial and technical support from external stakeholders. Answering this question will ultimately decide how to best leverage various telemedicine technologies in order to achieve the goal of making healthcare accessible to everyone.

Introduction

Lack of access to healthcare, as a result of poor infrastructure or economic factors, is a major problem facing many developing nations. It is especially acute among rural populations that are more likely to struggle with poverty and have no nearby medical facilities. Poor healthcare infrastructure was found to be responsible for 15.6 million excess deaths in low- and middle-income countries with 3.6 million deaths directly attributed to lack of healthcare (Kruk et al., 2018). Lack of healthcare also leads to poor health outcomes and decreases productivity thereby creating a drag on the economy while exacerbating the problem of endemic poverty within the country. According to Christophe Paquet, who serves as the head of the French Development Agency, the healthcare sector is “...drastically underfunded in the least developed countries...” with majority of these nations “...unable to provide basic healthcare to the public”. (“The Big Challenge is to Improve Poor Countries’ Health Care Systems” – Christophe Paquet,

2019). Mr. Paquet also does not see the situation improving since many of these governments are increasing public security spending at the expense of the healthcare sector.

This paper will focus on Sierra Leone, a country located in Sub-Saharan Africa, which happens to be the poorest region in the world. Sierra Leone ranked last among 179 nations according to the 2008 overall Human Development Index with 47.7 percent of the population living on less than \$1.25 per day (Trani, 2011). The country has struggled with political and economic stability since gaining independence in 1962 despite being blessed with abundant resources like diamonds and rare earth metals. The period between 1991 and 2002 was particularly traumatic with the country undergoing a civil war leading to widespread suffering and the decimation of the already weak healthcare system. Today, Sierra Leone has some of the poorest healthcare indicators in the world with life expectancy of a mere 39 years for men and 42 years for women, maternal mortality rate reaches 2,000/100,000 and an estimated 282 per thousand children die before their 5th birthday, mostly due to malnutrition, acute respiratory infections, diarrheal diseases, typhoid fever, HIV/AIDS, and tuberculosis (Trani, 2011).

Problem Description and Scope

Due to its weak healthcare infrastructure, Sierra Leone has faced numerous challenges related to healthcare access. Hospitals and clinics are scarce, especially in more remote rural areas, which leaves a significant chunk of the population with no access to medical services. The problem is particularly acute for pregnant women with 59% of urban and 90% of rural women experiencing either a delay in accessing appropriate care or being unable to access care altogether (Elston et al., 2019). Sierra Leone has a mere 1.4 doctors, nurses, and midwives per 10,000 people, which far below the 44.5 sustainable development threshold set in 2016 (Robinson, 2019). The country has a total of 1,000 medical professionals to serve its population of 7.8 million and is currently facing a severe shortage of approximately 32,000 medical personnel (Robinson, 2019).

To compound the problem, Sierra Leone only has medical school, which produces approximately 30 graduates annually, which is not nearly enough to address the deficit (Robinson, 2019). There are 45 private clinics and 27 private hospitals operating in Sierra Leone with the majority being situated in the Freetown area (Robinson, 2019). These private facilities tend to be of higher quality than government options but are also more expensive and are therefore unaffordable for much of the population. To make matters worse, the public healthcare system is highly corrupt with patients being routinely charged for medical services that should be free. A 2009 Amnesty International report concluded that medical staff ‘whether paid or unpaid, would unilaterally and illegally charge fees and keep the money’, thus further eroding healthcare access within the country (Pieterse & Lodge, 2015). This situation has resulted in numerous corruption scandals involving payment for free services and diversion of drugs to private pharmacies to be resold for profit (Pieterse & Lodge, 2015). A variety of factors including low pay, insufficient oversight, and lack of will within the government to crack down on these practices, contribute and compound the problem. The country’s healthcare is extremely reliant on international aid in the form of medications, medical equipment, and medical personnel, but these resources oftentimes fail to reach the intended recipients due to widespread corruption. For example, in 2013, 29 of the top health officials were charged with misappropriating \$500,000 in grant money provided by the GAVI Alliance (Nossiter, 2013). The list of indicted included the country’s chief medical officer, as well as much of Health Ministry’s top leadership including the director of primary care, permanent secretary and program manager for reproductive health (Nossiter, 2013). According to World Bank’s representative Francis Ato Brown this scandal “...virtually decapitated the ministry...” with indictments having the potential to destroy the country’s healthcare system (Nossiter, 2013). Subsequent investigations found a variety of infractions including nurses illegally selling donated drugs, doctors charging for free services provided by international donors and tens of thousands of dollars missing from an internationally finance maternal and childcare program as well as missing records for 23 of 55 bank accounts belong to the Health Ministry (Nossiter, 2013).

The aforementioned factors make expanding access to healthcare a herculean task thereby necessitating innovative and cost-effective solutions. Deploying telemedicine solutions is typically less time and resource intensive compared to building up brick and mortar healthcare infrastructure, especially in remote rural areas. Additionally, telemedicine can leverage existing internet and mobile networks to deliver healthcare through mobile apps, electronic medical record (EMR) software and remote consultations. However, currently there is little available literature dealing with the topic of deploying telemedicine solutions in not only Sierra Leone in particular, but the African continent as a whole. Thus, additional research into the feasibility of utilizing telemedicine technologies to improve healthcare access in Sierra Leone would be highly beneficial.

History of Sierra Leone

The area that came to be known as Sierra Leone was first populated by various tribes migrating from African interior around 600 years ago. Pedro da Cinta, a Portuguese explorer, was the first European to explore the area calling Sierra Leone, which translates to mountain lion. The country became a major slave trading hub by the mid-1550s attracting the attention of other European powers including the English, French and the Dutch. Freetown, the modern-day capital of Sierra Leone, was founded in 1787 by a group of British philanthropists to serve as a base of operations for suppressing slave trade. In 1808 Sierra Leone officially became a British colony when Sierra Leone Company transferred its land ownership to King George III. Freetown became a refuge for freed slaves after the British Parliament passed the Emancipation Act in 1833 with over 50,000 former slaves settling the city by 1855. When the country officially became a British protectorate in 1896, its political system revolved around autonomous chiefdoms with power being concentrated in the hands of the Paramount Chiefs and the ruling families who were largely left alone by the colonial and local governments (Allen, 1968). Sierra Leone became an independent nation on April 27th, 1961, with Sir Milton Margai serving as the country's first Prime Minister. At the time, he stated that "Sierra Leone will become a model state" (Allen, 1968). However, the political situation quickly deteriorated after Margai's death, and his half-brother Albert Margai being named the Prime Minister. The country experienced a period of political instability with intensifying allegations of corruption and abuse of power between the ruling

Sierra Leone's People Party (SLPP) and the opposition All People's Congress (APC). The APC won the plurality of seats, but its leader Siaka Stevens was arrested on the order of David Lansana, who was in charge of the country's military at the time, shortly after being sworn in as the new Prime Minister. Ultimately, the coup failed and Lansana was detained by Major Blake a few days after taking power (Allen, 1968). He was tried, convicted of treason, and executed on July 19th, 1975. Siaka Stevens served as a Prime Minister and then President until 1985. Prior to his retirement Siaka appointed Major General Saidu Momoh as his successor who was largely seen as a continuation of Siaka's regime. Due to domestic and international pressure, Sierra Leone adopted a new multi-party constitution in 1991. However, a conflict between the Revolutionary United Front (RUF) led by former Sierra Leone army corporal Foday Sankoh, and the Momoh government plunged the country into a civil war. Momoh was deposed after a coup by the National Provisional Ruling Council (NPRC) military junta led by Valentine Strasser, which was initially popular due to its promise of bringing peace. Despite the change in leadership the fighting continued and Strasser was removed from power in January 1996 after yet another coup. The country experienced a brief return to civilian rule after Ahmad Tejan Kabbah of the SLPP was named President in 1996, but it would not last as a coup orchestrated by the Armed Forces Revolutionary Council (AFRC) signaled a return to military rule. The AFRC was not officially recognized by either The United States, United Nations, or the African Union. Economic Community of West African States (ECOWAS) formed a military force that eventually defeated the AFRC/RUF junta and allowed Kabbah to return to power in 1998. While the military government was driven out of Freetown the government was unable to achieve total victory over the RUF, and under international pressure, was forced to negotiate for peace. The Lome Peace Accord was signed in 1999 but fighting resumed shortly thereafter prompting military intervention from Great Britain that ultimately resulted in a cease-fire, which finally ended the conflict in 2002.

The prolonged conflict resulted in over 50,000 deaths and displacement of over 500,000 people, which took a terrible economic and social toll on the country (Collier & Duponchel, 2013). Upon the conclusion of the conflict, Sierra Leone dropped to dead last in the United Nations human development index and remained there until 2008 (Collier & Duponchel, 2013). Research has shown that civil wars result in 2.2 percent loss of economic growth for each year of

conflict and impacted countries require an estimated 14 years to reach their counterfactual GDP (Collier & Duponchel, 2013). The civil war led to widespread loss of infrastructure, loss of skills among the workforce and almost total destruction of the already weak healthcare system.

According to Dr. Muctarr Amadu Sheriff Jalloh, a former president of Sierra Leone Red Cross Society, the civil war “...brought all of health and economic infrastructures down to zero...” with many clinics being “...completely demolished...” (Desai, 2010). Many healthcare professionals were forced to flee the country during the war, thus creating an acute shortage of trained staff. Sierra Leone’s service sector, which contracted from almost 50 to 15 percent of GDP during the war has seen a recovery and has gradually returned to prewar levels (Collier & Duponchel, 2013). However, foreign direct investment remains low with very few large corporations operating within the country due a number of factors including difficulty of doing business, rampant corruption, underdeveloped formal credit system, lack of access to electricity and availability of skilled workers (Collier & Duponchel, 2013). Thus, agriculture continues to be the dominant sector of Sierra Leone’s economy while widespread poverty and lack of infrastructure serve as roadblocks for future development.

Sierra Leone suffered yet another tragedy when it became a hotspot for an Ebola outbreak originating in neighboring Guinea in March of 2014. The disease quickly spread through rural areas of Sierra Leone overwhelming the healthcare system due to lack of personal protective equipment and means for controlling infectious diseases. The virus reached Freetown in July 2014 forcing the government to declare a state of emergency in the capital and deploy troops to enforce quarantine measures. However, Ebola continued to spread throughout the country with 5 people being infected every hour by October 2014 (Weaver & Boseley, 2017). The situation continued to deteriorate with lockdowns being instituted throughout the country as the virus continued to spread in the following months. The epidemic finally ended in 2016, but not before producing over 14,000 cases leading to nearly 4,000 deaths (Jalloh et al., 2020). However, Sierra Leone’s healthcare system took another big hit with a number of doctors and nurses succumbing to the virus, including Sheik Umar Khan, the country’s lone hemorrhagic fever expert. Unfortunately, the country suffered yet another calamity when strong rains triggered a major mudslide on the Sugar Loaf Mountain on August 14, 2017, in the capital city of Freetown. Torrential rains caused large section of the mountain to collapse resulting in the destruction of numerous homes and the

deaths of over 1,000 people (Trenchard, 2018). The worst natural disaster in the country's history was a result of unchecked development in areas known to be vulnerable to landslides. Lack of government oversight, corruption, deforestation, and climate change created ideal conditions for this catastrophe to occur.

With that being said, the government has made progress in meeting UN sustainable development goals (SDGs) number 4 (quality education), 8 (decent work and economic growth), 10 (reduced inequalities), 13 (climate action), 16 (peace, justice, and strong institutions) and 17 (partnerships for goals) (Government of Sierra Leone, 2019). According to the latest government report, the percentage of children engaged in child labor has decreased from 44.4 to 29.3 percent between the years of 2013-2017 thereby suggesting that an increased number of children are focused on schooling rather than providing for their families. Thus, the percentage children who have completed primary schooling has increased from 65.4 to 90 percent for girls and from 66.6 to 92 percent for boys (Government of Sierra Leone, 2019). Junior secondary education also saw an impressive jump in completion increasing from 48 to 67 percent for girls and from 53.6 to 67 percent for boys between 2015 and 2018 (Government of Sierra Leone, 2019). The creation of the Legal Aid Board, focused on providing low-income individuals living in rural communities with access to legal representation, advice, and education. The percentage of people being held in pretrial detention without an indictment also saw a significant reduction from 51.0 to 35.6 percent by March 2019 (Government of Sierra Leone, 2019). The government has also worked on reducing inequality through girl empowerment with a focus on educational opportunities, ending child marriages and reducing the number of teenage pregnancies. Additionally, the government is also promoting inclusive and special education initiatives in order to expand access to education for children with disabilities. The county is also taking action to combat climate change by enhancing environmental protections and monitoring compliance as well as incorporating global warming into school and university curricula. Sierra Leone is exploring a variety of private public partnerships for the purpose of SDG financing while improving public financial management and utilizing statistical systems to monitor and evaluate performance.

Introduction to Telemedicine

Telemedicine, also known as telehealth, is an ideal mechanism for delivering patient centered healthcare services to those who are facing obstacles to healthcare access in an efficient manner (Gogia & Gogia, 2020). Other frequently used terms such as mobile health (mHealth) and electronic health (eHealth) also fall under the umbrella of telemedicine. Telemedicine encompasses a wide variety of modalities for utilizing technology to deliver healthcare services, including email, messaging, and mobile applications. Telemedicine can be broadly broken out into 4 types, which are: teleconsultations, remote patient monitoring (RPM), intraoperative monitoring (IOM), tele homecare (THC) and diagnosis and treatment at the point of care (“Types of Telemedicine Technology”, 2017).

Leveraging technology for the purpose of providing healthcare services has numerous benefits such as improvement in health equity, reduction in the amount of time it takes to access healthcare, reduction in nosocomial infections and overall improvement in the health of the population while helping meet several SDGs (Guitton, 2020). Various telemedicine technologies have been found to have efficacy and patient satisfaction comparable to traditional in person model. Some examples include, teledermoscopy being shown to be more accurate than in-person dermatoscopic examination in 75% of reviewed cases and various studies proving telepsychiatry’s effectiveness in the follow-up of autistic spectrum disorder, attention deficit hyperactivity disorder, obsessive compulsive disorders, conduct disorders, eating disorders, paranoia, anxiety, PTSD as well as cognitive and mental functions assessments (Gogia & Gogia, 2020). Telemedicine can be applied to a wide variety of medical disciplines with a detailed breakdown found in figure 1 below.

Type	Description
Teleconsultation	Teleconsultations enable medical information sharing between specialists and patients or providers located in remote areas.
Remote Patient Monitoring	Remote patient monitoring leverages technology, such as smartphones or connected devices, to monitor patients at home. The versatility provided by modern communication technologies make telemedicine applicable for a wide variety of healthcare specialties as outlined below.

<p>Intraoperative Monitoring</p>	<p>Intraoperative monitoring enables experts to remotely monitor complex surgical procedures in order to detect potentially damaging changes in brain, spinal cord and peripheral nerve function (“Types of Telemedicine Technology”, 2017).</p>
<p>Telehomecare</p>	<p>Telehomecare provides remote care for people with chronic conditions, dementia or the elderly who are at a high risk of falling (“Types of Telemedicine Technology”, 2017). Various sensors are used to monitor changes in patient’s and environmental conditions and alert caregivers, family members and emergency services of any incidents.</p>
<p>Diagnosis and Treatment at the Point of Care</p>	<p>Point of care medicine utilizes portable diagnostic and monitoring equipment along with telehealth technologies to transmit test results for patients in remote areas to experts (“Types of Telemedicine Technology”, 2017).</p>
<p>Teleradiology</p>	<p>Teleradiology enables healthcare providers to transmit radiologic data, including x-rays, digital radiography, CT scans, MRI scans, ultrasound images, PET-CT scans, gamma cameras and angiographic data, over networks (Gogia & Gogia, 2020).</p>
<p>Telepathology</p>	<p>analyzing specimens and microscopic images, which makes an ideal candidate for digitalization (Gogia & Gogia, 2020). Mobile phones serve as ideal vehicles for telepathology with relatively inexpensive attachments enabling microscope image capture and transmission thereby providing access to specialist opinions from even the most remote of places (Gogia & Gogia, 2020).</p>
<p>Teledermatology</p>	<p>Dermatology, an area of medicine specializing in the diagnosis and treatment of skin disorders, is the third largest user of telemedicine behind teleradiology and telepathology (Gogia & Gogia, 2020). Patients are able to share images or live video captured via mobile phones during virtual visits enabling medical professionals to diagnose a variety of skin conditions remotely.</p>

<p>Telecardiology</p>	<p>Heart disease is becoming increasingly common in many developing nations that have a shortage of trained cardiologists, thus telecardiology utilizes technology to bridge this divide. Digital stethoscopes for remote hearing enable medical professionals to perform dynamic remote auscultation without having to be physically present at the location (Gogia & Gogia, 2020).</p>
<p>Teleobstetrics</p>	<p>Obstetric telemonitoring is a good alternative for reducing the distance between healthcare professionals and expecting mothers by leveraging technology to monitor their biomedical parameters (Gogia & Gogia, 2020). Many women, especially those living in the developing world, lack access to maternal care services. Teleobstetrics can aid in early detection of complications by utilizing smartphone applications to capture and track data, which can be shared with a specialist (Gogia & Gogia, 2020).</p>
<p>Teleoncology</p>	<p>Cancer one of the leading causes of death worldwide with 8.8 million cancer related deaths in 2015 and number of cases expected to rise by around 70% worldwide (Gogia & Gogia, 2020). A study of prostate cancer patients in the United States found in-person and telehealth visits to be equally as efficient in waiting time, total time dedicated to care, face time with a doctor and satisfaction (Gogia & Gogia, 2020). Teleoncology can be vital in early detection of cancers thereby increasing survival rates and patients' quality of life.</p>
<p>Teleneurology</p>	<p>Neurology, an area of medicine dealing with the nervous system, also leverages technology to improve service delivery and patient outcomes. Much like with many other specialties, there is a great disparity between the demand for neurological services and the number of neurologists particularly in remote and underserved areas. Teleneurology was proven to be effective in evaluating patients with dementia, headaches, epilepsy, movement disorders,</p>

	neuroophthalmological disorders, neurocritical care issues and stroke (Gogia & Gogia, 2020).
Telepsychiatry	Telepsychiatry uses technology to deliver mental health services including psychiatric evaluations and individual, group or family therapy. World Health Organization has identified telepsychiatry as a vital part of improving the accessibility of mental health services (Gogia & Gogia, 2020).
Telesurgery	Telemedicine is also employed in the surgical arena in the areas of distance-based support for pre and postoperative care as well as performing actual surgical procedures remotely, known as telerobotics (Gogia & Gogia, 2020). Modern telesurgery leverages endoscopy with surgeon controlling computerized surgical instruments while observing the operating area via a monitor.

(Figure 1)

Methodology, Data Collection and Analysis

The study utilizes literature review research methodology to systematically synthesize prior research regarding the effectiveness and benefits of deploying telemedicine solutions worldwide. Benefits of telemedicine, challenges with deploying various technologies and lessons learned from previous projects will be invaluable in formulating future projects for leveraging telemedicine to improve healthcare access in Sierra Leone. The initial pool of publications consisted of over 50 articles pertaining to the topic of telemedicine selected from a variety of academic journals from the Arizona State University library. All publications were retrieved from the following databases: PubMed, ScienceDirect, JSTOR, ProQuest and ERIC. Database search was conducting using various combinations of the following keywords: Sierra Leone, telemedicine, Africa, telehealth, eHealth, healthcare and rural. Each article was carefully screened in order to ensure that it came from a reputable source and was relevant to the topic at hand. Priority was given to articles discussing telemedicine projects in Africa with a focus on Sierra Leone in particular. All of the publications were using a scorecard seen in figure 2 with

only those meeting all five criteria being selected for literature analysis, which resulted in 23 articles being included in this study.

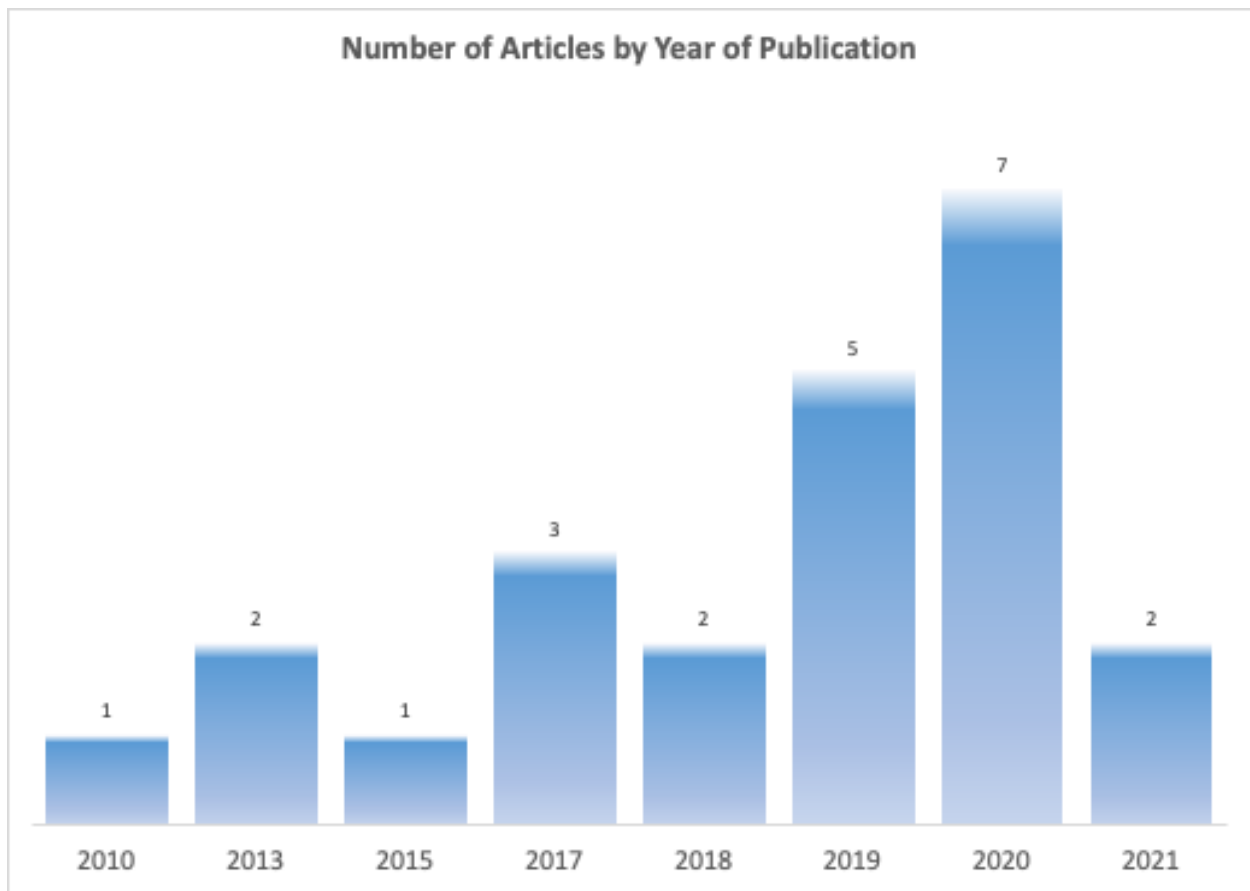
Criteria	Y/N
Study is in English	
Study published within the last 10 years	
Relevant to the topic of telemedicine	
Findings provide valuable insight	
Research is applicable to developing nations, Africa and Sierra Leone	

(Figure 2)

The figure 3 below provide a breakdown of all sources used for this project along with a number of articles by year of publication.

1	African Affairs
2	African Journal of Primary Health Care & Family Mec
3	BMC Infectious Diseases
4	Computers in Human Behavior
5	Health Policy and Planning
6	Health Security
7	International Health
8	Journal of Conflict Resolution
9	Journal of Medical Internet Research
10	PLOS Neglected Tropical Diseases
11	Sourh Eastern European Journal of Public Health
12	Transnational Corporation Review

(Figure 3)



(Figure 4)

These articles were reviewed and analyzed in order to extract information regarding various telemedicine initiatives within developing nations with strong focus on Sub-Saharan Africa and Sierra Leone. Particular attention was paid to the challenges faced and lessons learned throughout the implementation of various telemedicine projects. A sample worksheet utilized for data collection and synthetization can be found below.

Category	Notes
Project name	
Project location	
Implementation timeline	
Roadblocks	
Results	
Lessons learned	
Conclusion	

(Figure 5)

This tool streamlined the process of extracting valuable insights pertaining to challenges, lessons learned as well as best practices associated with the implementation of telemedicine and electronic health projects. Particular attention was paid to the challenges associated with providing healthcare access to marginalized and hard to reach communities as these groups make up a significant portion of the population in many African countries. Gathered information was subsequently synthesized and carefully analyzed in order to isolate key takeaways from these materials. These data points were subsequently compiled into a cohesive research portfolio that was leveraged throughout the duration of this study.

A strengths, weaknesses, opportunities, and threats (SWOT) analysis was also conducted in order to gauge the feasibility of leveraging telemedicine to improve healthcare access in Sierra Leone as seen in figure 6. Telemedicine has a number of strengths that are very much applicable to Sierra Leone such as the ability to leverage existing mobile network and internet infrastructure to deliver healthcare to even the most remote populations in a cost-effective manner. The fact that telemedicine can be deployed much quicker compared to constructing new medical facilities, especially in hard-to-reach areas, is another plus. There exists an opportunity for private public partnerships in order to expand mobile and internet coverage throughout Sierra Leone in order to enable as much of the population as possible to access telemedicine services. Remote medical consultations are also an ideal solution for mitigating chronic shortage of medical professionals within the country. While telemedicine is applicable to wide variety of medical scenarios some medical procedures cannot be done remotely, thus it is important to account for such scenarios and plan accordingly. Additionally, the viability of such projects is

contingent upon political and economic stability, adequate funding and the ability to sustain long-term support for telemedicine solutions throughout the country. Having sufficient expertise and financial resources is vital to properly safeguarding sensitive healthcare data and encourage adoption among providers. Lastly, bringing down the cost of these services thereby making them attainable to the most vulnerable populations is vital to meeting the goal of expanding healthcare access.

SWOT Analysis

PURPOSE		Utilizing telemedicine to improve healthcare access in Sierra Leone					
S	STRENGTHS	W	WEAKNESSES	O	OPPORTUNITIES	T	THREATS
1	Ability to leverage existing network infrastructure.	1	Poor technological infrastructure, particularly in more remote and hard to reach areas.	1	Private public partnership for continual expansion of mobile and internet access.	1	Political and economic instability.
2	Less resource intensive compared to building or expanding medical facilities.	2	Some procedures cannot be done remotely.	2	Mitigation shortage of medical professionals through telemedicine.	2	Inability to sustain and support telemedicine solutions due to lack of funding.
3	Time to deployment.	3	Successful implementation requires substantial provider and end user training.	3	Take advantage of experts worldwide by utilizing teleconference to train doctors and nurses.	3	Healthcare costs pose a challenge for rural populations that struggle with poverty.
4	Can be deployed in rural and remote areas.	4	Poor quality of healthcare information.	4	Improve healthcare access in hard to reach communities.	4	Slow adoption of telemedicine technologies by healthcare providers.
5	More convenient compared to traditional face to face visits.	5	Potential organizational and bureaucratic difficulties.	5	Leverage existing mobile networks for healthcare delivery.	5	Security incidents involving confidential healthcare data.

(Figure 6)

Findings

This study reviewed and analyzed a number of telemedicine projects that have been previously implemented on the African continent as shown in figure 7 below.

Project	Location
Clinicopa Drug Resource Enhancement against AIDS and Malnutrition (DREAM)	Tanzania, Malawi & Mozambique
Ebola Contract Tracing (ETC) application	Sierra Leone
Electronic Integrated Disease Surveillance and Response (eIDSR)	Sierra Leone
EQUI-ResHUS	Mali
Keneyan Blow	Mali
OpenMRS-Ebola Electronic Health Record System	Sierra Leone
RAFT Telemedicine Network	Madagascar, Rwanda, Mali, Morocco & Mauritania
Save the Children's COVID-19 and Sexual Health Mobile App	Sierra Leone
Static-image Telepathology Program at Butaro Cancer Center of Excellence	Rwanda

(Figure 7)

As a result of this research, it has become clear that technology is the best solution for delivering healthcare services to rural and remote populations. Africa is the world’s poorest continent, thus the vast majority of governments struggle to provide even the most rudimentary levels of healthcare to their populations. This is especially true in Sierra Leone, which is one of the poorest countries on earth and lacks financial, human, and institutional resources for such an undertaking. Thus, constructing more clinics, especially in remote hard to reach areas, or increasing the number of trained medical professionals, is largely out of the question. Even if the resources were to be made available, building strong healthcare systems is a long-term project that won’t bear fruit for years, or in many cases, decades to come. However, technologies such as the internet, mobile networks, and smartphones, can be deployed quickly and cost effectively with potential of reaching even the most remote areas of the country.

While Sierra Leone faces numerous challenges in regard to healthcare access, the country has strong mobile phone penetration rate with 6.9 million connections, which constitutes 87% of the population (Kemp, 2020). Although as of 2019, only 62% of Sierra Leoneans had access to a 3G or faster mobile networks, but that constitutes a 22% increase since 2014 and 10% since 2018 alone, thus demonstrating the fact that the country is making strides in this area (“2020 GSMA Mobile Connectivity Index - Sierra Leone”, 2020). Expanding mobile network access combined with high levels of smartphone penetration enables the delivery of healthcare services to previously hard to reach populations. Mobile Applications for conducting virtual doctor visits, symptom monitoring, and health-related educations can be deployed quickly and with comparably low investment compared to traditional healthcare infrastructure. Prior studies have shown that these solutions are able to improve health outcomes and compare favorably with traditional face to face doctor visits.

Therefore, telemedicine appears to be an ideal solution for delivering healthcare to individuals and communities that lack access to medical facilities. In fact, some initiatives are already underway with Save the Children launching an interactive sexual health application in order to prevent a surge of teenage pregnancies and save lives since pregnancy complications are the number one killer of 15- to 19-year-old girls in Sierra Leone (Save the Children International, 2020). The app was built by Denmark's Lulu Lab with input from young Sierra Leoneans and Limkokwing University in order to make the content engaging and relevant for the target audience. By offering accurate and reliable information regarding sexual health the app helps protect young people from sexually transmitted diseases, pregnancy as well as COVID 19 (Save the Children International, 2020). The app proved invaluable for many youths living in rural and traditional communities where discussing sex is considered taboo by providing them with information on accessing free family planning resources. Innovative projects such as this illustrate potential for using mobile phones to deliver healthcare to vulnerable populations in Sierra Leone.

Telemedicine, in the form of a mobile application for contact tracing within 11 Chiefdoms in Port Loko District of Sierra Leone. This application is based on the open-source Dimagi's CommCare platform for collecting and analyzing electronic data (Danquah et al., 2019). A mobile application based on the open-source Dimagi's CommCare platform for collecting and analyzing electronic data, which was deployed within 11 Chiefdoms in Port Loko District of Sierra Leone has proven to be a more accurate and timely method of storing and managing information compared to the traditional paper-based alternatives (Danquah et al., 2019). The implementation of the OpenMRS-Ebola EHR during the 2014 Ebola outbreak was another example of successfully leveraging technology to manage a healthcare crisis. The application was developed by two teams with the operation team being located in Ebola treatment centers within Sierra Leone and developers from ThoughtWorks in Uganda (Oza et al., 2017). Medical professionals working in Ebola treatment centers were provided with Sony Xperia Z2 Android tablets to perform a variety of functions including registration, bed allocation, discharge, recording vital signs and symptoms, ordering medication and IVs, accessing lab results and exporting data. The application performed well and was found to have

fewer age, gender or ID errors compared to traditional paper methods since the medical staff was able to enter data directly in the EHR while pen and paper records had to be copied from handwritten notes by data entry clerks. The electronic alternative was proven to be a superior solution for data entry, analysis, and reporting.

Technology can also assist in dealing with the severe shortage of medical professionals by utilizing teleconsultations, sample analysis and remote patient monitoring. A telemedicine network that includes doctors and nurses from other countries would allow patients to get access to a much bigger number of providers. Additionally, Sierra Leonean medical professionals could also connect with peers worldwide via tele or video conferencing. These technologies can also be leveraged to grant medical students access to expertise that may not exist within the national healthcare system.

Discussion

Research findings suggest that telemedicine is a viable solution for improving healthcare access in Sierra Leone. Delivering healthcare services in low resource environments such as Sierra Leone presents a number of challenges including lack of medical facilities along with chronic shortages of medical supplies and trained personnel. However, taking advantage of relatively high levels of smartphone penetration, appears to be an ideal solution for mitigating the lack of medical facilities and providers while delivering healthcare to areas facing such challenges. Telemedicine services that can be accessed through mobile applications, social networks and text messaging can expand healthcare access to large swaths of people who are currently unable to access much needed medical services.

It is vital that one applies lessons learned from other telemedicine projects across Africa when designing future initiatives. For example, a project named Keneya Blown, translating to ‘health vestibule’ in Bambara language, which was launched in Mali in 2001, was one of the first telemedicine projects undertaken in Africa. It was financed by the Geneva government and Geneva University Hospitals and focused on providing follow up teleconsultations for patients that were previously operated on in Geneva as well as utilizing tele-education to train physicians (Oluwakorede et al., 2021). Although this project yielded improvements in physician

education and post-discharge care it was also hampered by poor telemedicine infrastructure and internet connectivity (Oluwakorede et al., 2021).

The limitation of these findings is the fact that very few large-scale telemedicine projects have been undertaken within Sierra Leone, thus the body of research concerning the subject is quite limited at the moment. Additionally, the majority of such projects were organized and funded by foreign sources so long-term sustainability is also a question mark. Thus, more research is needed in order to ascertain whether Sierra Leone's public and private sectors are able to successfully plan, design, roll out and provide ongoing support for home grown telemedicine solutions without intervention from external stakeholders.

Conclusion

Lack of access to healthcare is a monumental challenge in Sierra Leone as the lack of adequate financial and human resources make providing adequate medical services to largely poor and rural populations a herculean task. This paper explored the viability of leveraging the growing smartphone and mobile network penetration to implement telemedicine solutions for healthcare delivery. After reviewing numerous academic papers pertaining to the subject, it has become clear that telemedicine can be an effective solution for expanding healthcare access to many difficult to reach populations with effectiveness comparable to that of traditional face to face interventions. Existing research pertaining to various telemedicine projects in other developing nations, including those in Africa, has demonstrated the technological feasibility of these initiatives. Additionally, recent Sierra Leone telemedicine initiatives include a mobile app for providing information regarding reproductive and sexual health for curbing teenage pregnancies during COVID-19 lockdowns and an electronic system for Ebola tracking and surveillance were successful in utilizing technology to streamline the process of delivering medical services.

With that being said, the question of sustainability remains as both projects received external funding and support. Thus, although telemedicine holds a tantalizing promise of expanding healthcare access, it is entirely unclear whether similar solutions can be planned,

developed and implemented by internal stakeholders. While these projects are less time and resource intensive than constructing adequate medical facilities in rural areas that oftentimes lack basic infrastructure such as roads and availability of reliable power, they still require significant commitments from various governmental institutions. Lack of adequate infrastructure was found to be one of the biggest limiting factors in virtually every project reviewed throughout this research, thus the importance of clearing this hurdle cannot be overstated. Making widescale availability of telemedicine services a reality will require significant infrastructure investments into ensuring reliable supply of electricity along with continued expansion of internet and mobile network coverage.

Ultimately, the future of telemedicine in Sierra Leone depends on those in power committing to expand healthcare access to every citizen regardless of their geographic location or socioeconomic status, and continual collaboration between the public and private sectors to develop and provide long term support for homegrown telemedicine solutions.

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