How Digital Health Promotes Health System Development in Africa

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Introduction to the Report

The World Health Organization's assessment reveals a positive trend in Africa's health, with a remarkable 10-year increase in healthy life expectancy from 2000 to 2019. This improvement signifies a growing emphasis on the overall well-being of individuals on the continent. Notably, Africa boasts the world's highest birth rate, projected to reach 2.5 billion by 2050, and its urban population is anticipated to surpass that of China and India. By 2100, the populations of 10 African countries are expected to quintuple. Concurrently, the burgeoning middle class, now comprising 34% of the population, further contributes to Africa's evolving landscape.

As the population and middle class expand, there arises a heightened demand for medical services exceeding the global average. Projections estimate an 8.4% increase in medical treatment demand in Central and Eastern Africa in the coming years. To address evolving healthcare needs, substantial collaborative efforts involving governments, international partners, technical agencies, researchers, and stakeholders are underway to fortify the region's health systems.

While private medical institutions have assumed a crucial role in healthcare provision and financing, their involvement varies across African countries. This diversity necessitates the exploration of additional medical solutions attractive to private entities. The accelerating technological development, particularly evident during the COVID-19 pandemic, has propelled various sectors forward, including healthcare in Africa. The continent has emerged as a fertile ground for innovative digital health solutions.

Governments across Africa, spurred by the pandemic, demonstrated agility and innovation, testing over 120 technology-based solutions to control the spread of COVID-19. Among these, the Medical Imaging Diagnostic Centre has emerged as a pivotal digital tool, streamlining healthcare operations and enhancing accessibility for health management departments, disease control entities, clinics, and patients. Digital health solutions, exemplified by medical imaging centers, offer comprehensive professional services, addressing the challenge of uneven medical resources and inadequate supply in Africa. Some countries have witnessed the rise of small, cost-effective medical imaging centers, yielding substantial operational benefits. A thorough investigation into these centers can provide valuable insights, benefiting both service providers and recipients, while offering recommendations for broader digital health solutions in the region.

Chinese support, both public and private, has been instrumental in Africa's health sector, with a notable surge during the pandemic. This report aims to guide collaborative efforts between Chinese and African health actors toward superior digital health solutions. The focus is on fostering a collective commitment to quality care delivery services, expansive program coverage, and increased efficiency. This collaboration is pivotal for transforming Africa's health information systems and local health governance structures, thereby advancing global health improvements and economic stability.

The report targets Uganda, Angola, and Ethiopia, representing distinct development patterns in the region. Uganda's consistent economic growth and experience with digital health pilot projects offer valuable insights. Angola's unique characteristics, such as its oil-rich economy and Portuguese-speaking population, provide an intriguing case study. Ethiopia, as one of the continent's fastest-growing economies, presents a dynamic environment for digital health development. Each investigation will not only cover general information about digital health but also focus on independent medical imaging centers, providing a comprehensive reference for businesses and local governments seeking opportunities for future cooperation.

Abstract

Digitalizing health services has been a widely discussed topic in African countries, while progress has been made slowly, especially in areas of health services, such as medical imaging services. This report examines the current status and potential of digital health development in Ethiopia, Uganda and Angola, with a closer look at medical imaging services in these three countries. Through desk research and field visits, the research team identified several ways of action to strengthen current efforts in this industry. New policies, new tools and new financing models are suggested to be created, to make such services more affordable, sustainable and possible to reach to a larger customer base.

Chapter 1 Ethiopia

1.1 Holistic analysis of quality health services and advantage assessment in Ethiopia

1.1.1 Needs for quality health services

- **Basic local data of Ethiopia**

Ethiopia is located in the northeast of Africa, and two-thirds of it is the Ethiopian Plateau, with an altitude of 2,500-3,000 meters, which is the highest on average among African countries[1]. With more than 127 million residents, it is the most populous landlocked country in the world and the second most populous African country (after Nigeria). At present, the annual growth rate of local population is 3.02%. At the current growth rate, Ethiopia's population will double in the next 30 years and reach 210 million in 2060. It is predicted that most of the world population growth in the next 40-50 years will come from Africa, and Ethiopia will be a large part of the growth. The land area is 1.1 million square kilometers, and Addis Ababa is the capital and the largest city[2].

Due to the influence of colonial period, the influx of refugees and El Niño phenomenon, the demand for quality medical care in Ethiopia is huge. At present, Ethiopia is experiencing typical public health problems in this underdeveloped country, mainly involving the following three aspects: infectious diseases (AIDS, malaria, tuberculosis, etc.), maternal and child health problems (diarrhea and dehydration, pneumonia, neonatal problems, etc.) and malnutrition. At the same time, the proportion of some non-communicable diseases (cardiovascular

diseases, cancer and mental diseases) is also increasing.

- **Major health problems**

Local health services are mainly managed in three levels, including primary, secondary and tertiary care. Primary health care, including primary hospitals, health centers and health stations, is responsible for community health management. However, at present, there are only hospitals with full-time doctors in big cities, and most of them are in Addis Ababa. People have very limited access to modern medical care, and they can't enjoy the corresponding medical security in many rural areas[2]. At the same time, most medical institutions are owned by the government, and the number of general practitioners and a few specialists trained by medical schools in this country cannot meet the growing demand for medical services.

According to statistics, there are 3,867 private clinics and 43 private hospitals in Ethiopia[3]. Some members of China's medical team who assisted Ethiopia visited the largest private hospital in Bahir Dar, northern Ethiopia. It was found that the hospital included departments such as ophthalmology, obstetrics and gynecology, anesthesia operating room, general surgery, orthopedics and pathology laboratory, etc. There were a large number of patients seeking medical treatment every day, and the conditions provided by the hospital were very simple, so it was impossible to provide real-time medical image examination items in the hospital.

The high burden of medical expenses also prevents many people with poor economic conditions from obtaining quality medical services. In Ethiopia, a large part of the population is facing great pressure of life related to the cost of medical services. The Ethiopian government aims to achieve universal health coverage by 2030, but despite many reforms in health care financing (HCF), the Ethiopian health system is still struggling to cope with low health care funds and high out-of-pocket (OOP) expenditures.

- **Ethiopia's local expectations for digital medical care after the epidemic.**

Ethiopian Ministry of Health (MOH) launched the first digital health innovation and learning center (DHILC) in Addis Ababa on August 6th, 2020. At the same time, in response to the Global Digital Health Strategy 2020-2025 put forward by the World Health Organization, Manyazewal T[3] and others also actively tracked the acceptance of digital health in Ethiopia, and conducted a survey on 596,128 patients from six dimensions, including electronic health records and telemedicine. The results showed that although the radiation image range of digital health in Ethiopia was still limited, its potential in clinical and public health practice was worth looking forward to[4]. Its appearance is expected to solve the major clinical and public health backlog in Ethiopia, strengthen the construction of the overall

health care ecosystem in Ethiopia, and promote the realization of WHO's global digital health strategy.

1.1.2 Existing market size

Artificial intelligence has the potential to improve radiology workflow. In the future, it may help to explain by automatically detecting abnormalities in the chest, brain and other body parts, which will have a considerable impact on low-and middle-income countries like Ethiopia. At present, many medical imaging devices have joined the concept of AI in the use process, and the code of the solution is provided to the outside world in the form of open source. With the development and improvement in the future, artificial intelligence solutions will undoubtedly have a considerable impact on medical imaging in low-and middle-income countries like Ethiopia, and at the same time, it is invisibly promoting the popularization of the concept of digital health.

By 2022, ultrasound has occupied 31.6% of the whole medical imaging market, and it is expected to maintain a leading position in the forecast period[5]. The growth of this market segment can be attributed to the increase in the number of ultrasonic applications. The latest development of advanced ultrasonic transducers has opened up a new way for ultrasonic equipment to enter biomedicine and cardiovascular imaging. In addition, the high attention to the development of portable ultrasonic equipment is expected to expand the application of this method in outpatient and emergency care.

The Digital Health Blueprint (DHBP) makes Ethiopia one of the few countries that correctly state its vision of improving the health level of the population in a comprehensive way. In the process of promoting the concept of digital health, the bold commitment made by the government to maximize the use of digital technology in all sectors, especially the leadership commitment of the health sector, has played a special role in promoting by going up one flight of stairs.

Although the country has everything it needs to change the field of digital health/e-health, it must overcome some obstacles to support and manage all digital health work. Although the industry continues to promote the development of digital tools, infrastructure investment seems to lag behind[6]. Although a lot of work has been done in reorganizing the governance of HIS, further modifications are needed to support and manage all digital health work. Although the department continues to promote digital tools, infrastructure investment seems to lag behind. Without reliable ICT infrastructure at service providers, the long-awaited journey to full digitalization will be difficult to achieve. The decision to invest in infrastructure, from mobile phones and tablets to data centers and host substitutes, should be carefully analyzed and decided. In addition, it is also very important to design a method for the continuous maintenance and replacement of

hardware (life cycle management) and rethink how we use local investment in ICT equipment manufacturing. To say the least, it is decisive to establish a mechanism for recruiting and retaining excellent employees in HIS field. Without qualified and active staff in the ecosystem, it will be difficult to achieve the goals set in all our national documents. If the environment is favorable, the private sector can bridge the gap between professional knowledge and labor force in the short and long term. The health sector needs to work hard to create opportunities while ensuring that the private sector is given the time and support it needs to grow into a reliable partner. Most importantly, in addition to formulating strategies and improving policies, due attention should also be paid to actual implementation.

Nigatu, A.M[4] and others explored the challenges faced by public hospitals in Ethiopia in the process of medical imaging consultation, and communicated with 21 subjects in a semi-structured interview mode, covering the different identities of hospital directors, department directors, medical imaging operators and patients. According to statistics, there are still many problems in the medical imaging consultation service, such as frequent failures of imaging equipment, delayed maintenance of equipment, insufficient infrastructure, budget shortage and lack of radiologists. At present, the digital health care model is still implemented in Ethiopia in a pilot way, and there are limitations in the sustainable service of this concept and technology.

At the same time, Ethiopia, as one of the countries with rapid population growth in Africa, has an overall population of over 127 million. The average age of the population is 70 for women and 65 for men. Combined with the current statistics, although the overall numerical trend of population growth rate in recent years is relatively stable, there is still a huge gap in medical care due to the large population base, which also provides a broad development space for the participation of new medical models such as independent medical imaging centers.

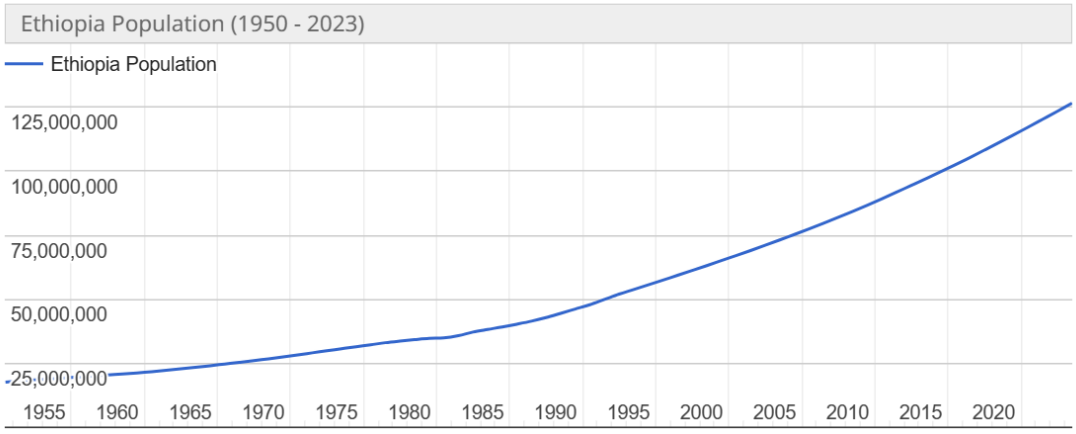

Fig.1 Population situation in Ethiopia

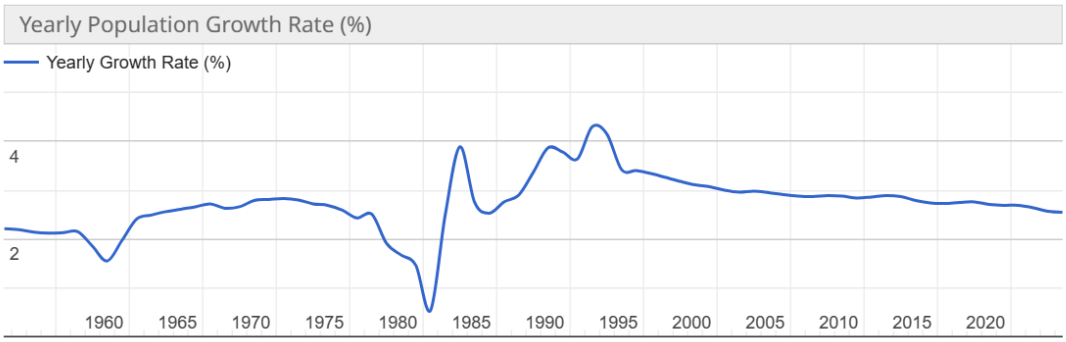

Fig.2 Ethiopia's population growth rate

It is expected that the CT scanner market segment will achieve the fastest growth. CT system is one of the main diagnostic tools for COVID-19 patients. The high demand for bedside CT equipment and the development of high-precision CT scanners by integrating AI and ML and advanced visualization systems are the main factors driving this market segment.

1.1.3 Competition

- **Development Status of Medical Companies in Ethiopia**

The latest trend of cooperation between local and global companies in Ethiopia is expected to have a synergistic effect on market growth. This kind of cooperation and technical exchange will help to accelerate development and promote market competition, thus providing a complex and affordable imaging system. Some key players in the global diagnostic imaging market include:

GE Healthcare
Philips N.V.
Siemens Healthineers
Canon Medical Systems Corporation
Mindray Medical International
Esaote
Hologic, Inc.
Samsung Medison Co., Ltd.
Koning Corporation
PerkinElmer Inc.
FUJIFILM VisualSonics Inc.
Cubresa Inc.

In 2021, International Finance Corporation (IFC) established the African Medical Equipment Fund, and joined hands with Philips and Kenya Cooperative Bank to help African medical institutions improve the shortage of necessary equipment and quality medical services. The International Development Association Private Sector Window (IDA-PSW) hybrid financing mechanism and the Global Financing

Facility for Women, Children and Adolescents (GFF) support the African Medical Equipment Fund. Philips' medical imaging business mainly provides MRI, CT, X-ray and other products, ranking among the top in the world in the field of imaging diagnosis.

In 2018, Philips signed a seven-year agreement with the governments of Ethiopia and the Netherlands to establish the first specialized heart care center in Ethiopia. The agreement not only includes the construction of a new heart care center, It also includes the renovation of the existing part of the existing Tikur Anbessa specialist hospital in Addis Ababa, Ethiopia. INTERMS of hospital renovation included installation of a dedicated cardiology operating theater, A new Philips bi-plane intervention laboratory and a cardiology ICU to solve the serious shortage of cardiology services in Ethiopia. Headquartered in Addis Ababa, Philips Ethiopia Company is responsible for the overall design, construction, equipment and commissioning of the hospital site, as well as staff education and equipment maintenance five years after completion.

In terms of equipment supply of medical equipment, companies such as Philips are also expanding their markets in Africa, providing basic medical imaging equipment, helping the construction of local digital health in Africa, and expanding the local medical infrastructure market. Let's take Philips as an example to explain in detail:

(1)Ultrasound

Among the ultrasonic machines and imaging equipment provided by Philips, ClearVue 850 improves the accuracy of clinical examination, and EPIQ 5 nSIGHT is an effective high-end ultrasonic imaging platform developed by Philips, with flexible and innovative ergonomic design. Therefore, help medical institutions to provide accurate clinical services for patients.

(2)Computed Tomography

Among the CT equipment provided by Philips, the new nano-CT adopts a tube with a physical capacity of 8M, which ensures the operating efficiency of the equipment and the benefit of the department. Ingenuity CT has a 1-megapixel technology and a platform for removing metal artifacts, which improves the detail resolution and can remove metal implant artifacts to achieve clear imaging.

(3)Magnetic Resonance Imaging

Among the MRI equipment provided by Philips, Prodiva medical magnetic resonance imaging system (1.5T CX) can be widely used, including nerve, whole body, bone and joint, tumor and heart. The machine can reduce the setting steps

to a certain extent in the workflow, and improve the progress of inspection work.

(4)X-ray Devices

The mobile X- ray system series provided by Philips can provide good image quality for patients' surgery, and can play a key role in percutaneous coronary intervention, structural heart disease and congenital heart disease.

(5)Mammography system

The mammography system provided by Philips will help you realize more personalized low-dose care for women. MicroDose SI can perform fast and comfortable low-dose mammography, and obtain excellent imaging quality and non-contrast spectral imaging applications. With IntelliSpace Breast, you can watch all the research reports of mammography, ultrasound and magnetic resonance imaging in one workstation, helping doctors get comprehensive and detailed images.

- **Market competition pattern of medical influence equipment**

(1)The Global Layout

Major medical equipment companies gain greater market share through global distribution. Philips, Siemens and other multinational companies have production and sales organizations in the United States, Europe, Africa and other important medical markets. Africa has a shortage of medical equipment and a large population. Global production can reduce costs and expand the influence of global sales, especially in underdeveloped areas of developing countries.

(2)Acquisition Integration

Enterprises enhance their technical strength and improve their product lines through acquisition and integration. For example, Philips acquired Cadilhac Vascular, an American medical technology company, which enhanced the advantages of angiography and intravascular surgery equipment. Acquisition and integration help enterprises to quickly occupy sub-sectors.

(3)Research and Innovation

Medical equipment enterprises improve product performance through independent research and innovation. The proportion of R&D investment in sales revenue is usually above 8%. In June 2023, Philips Medical and Polarean reached a cooperation to introduce ZENOVIEW, the first and only hyperpolarized inhaled MR contrast agent approved by FDA, into its MR 7700 system, so that users can

directly image lung function through Mr scanning. The combination of Philips MR 7700 multi-core MRI scanner and Polarean XENOVIEW hyperpolarized xenon contrast agent allows clinicians to observe patients' lungs in more detail and accurately measure lung ventilation. Therefore, developing innovative technologies and promoting the introduction of advanced products will help to seize the commanding heights of technology.

(4)Service added Value

The level and quality of after-sales service provided by enterprises is also an important way of competition for enterprises. A perfect service system can improve customer stickiness and build loyalty. Toshiba and General Electric Company (GE) have invested heavily in services to maintain their advantages.

(5)Strategic Alliance
Medical enterprises also integrate resources through strategic alliances. For example, Philips cooperates with Amazon web service(AWS) to use cloud computing to improve medical diagnosis services. Alliance allows enterprises to concentrate their own advantages and obtain synergy.

Tab.1 Ethiopia's current market size import and export ratio in medical health industry

USD '000	2020	2021	2022	2023 （estimated）
Total Market Size	27,372	122,193	134,412	147,853
Total Local Production	22,500	24,750	27,225	29,947
Total Exports				
Total Imports	4,872	97,443	107,187	117,905
Imports from the United States	592	682	750	825
Exchange Rate	44.38	51.00	51.75	

As can be seen from the data in the figure, most of the medical instruments involved in digital medical treatment and medical imaging in Ethiopia need to be imported from the United States, which also adds new challenges to the in-depth construction of independent medical imaging centers in Ethiopia.

1.1.4 Advantage assessment

- Better design

Ethiopia's government primary health care delivery organization is comprised of health posts, health centers, and primary hospitals. A health post, the lowest level of the primary health care system, mainly provides promotive and preventive health care services; serving 3000–5000 people in a woreda. A health center is a referral center for health posts, and provide promotive, preventive, curative and rehabilitative outpatient care including basic laboratory and pharmacy services; serving 15,000–25,000 people in a woreda. A primary hospital is the highest level of primary health care and provides inpatient and ambulatory services.

This includes all of the same services offered at health centers, as well as additional emergency surgical services, including caesarian sections and blood transfusions, and serves as a referral center for health centers that reside within the primary hospital's catchment area. Primary hospitals serve 60,000–100,000 people in a woreda. Investment in primary hospitals is still ongoing so not all health centers are linked with primary hospitals and some primary hospitals may serve several woredas.

- Price

The existing medical care system in Ethiopia is mainly based on the form of medical health insurance. By establishing a health insurance strategy, the government aims to provide systematic coverage for the medical care of the whole people. At the same time, the strategy also mainly determines two types of insurance systems.

- ✓ Social health insurance (SHI) is a formal sector that only the rich can afford.
- ✓ Community health insurance (CBHI) is suitable for rural and urban informal sectors.

The development of community health insurance aims to cover the very large rural and agricultural sectors and small informal sectors in the urban environment as much as possible, and provide them with fair, accessible and increased financial risk protection.

Ethiopian Drug Supply Bureau (EPSA) is a public procurement agency responsible for purchasing drugs, medical supplies and equipment in all parts of Ethiopia. Its distribution center is close to medical institutions all over Ethiopia, and an effective inventory and information management system is established, which provides the possibility for independent medical imaging centers to save labor costs and facilities costs.The government is also making efforts to adjust and improve EFDA and operational efficiency, with the aim of ensuring 100% provision of important and essential drugs at all levels of the health care delivery system without stock shortage. At present, EFDA is trying to implement a "zero backlog" strategy for drug registration and licensing activities.

The GOE encourages private sector participation in the area of quality of care and quality of service. The government is also working with the private sector to build advanced tertiary care hospitals to meet domestic demand that would otherwise be met through outbound medical tourism. The Ethio-American Hospital, which is under construction, and the recently announced Roha Group medical center, which will be built with a cost of $300 million in Addis Ababa are examples of the government's commitment to developing major new healthcare facilities. These projects also demonstrate the government's commitment to encouraging foreign investment in the sector through public private partnership (PPP) arrangements.

The Ethiopian Control Authority (FMHACA) is also involved in the supervision of medical devices and the procurement of medical devices in Ethiopia. In the procurement process, suppliers need to abide by strict registration procedures and procurement procedures.

Every hospital should establish a Medical Equipment Committee (MEC) to provide suggestions for the management of medical equipment. These are expected to become cooperative institutions of independent medical imaging centers in the process of equipment raising.

- Technology

Artificial intelligence can perform multi-field medical care tasks well (especially in the prediction of medical diagnosis results), and provide sustainable learning and professional guidance and suggestions for professionals in the medical field. Relevant health departments in Ethiopia are actively promoting the coverage of precision medical diagnosis and treatment, and trying to innovate in research fields and clinical trial methods to further improve the level of medical care services.

Combined with the analysis of economic market data, the revenue of medical technology market in Ethiopia is expected to reach $219.9 million in 2023. The largest market in this market is medical equipment, and it is estimated that the market size in 2023 will be 182.7 million US dollars. The higher income and profit of the medical device market can also effectively promote the local economic development.

- Location

Ethiopia is a country with a population of over 100 million, and many clinics in rural areas provide medical services, most of which are located in larger towns[7].

Tab.2 Currently the below list of health care facilities are available in Ethiopia

Type	Number
Health Posts	17,154 available and 438 under construction
Health Centers	4,063 available and 68 under construction
Hospitals	338 available and 218 under construction
Private Clinics	3867
Private Hospitals	43

In recent decades, Ethiopia has made considerable progress in the development of health sector, which advocates giving priority to community-based health interventions and promises to achieve universal health coverage. However, people's access to health services is often disproportionate, benefiting those with better economic conditions, higher education or living in urban areas. Medical institutions and influential hospitals are mostly concentrated in big cities, but the coverage of rural and remote areas is relatively small.

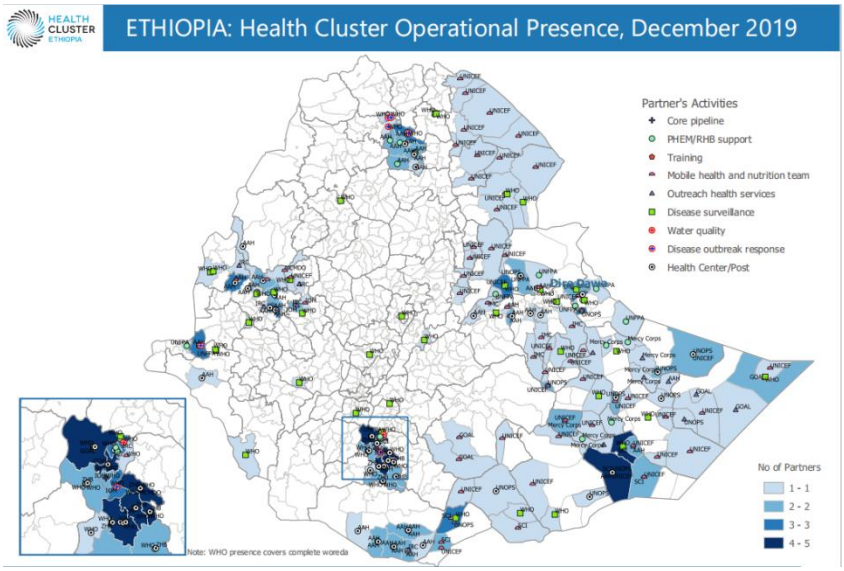

Fig.3 Ethiopia's health cluster operational presence

■ Addis Ababa Silk Road General Hospital

Since the implementation of the "the belt and road initiative", the economic and trade cooperation between China and Ethiopia and other African countries has developed rapidly, and China citizens and enterprises have started businesses or expanded their markets in Ethiopia and other countries. In the field of medical and health care， Addis Ababa Silk Road General Hospital has become a prominent symbol. Addis Ababa Silk Road General Hospital is playing a leading role in tackling

the coronavirus pandemic in the country.

As the first Chinese-funded hospital in Ethiopia, it integrates emergency treatment, first aid, general outpatient service, operation center, intensive care center, diagnosis center and rehabilitation physiotherapy center, and has 15 main departments including neurosurgery, general surgery, orthopedics, cardiology and respiratory department, with about 150 beds, including 8 ICU beds.

The serious shortage of medical resources in Ethiopia provides a broad world for the development of imaging diagnosis centers. Wang Jianhua, director of Addis Ababa Silk Road General Hospital, pointed out that in Addis Ababa, there are 10 public hospitals run by the government and more than 10 well-known private clinics. These medical institutions have maintained close cooperation with his imaging diagnosis center.

Addis Ababa Silk Road General Hospital adheres to the attitude of being responsible for patients and the lofty spirit of humanistic care. In Ethiopia, it can not only provide high-quality medical and health care services, but also equip with world-class medical conditions and multifunctional operating room environment to fully ensure the treatment effect of patients.

As early as the beginning of 2019, Effie also signed a cooperation agreement with Addis Ababa Black Lion Hospital, which will provide 240 critically ill patients with free medical services every year. In August of the same year, Addis Ababa Silk Road General Hospital also donated more than 700,000 Birr for the "2019 Annual Meeting of Ethiopian Society of Neurosurgery Professionals" held at the Hyatt Regency Hotel in Addis Ababa. In the process of helping the development of local digital medical images, Addis Ababa Silk Road General Hospital has never stopped helping, and also actively cooperated with local medical institutions to radiate the key role of medical images to the outside world.

Fig.4 Photographs of internal departments of Addis Ababa Silk Road General Hospital

In terms of medical imaging, Addis Ababa Silk Road General Hospital is equipped with 1.5 Tesla MRI, 128-slice CT, digital subtraction angiography, 4D ultrasonic instrument and neurosurgical microscope system.

Fig.5 Photographs of internal instruments in Addis Ababa Silk Road General Hospital

Hospital CT scans are about 50 times a day, and B-ultrasound and magnetic resonance imaging are about 30 times. In general, the price of a nuclear magnetic resonance is 3000 birr, and the price of a computerized tomography is 2000 birr. In addition, since the establishment of Effie Hospital, more than 3,000 poor local patients have been provided with free examinations to help more patients get timely and accurate treatment.

In order to further promote the coverage of digital images in the local area, Addis Ababa Silk Road General Hospital actively held a large-scale activity of "Action Plan for Medical Rescue of Neurosurgeons", and invited a team of neurosurgeons from top medical institutions in China to join in, so as to provide high-quality medical services for local patients. A total of 61 patients were collected in this activity, and Addis Ababa Silk Road General Hospital provided free screening service and neurosurgery for patients who met the standards.

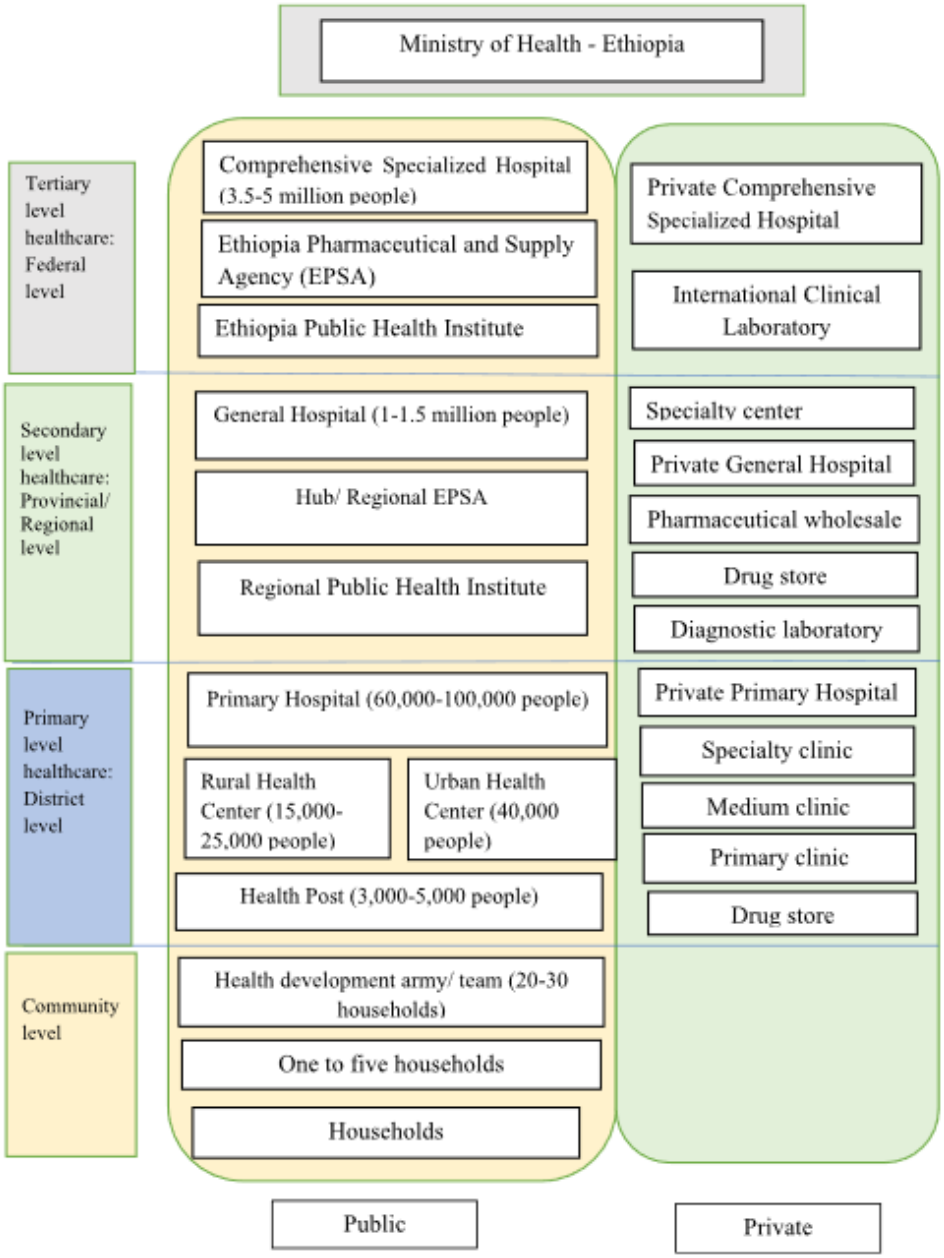

Fig.6 Ministry of Health in Ethiopia

1.2 Obstacles in Developing Quality Health Services in Ethiopia

The Global Strategy for Digital Health (2020-2025) issued by the World Health Organization (WHO) once pointed out that digital health should be understood as "the knowledge and practice related to the development and use of digital technology to improve health", including a wider range of smart devices, digital consumers who use smart connected devices, and health service content combined with artificial intelligence and other technologies. Driven by this environment, digital health has developed to a certain extent in Africa, but there are also many obstacles.

1.2.1 Capital requirements

According to the estimate of the WHO, half to two-thirds of the world's population cannot fully obtain basic imaging technologies such as X-rays and ultrasound. At the same time, the utilization rate of medical imaging technology is quite different between low-income countries and high-income countries[8]. For example, only 14% of every 1 million people in low-income countries receive at least CT scanning, while the proportion in high-income countries is 100%. In addition, due to technical and non-technical problems, about 38.3% of medical imaging machines in developing countries can't work normally.

At the same time, the current number of medical imaging equipment in Ethiopia can not fully meet the needs of local people, and there are limitations in promoting digital health[4].The import of medical equipment and supplies in Ethiopia is mainly controlled by several companies, which limits the ability of medical institutions to obtain the latest and most advanced products. The dependence on a single source of medical supplies also raises concerns about the sustainability of medical care and the long-term cost-effectiveness of the equipment and supplies used by the medical and health departments.

The lack of sufficient operational talents in management institutions makes it difficult to implement necessary regulations and standards, which in turn leads to poor quality and effect of imported products and equipment. At the same time, it also affects the ability of regulators to effectively monitor and enforce the quality of care provided by health care providers.

1.2.2 Availability

Due to the high sensitivity of Ethiopia's domestic market to the price of medical products and the serious lack of professional knowledge to distinguish product quality, it is difficult for medical institutions to make wise purchasing decisions, which leads to a large number of low-quality products that do not meet the necessary standards being imported into China. This not only affects the quality of care provided to patients, but also exposes medical institutions to the risk of economic losses.

The prevailing bureaucracy within the Ethiopian government has also caused serious obstacles to the development of the health care sector. Due to the delay in the bidding process caused by government departments and the mixed data reports, it is difficult for medical institutions to make wise decisions and effectively manage and operate the overall medical structure. This also indirectly leads to the low detection and consultation efficiency of medical institutions and higher time and economic costs for patients.

There are also technical barriers in the process of promoting digital health, so it is necessary to reorganize the governance of medical information system (HIS) to support and manage digital medical work.

1.2.3 Affordability

One of the biggest challenges faced by Ethiopia's health sector is that the private sector lacks enough available foreign exchange to import necessary medical equipment and medicines. At the same time, this problem also makes medical institutions have a significant impact on the quality of treatment and care for patients. If the latest medical equipment and drugs are not available, the ability of diagnosis and treatment of patients in relevant hospitals will be greatly limited, and satisfactory results can not be obtained for both doctors and patients.

The poverty rate in this country is higher than 90% all the year round, and there are nearly 2.35 million unemployed people in Ethiopia by 2022. Compared with the previous year, this figure has increased. At that time, nearly 2.07 million people were unemployed, but they were still in the labor force. Generally speaking, the unemployment rate in Ethiopia has been on the rise since 2012, and it will rise sharply in 2020.

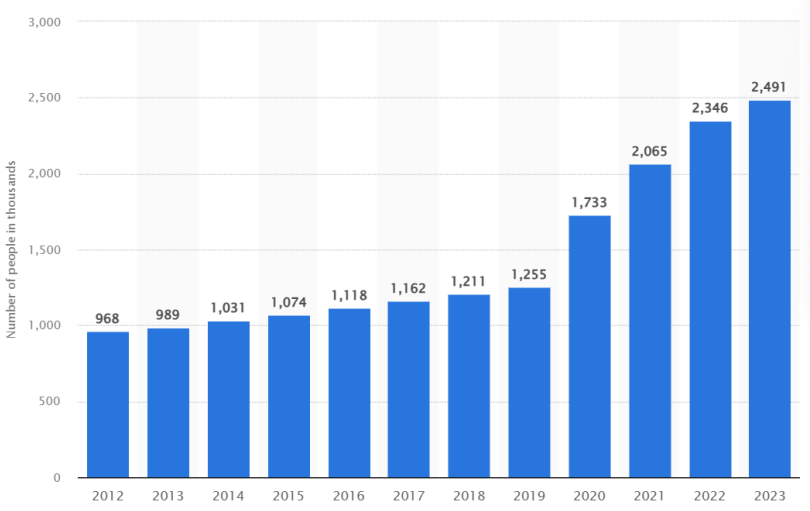

Fig.7 The poverty rate in Ethiopia

1.2.4 Effective marketing factors assessment

In addition to the lack of manpower in regulatory agencies, Ethiopia's health care sector is also facing a shortage of talents in other medical services and marketing, which not only greatly limits the nursing and rescue capabilities of medical institutions, but also reduces the acceptance of digital medical care in the entire medical capital market, and even reduces the ability to remain competitive in the rapidly developing medical and health care field. The popularity of the concept of digital health is still lacking, and it is still implemented in Ethiopia in a pilot way.

Most people have no idea about cloud diagnosis and mobile medical platforms, and the overall publicity scope is small. At the same time, they also lack cooperation and exchanges with large non-profit organizations and other friendly countries.

1.2.5 Policy consistency

Although several reforms have been implemented in HCF, it has made great contributions to medical infrastructure, medical supplies, diagnostic ability, drugs, financial risk protection and medical care services[9]. However, the Out-of-pocket(OOP) expenditure of Ethiopia's health system is still beyond the reach of a large part of the population.

Tab.3 Source of Health Financing in Ethiopia

Number	Source	Share of health spending
1	Donors	36%
2	Out-of-pocket	35.8%
3	Government	16.5%
4	Others	0.9%

1.3 Technical feasibility and costs involved in setting up a medical imaging center, operating and maintaining it.

Medical images in digital health play an important role in the diagnosis and treatment of diseases. Medical imaging widely includes X-ray, scanning technology (CT), magnetic resonance imaging (MRI) and ultrasound. However, due to the shortage of equipment and professionals, the popularization of medical imaging in Ethiopia is still in the initial stage of development. In order to effectively promote the development of digital medicine in Ethiopia, from the perspective of preparing for the establishment of a medical imaging center, it is necessary to consider the following aspects.

1.3.1 Equipment

In 2022, the global medical imaging market will be US$ 32.3 billion, and it is expected to grow at a compound annual growth rate (CAGR) of 4.8% from 2023 to 2030[10]. It is said that the increasing prevalence of lifestyle-related diseases, the increasing demand for early detection tools, technological progress to shorten turnaround time, the increase of investment and reimbursement measures taken by the government and the expansion of new facilities by market participants in developing countries will promote market growth.

Hospital-based imaging services should involve advanced diagnostic and interventional radiology functions, including neuroimaging, chest and abdomen imaging, tumor imaging, musculoskeletal imaging, breast imaging, pediatric

imaging, cardiovascular imaging and interventional radiology. Medical imaging center should be equipped with high-end ultrasonic scanner, digital radiography, fluoroscopy and mammography equipment, higher-level multi-slice CT, 1.5T MRI scanner with at least advanced software and all coils, and digital subtraction angiography equipment. Ideally, the medical center should also include nuclear medical equipment, including SPECT and PET. Nuclear medicine increases the complexity of surgery and relies heavily on the supply of radioactive tracers, but it is very important for the management of tumor diseases. When neurological and musculoskeletal diseases must be examined, MRI is very important, and when MRI examination is impossible, stroke management can rely on CT. According to the Imagine database and the data of the World Bank, in order to reach the level of high-income countries in terms of equipment, we need to invest an additional 11.4 CT per million people and 5.2 MRI per million residents in low-and middle-income countries.

In combination with the local medical situation in Ethiopia and the use and coverage of medical imaging equipment, the establishment of an independent medical imaging center should at least involve the following equipment:

(1) Computed Tomography

By Technology

High end slice

Mid end slice

Low end slice

Cone beam

(2) Magnetic Resonance Imaging

By Architecture

Closed System

Open System

(3) Ultrasound

By Portability

Handheld

Cart/Trolley Based

(4) X-ray Devices

By Modality

Radiography

Fluoroscopy

Mammography

Breakdown by application:

(1) Obstetrics and gynecology health;

(2) Orthopedics and musculoskeletal;

(3) Nerve and spine;

(4) Cardiovascular and thoracic cavity;

(5) General imaging examination

Breakdown by end user：

(1) Hospital
(2) Diagnostic center
(3) Academic institutions

1.3.2 Facility location and design

- **Computed Tomography**

Tab.4 Design of CT

Index	Parameter range
Movable range of scanning bed	≥1750mm
The speed of horizontal movement of the scanning bed	≥200mm/s
Minimum speed of horizontal movement of scanning bed	≤1mm/s
The scanning bed can be lowered to the distance from the ground.	≤450mm
The scanning bed can be raised to the distance from the ground.	≥960mm
Positioning accuracy of scanning bed	≤±0.25mm
Table load	≥205kg

Fig.8 Computed Tomography

- **Magnetic Resonance Imaging**

Tab.5 Design of MRI

Index	Parameter range
Power	1.5T
Effective diameter	60cm
Scanning speed	6 mm2/s
Maximum scanning field strength	45mT/m
Length	190cm
Width	70cm
Height	60cm
Weight	3000kg

Fig.9 Magnetic Resonance Imaging

- **Ultrasound**

Tab.6 Design of Ultrasound

Index	Parameter range
Color Doppler ultrasound machine Length	≤1500mm
Color Doppler ultrasound machine Width	≤600mm
Color Doppler ultrasound machine Height	≤1500mm

Fig.10 Ultrasound

- **X-ray Devices**

Tab.7 Design of X-ray Devices

Index	Parameter range
Bed height	690mm
Bed surface size	2000mm×760mm
Distance from bed surface to film	50mm
Transverse travel of bed surface	220mm
Longitudinal travel of bed surface	900mm
Tube strut moves longitudinally	1300mm
Tube strut moves vertically	800~1200mm
Camera	500mm,horizontal shifting

Fig.11 X-ray Devices

1.3.3 Cost of personnel (including tax, insurance, etc)

In Ethiopia, there are three main ways for people to get health insurance[11][13]:

- Government-funded CBHI/SHI programs cater to low-income individuals and those employed in the informal and formal sectors.
- Employers often provide health insurance as part of their welfare plans.
- Private health insurance options, such as those provided by William Russell, provide comprehensive protection for individual needs, whether you are a foreigner or a native of Ethiopia.

In Ethiopia, CBHI and SHI insurance systems provided by the government are the most popular. The CBHI scheme seeks to put an end to debilitating and potentially devastating out-of-pocket health expenses for the approximately 85% of Ethiopians who work in the informal sector[17]. Run by local district-level government with the guidance and financial support of the Ministry of Health and the Ethiopian Health Insurance Services, the CBHI scheme was first piloted in 13 woredas (districts) in 2010 and has since expanded to cover almost all the 832 woredas in the country[15]. Members pay a small yearly premium payment of 500 Ethiopian Birr (US$ 10), while there is a reduced fee of 240 Ethiopian Birr (around US$ 5) for dependents aged above 18 years[10].

SHI needs to pay 3% of everyone's monthly salary. According to the survey results, about 55.1% of the audience agree with the Ethiopian government's implementation plan for SHI (surname), 16.2% are neutral, and 28.7% disagree. Among those who don't accept the proposed SHI, 17% lack trust in obtaining various types of treatment through insurance, free treatment from their organizations and the implementation of the plan. Other reasons are inability to pay monthly premiums, poor quality of medical services, government/organization responsibility, feeling healthy and being able to pay

medical expenses, accounting for 18.5%, 13.5%, 12.8%, 11.8%, 9.8% and 0.9% respectively[16].

1.3.4 Supply availability

In the process of establishing an independent medical imaging center, it is also necessary to ensure the supply of relevant equipment and materials, and ensure the daily number of patients in the independent imaging center.

- **Medical imaging equipment**
  At least 2 X-ray devices, 1 64-sliceCT and 128-slice CT, 1 MRI1 with 1.5T or above, and 3 ultrasound devices are required. In addition, two electrocardiographs are also necessary.

- **Oxygen supply device and negative pressure suction device**
  Each radiation examination room must be equipped with radiation protection articles and basic rescue equipment, and the CT examination room must be equipped with cardiac defibrillator, simple respirator, oxygen supply device, negative pressure suction device and related drugs.

- **Occupational protective articles**
  In order to ensure the safety of doctors and patients, some common occupational protective articles such as helmets, goggles, protective masks, protective gloves, protective shoes and other equipment are also essential.

1.4 Assets required for operation and maintenance

1.4.1 Item

An independent medical imaging center should consist of the following parts:

- Required departments: including radiology, ultrasound, equipment information and auxiliary departments.
- Selected departments: other departments related to the independent medical imaging center, such as nuclear medicine department or personnel training department.
- Equipment: at least two X-ray devices, one 64-sliceCT and one 128-slice CT, and one MRI1 of 1.5T or above shall be equipped; 3 sets of ultrasound (with color Doppler flow imaging, cardiac ultrasound examination, contrast-enhanced ultrasound and quantitative analysis functions); 2 electrocardiographs. On this basis, SPECT, PET-CT and PET-MRI can be selected to carry out nuclear medicine examination and diagnosis. At the same time, protective and first-aid equipment, information equipment,

rescue rooms, rescue equipment and first-aid drugs are also essential.

- Independent medical imaging center can be equipped with examination room, control room, film reading room and computer room according to specific conditions.

1.4.2 Source

The high cost of radiation equipment puts high demands on the budget of public health departments. When supplemented by non-governmental organizations, this unbalanced distribution may be solved to some extent. However, the imaging cost of the public cannot be completely reduced, and the public must pay part of the cost.

1.4.3 Cost

In order to promote the operation of the local independent medical imaging center in Ethiopia and the development process of digital medical care, it is necessary to consider the overall operation and maintenance expenses from the following aspects.

- Equipment purchase and maintenance expenses: including the purchase and maintenance expenses of medical imaging equipment such as CT, MRI, ultrasound and X-ray Devices.
- The salary and training expenses of the imaging personnel: not only the staff of the imaging center, but also the technical support personnel and IT maintenance personnel that may be needed.
- Power and network costs: Power consumption and network connection costs are the basic needs of the daily operation of the image center.
- Rental and maintenance expenses of the site: During the operation of the imaging center, it is necessary to pay the government the rental expenses of the site, including the maintenance and repair expenses of the property.
- Administrative and other miscellaneous expenses: including office supplies, equipment maintenance, insurance, taxes and other administrative and other miscellaneous expenses of the imaging center.

1.4.4 Available financing methods

The Ethiopian banking sector is currently comprised of a central bank (The National Bank of Ethiopia or NBE), one state owned development bank, a government owned commercial bank, and twenty one private banks, including newly established banks Amhara Bank, Zamzam Bank and Hijra Bank.
Currently, Ethiopia has allowed a small number of foreign banks to open liaison offices in Addis Ababa to facilitate credit to companies from their countries of origins. Chinese, German, Kenyan, Turkish, and South African banks have opened

liaison offices in Ethiopia.

Based on the most recently released data, the Commercial Bank of Ethiopia (CBE) holds more than 60% of total bank deposits, bank loans, and foreign exchange. NBE controls the bank's minimum deposit rate, which now stands at 7%, while loan interest rates are allowed to float.

1.5 Impact on the health system and communities in Ethiopia

1.5.1 Impact on the health system in Ethiopia

In view of the overall quality of medical and health services in Ethiopia, combined with the induction of survey data, in order to effectively promote the local digital health process in Ethiopia, the diagnosis and treatment model of digital health represented by medical imaging technology needs to be continuously improved from the following six aspects, so that it is easier to help the digital health industry make greater contributions in Ethiopia[19]. These six aspects include： the quality of local medical and health services from the following seven directions, including the hardware indicators of medical environment, the technical quality of medical care, the degree of humanistic care of medical care, the perfection of medical security system, the medical management framework, the fairness of medical care.

Tab.8 Quality factors and indicators, as found in the literature

Author (s)	Service-quality factors and indicators	Outcome/Model/Application
Donabedian (1980)	7 factors: efficacy, effectiveness, efficiency, optimality, acceptability, legitimacy and equity	In healthcare studies
Maxwell (1984), in the UK	6 factors: effectiveness, efficiency, acceptability, accessibility, equity and relevance	In healthcare studies
Parasuraman, et al (1985), in the USA	Parasuraman, et al (1985), in the USA	Developed the SERVQUAL model for services
John (1989)	4 factors in healthcare: curing, caring, access and physical environment	In healthcare studies
Reidenbach and Sandifer Smallwood (1990), in the USA	Patient confidence, empathy, waiting time, physical appearance, support services and business aspects	In healthcare studies

Cunningham (1991), in the USA	Clinical quality, patient- and economics-driven quality	In healthcare studies
Headley and Miller (1993)	6 factors: dependability, empathy, reliability, responsiveness, tangibles and presentation	Used original SERVQUAL items for medical services
Peyrot, Cooper and Schnapf (1993)	3 factors: (1) staff behaviour; (2) pre-examination comfort; and (3) examination comfort	In healthcare studies
Gabott and Hogg (1994)	6 factors: (1) service range, (2) empathy), (3) physical access, (4) doctor specific, (5) situational, and (6) responsiveness	In healthcare studies
Tomes and Ng (1995), in the UK	8 factors: empathy, understanding of illness, mutual respect, religious needs, dignity, food and physical environment	In healthcare studies, using the Gap model
Zairi (1998), in the UK	Deming Prize, Malcolm Baldridge National Quality Award (MBNQA), European Quality Award, and the George M Low NASA quality award	In healthcare studies
Gross and Nirel (1998), in Ireland	Accessibility, structure, atmosphere and interpersonal relations	In healthcare studies
Shemwell and Yavas (1999)	3 factors: search attributes (5 indicators), credence attributes (4 indicators), experience attributes (5 indicators)	Hospital service quality (perception only scores) in the USA
Ovretveit (2000a), in Sweden	Client, professional and management quality	In healthcare studies
Drain (2001)	4 factors: (1) care provider, (2) access to care, (3) office visit, and (4) personal issues	In healthcare studies
Lim and Tang (2000), in Singapore	Parasuraman, et al (1985) 5 factors plus accessibility/affordability	Applied SERVQUAL in healthcare services
Sower, et al (2001), in the USA	8 factors: respect and caring (26), effectiveness and continuity (15), appropriateness (15), information (7), efficiency (5), effectiveness - meals (5), first impression (1), staff	Perception-only scores

	diversity (1)	
Trucker and Adams (2001)	Caring, empathy, reliability and responsiveness	Applied SERVQUAL in US hospitals
Walters and Jones (2001), in New Zealand	Security, performance, aesthetics, convenience, economy and reliability for measuring the service quality of hospitals	In healthcare studies

Through literature research and data review, the repeated factors and indicators are eliminated. According to the structure of local health system in Ethiopia, the establishment of independent medical imaging center can make a positive impact on local medical system in Ethiopia from the above six aspects.

Tab.9 Impact on the health system in Ethiopia

Items	Contents
Tangibles	Including the renewal iteration of physical facilities and the high efficiency of case file exchange between doctors and patients.
Technical qualities	Including professional medical practitioners, high-precision medical equipment and reasonable expenses.
Personnel care	Including the improvement of medical staff's empathy, caring, hotline and support staff's responsiveness (willing to help customers and provide timely services), support services, food, noise, room temperature, privacy, cleaning and treatment explanation.
Assurance	Including the improvement of medical knowledge competence (knowledge), treatment quality, courtesy and safety, communication, credibility, accessibility (waiting time), pleasant environment and patient confidence.
Medical-administration procedure	Including the improvement of input (admission process), clinical nursing process, output (discharge process), patient outcome (relieving pain, saving lives, or gaining a better outlook on life), cooperation and social responsibility (service environment).
Reliability	Including the improvement of fairness and equity

1.5.2 Impact on Ethiopian communities

Under the background of digital health promotion, considerable progress has been made in achieving development results, especially in the health sector. Its core is reform, giving priority to community-based health interventions[11].

Through the training and deployment of 30,000 health workers who are responsible for providing outreach services, the health care program is being implemented in all regions of the country. With kebele as the center, this is the smallest administrative organ, with an average of about 5,000 people[12]. hep is in a health station, which is the business center of two hew. Health departments at the federal, regional and county (district) levels are responsible for supervising health care services, which are linked with voluntary community health workers to further support the sharing of health knowledge and skills at the family level. The intervention focuses on families and communities, but the program requires coordinated actions of governments at all levels, and larger administrative agencies provide referral care, technical and practical support for Health Extension Program（HEP）at the community level[14]. Through this decentralized way of providing health care services, the government provides funds to regional and county governments to cover the curriculum development, training and salary of health care personnel, so that health care personnel can become civil servants with clear career development paths.. External support from donors is also the core of public health projects, which are designated as the construction of health stations, the purchase of equipment, goods and supplies, training and capacity building.

Chapter 2 Uganda

2.1 Holistic analysis of quality health services and advantage assessment in Uganda

2.1.1 Needs for quality health services

Uganda is a landlocked country in East Africa. It is bordered by Kenya in the east, South Sudan in the north, the Democratic Republic of the Congo in the west, Rwanda in the southwest, and Tanzania in the south. The southern part of the country includes a large portion of Lake Victoria, which is shared with Kenya and Tanzania. Uganda is located in the Great Lakes region of Africa, within the Nile River Basin, and has a diverse but generally modified equatorial climate. As of 2023, it has a population of about 49.6 million, of which 8.5 million live in the capital and largest city, Kampala, near Lake Victoria.

Fig.12 Geographical location of Uganda

- **Age Structure and Population Policy**

Uganda's population has gradually shifted from a population-responsive policy to a population-influencing policy. The aim is to accelerate the decline in fertility and mortality and to achieve a population age structure conducive to development by reducing the burden of dependency and increasing investment in young people. Consequently, the 23rd edition of the SUPRE will run under the theme, "Mindset Change for A Favourable Population Age Structure: A Prerequisite for Wealth Creation." The theme recognizes that a positive mindset, a balanced population age

structure, and dynamic wealth creation policies are crucial in creating an environment conducive to long-term economic growth and stability.

In the area of reducing female fertility, Uganda is working to reduce the rate of teenage pregnancies, as well as to reduce the risk of unwanted pregnancies, improve maternal and child health and achieve eugenic fertility. These have demonstrated the need for diagnostic and related quality care in imaging centers.

Uganda's young demographic also opens up possibilities for the country's current health-care workforce shortage, which is of varying quality. If institutions and governments can invest in training and education for young people, the large young population can gradually be effectively utilized to secure employment in quality healthcare. At the same time, as life expectancy (61.7 years for men and 65.9 years for women)and urbanization rates continue to increase in Uganda, there is a growing social demand for quality health care.

- **Disease burden**

The disease burden in Uganda is dominated by communicable diseases, which account for more than 50 percent of morbidity and mortality. Malaria, HIV/AIDS, tuberculosis (TB), respiratory diseases, diarrhea, epidemics and vaccine preventable diseases are the leading causes of morbidity and mortality. The burden of non-communicable diseases (NCDs), including mental illness, is also increasing. Maternal and perinatal diseases also contribute to high mortality rates. Neglected Tropical Diseases (NTDs) remain a big problem in the country, affecting mainly poor rural communities. In addition, there are wide variations in health status across the country, which are closely linked to underlying socio-economic, gender and geographic differences.

Uganda has the third highest malaria case burden globally in 2021 (5.1%) and the seventh highest number of deaths (3.2%). it has the highest proportion of malaria cases in East and Southern Africa in 2021, at 23%. The country is off-track to meet the Global Technical Strategy for Malaria targets as the incidence rate per 1,000 population has increased since 2015, widening the gap between the targets and the actual incidence rate. Uganda's Malaria Roll Back and Elimination Strategic Plan 2021-2025 aims to reduce malaria infections by 50 per cent, morbidity by 50 per cent and mortality by 75 per cent by 2025. The plan aims to achieve these targets through a tiered approach that ensures an appropriately adapted mix of interventions for various epidemiological settings, universal coverage of services (including the private sector), strong data management and social behavioral change, multisectoral collaboration, and elimination of malaria in two districts. For HIV, the estimated total number of PLHIV was 1,400,000 as of Dec 2020 compared to 1,200,000 in 2010.

Tuberculosis is an another very prevalent and expensive disease in Uganda. The number of TB cases in 2020 was estimated at 90,000 giving an estimated burden of 199 TB cases per 100,000 population. Approximately 1.2 million people were receiving antiretroviral treatment in 2022For any TB patient to start treatment, a chest X-ray is required. This highlights the huge need for diagnostic imaging.

- **Health needs**

Uganda's health system has made significant progress in the last few decades. According to the Government Report 2021, all Districts in Uganda have a District Referral Hospital/Health Center IV, and 86% of the population lives in an area with a health facility within 5km with access to basic health services. Meanwhile, private health facilities provide about 50% of hospital health services and 35% of primary health care services, although most of them are located in relatively developed urban areas.

Primary health care is provided mainly through government-run public facilities with national and district referral networks, which account for 66% of the country's health service delivery output. Uganda provides primary health care through its National Minimum Health Care Package (NMHCP), which aims to provide equitable health promotion, disease prevention, and child and maternal health through the provision of a range of essential services to the entire population.

However, In Uganda, access to health care is still limited, with out-of-pocket payments at 41%. This means that sometimes people have to sell their investments to pay for health care, which keeps them in poverty.

- **Overview of Uganda's health system**

Administratively, Uganda is divided into 136 Districts and 191 Counties; each County is divided into Sub-Counties and they are divided into Parishs.

In Uganda's health service hierarchy, Level 1 health services are mainly provided by village health teams composed of volunteers who are not able to provide laboratory testing services, while Level 2 is usually located in relatively remote or underdeveloped areas with basic and rudimentary facilities that can only provide the most accessible health services at the grassroots level (only screening for basic diseases such as hepatitis and malaria using rapid tests) and weak professional capacity of the health service personnel. The professional capacity of health service providers is weak. Level 3 facilities are able to conduct pregnancy tests (HCG), etc. Level 4 facilities have a wider range of tests and can usually offer: HIV 1&2 screening, Hepatitis B, Syphilis, Sickle Cell screening, etc. The most difficult tests are usually conducted in Level 5 facilities, usually in General

Hospitals/District Referral Hospitals, located in capital cities or more developed provincial cities. The most difficult tests are usually performed in Level 5 facilities, usually General Hospital/District Referral Hospitals, which are located in capital cities or more developed provincial capitals.

Vertical inequalities in test access are high, with limited testing capacity in Level 2-4 facilities, which make up the bulk of the health system, and the need for smaller, more portable and adaptable testing equipment (e.g., POCT) to facilitate decentralization and decentralization of high-quality testing, and to improve diagnostic and therapeutic capacity by increasing access to testing nationwide.

As for the situation of public and private health services, in general, the Ugandan health system is highly centralized, with public facilities and their referral systems at the heart of the health system. And the higher the level, the more dominant the public system. While private facilities are numerous, a large number of small grassroots clinics and a small number of high-end hospitals are located in the more developed areas. In terms of equipment procurement, the public system is strongly centralized and highly dependent on international cooperation, while the private market is relatively fragmented.

Tab.10 Structure of the Uganda Health System in 2021[24]

HEALTH UNIT	PHYSICAL STRUCTURE	LOCATION	POPULATION
Health Centre 1/ CHW	None	Village	1,000
Health Centre ll	Outpatient services only	Parish	5,000
Health Centre lll	Outpatient services, maternity.general ward, laboratory	Sub-county	20,000
Health Centre IV	Outpatients, wards, theatre,laboratory, blood transfusion	County	100,000
General Hospital	Hospital, laboratory, x-ray	District	100,000 – 1,000,000
Regional Referral Hospital	Specialist services	Region	1,000,000 – 2,000,000
National Referral Hospital None	Advanced tertiary care	National	Over 20,000,0000

- **Digital Health in Uganda**

Before Pandemic, Uganda has failed to move ehealth from the periphery to the

center of strategic health planning. This is largely due to the fact that the current state of ehealth development in developing countries has led to a proliferation of unsustainable pilot projects that expire once the initial funding is depleted. For example, Uganda had 23 eHealth initiatives in 2008 and 2009 that were not scaled up after the pilot phase.

Uganda launched in May 2018 its National eHealth Policy and Strategy. Leadership and governance, workforce development, enterprise architecture, and health information systems integration and interoperability are key areas for the strategy's implementation. Most importantly, the strategy calls for "the adoption of harmonized eHealth initiatives at all levels," considering the various digital health information systems (HIS) that have taken root in the country. At this point in time, technologies such as cloud computing, big and open data, data analytics, intelligent systems, digital services and the Internet of Things (IoT) have been adopted in Uganda, but not in an organized manner.

A typical project to address the above is the Digital Health Atlas. It provides an opportunity to harmonize the major investments being made and to enable ministries of health and their partners to fully understand the current state of functionality, interoperability and reusability of current investments in technology platforms.

The Digital Health Atlas (DHA) is a web-based technology registration and evaluation web platform developed by an open-source digital health software to enable governments, technology implementers, and donors to manage information existing and new digital health deployments, supporting cataloging of relevant sizes, functionalities, data capture, investments, and uses. It becomes Uganda's registration and evaluation platform for the Ministry of Health, technology implementers, and donors to manage information about existing and new digital health deployments. It will support the implementation, validation and certification process for government-led digital health investments. At the same time, investors will be able to review the current scale and health focus areas, as well as the relative readiness of a particular scale of digital health projects. At the time of 2018 DHA showed that Uganda had a total of 3 relevant programs at the national level. （mTrac、UgandaEMR/OpenEMR、DHA Wiki）, In 2023, there are 34 related projects at the national level and 17 at the Sub-National level.

Second is Stre@mline, developed to develop rural and remote health facilities in sub-Saharan Africa, by software developers at a Ugandan technology startup called istreams (an acronym for Innovation Streams) and a team of doctors at Kisiizi Hospital, a private, not-for-profit hospital in southwestern Uganda. The electronic health record (EHR) is an important part of the successful management of diseases such as HIV/AIDS and tuberculosis. One of the public health challenges is the high rate of "lost to follow-up" patients, and EHR is considered one of the best solutions.

Preliminary evidence suggests that EHRs can significantly reduce the number of HIV patients lost to follow-up by approximately 24%. In addition, EHRs can be used for long-term follow-up of chronic diseases such as cancer, hypertension, and diabetes, and to ensure that patients are receiving treatment according to the correct guidelines. In addition, accurate and thorough data collection using EHRs can also inform the targeted allocation of limited resources by identifying trends and helping to set priorities.

Tab.11 Key local health care challenges addressed by Stre@mline[25]

Issue and problem	Stre@mline response
Follow-up for long-term treatments	
High number of patients lost to follow-up	Monitoring of follow-up attendance, facilitation of contacting patients to ensure good on-going care in place
Medicines	
Severe shortages of drugs	Live monitoring of stock levels of medicines and triggering ordering in good time to avoid stock-outs
Drugs often expire in storage, wasting valuable resources	Warns pharmacists of drugs due to expire in 2 months, facilitating better resource planning by pharmacists and prescribers
Auditing of drug prescribing errors is often poor or erratic	Facilitates 100% capture of prescribing errors through built-in linkage to the Uganda National Drug Authority drug reactions reporting system
Triage	
Triage often poorly done, especially in children	Incorporates the World Health Organization Emergency Triage, Assessment, and Treatment (ETAT) tool and the locally developed Kisiizi Early Warning System
Paper-based triage systems were often omitted or only partially done	Ensures that 100% children are properly triaged using ETAT tool as it uses mandatory fields. Users rapidly learn the new routine and comply happily as they see the benefits.
Medical records	
Often incomplete, poor quality records were kept	Captures key data relating to a patient's symptoms, investigations, treatment, and follow-up
Patients often forget to bring previous notes, images, etc, and may end up undergoing unnecessary	Allows files to be stored (eg, x-rays, clinical letters, and photographs, for immediate access in future)

duplicate tests	
Customization	
Commercial systems are often difficult and expensive to customize to local requirements	Stre@mline is designed to allow free, easy, and comprehensive customization by local institutions to ensure that the system is optimal for the local environment

In summary, Stre@mline can be understood as a locally developed EHR system in Uganda, tailored to the specific needs of a resource-constrained environment. It is unique in that it was developed entirely locally through a partnership between a local hospital and a local technology company.

By 2023, over 40+ hospitals in Uganda are already using Stre@mline, and according to reports, users are generally very satisfied with Stre@mline's ease of use and have found that Stre@mline helps to improve clinical efficiency and enhance patient care.

During the Pandemic period, although Uganda's health system was experienced in responding to outbreaks of infectious diseases such as Ebola and cholera, the public health sector was chronically underfunded and understaffed, especially in rural areas. The doctor-patient ratio was only 4 percent of the World Health Organization's recommendation, and most health professionals worked in several large cities. For a country of about 44 million people, there is almost no available protective equipment, and only 55 ICU beds are available, 83% of which are located in Kampala City and 75% in private hospitals.

At the same time, in response to the 2019 coronavirus, Uganda has put in place operational restrictions to curb the spread of the disease. However, this has also rendered the healthcare system incapable of meeting most of the healthcare needs of the population outside of hospital premises, which in turn has led to an unprecedented demand for remote delivery of health information and telemedicine using digital health technologies. A survey that quantified the imaging needs of five selected hospitals in Uganda based on the burden of disease in those hospitals concluded that the imaging equipment available in Uganda during the pandemic met only 36% of the imaging needs of those hospitals. And up to 50% of patients required ultrasound and X-ray (in most cases) imaging. Recently, the Infrastructure Department of the Ministry of Health, with the assistance of the Institute of Infectious Diseases (IDI) at Makerere University, has begun to expand this medical equipment database, however, the relationship between national health expenditures, national health indicators, and in-country access to diagnostic imaging has not yet been rigorously evaluated.

A recent survey showed that 91 digital health tools were used in Uganda's health

system between 2010 and 2020, of which 35 have been deployed to support the COVID-19 response.The use of telemedicine addresses the remote delivery of healthcare services using information and communication technologies to support and enable remote patient care, maintenance of patient health records and delivery of patient and professional health services. The pandemic has expanded the use of related technological developments such as telemedicine in the delivery of healthcare services in Uganda. The use of teleconsultation by private traditional healthcare providers has helped improve the correctness of hospitalizations and referrals to specialist services, effective response to requests for diagnostic tests and management of chronically ill families. This has also provided a better digital communication platform for the development of Medical Imaging Center.

One example is that during the epidemic, a local consortium in Uganda, in collaboration with the Ministry of Health, developed a telemedicine approach through the establishment of a call development center in Kampala, designed to inform community health workers about COVID-19, support them in identifying, referring, and managing cases, and assist them in delivering basic health services and products. The call development center, staffed by nurses and doctors, supports approximately 3,500 community health workers working in 23 rural areas and is supported by a non-profit organization called Healthy Entrepreneurs (HE). Research has demonstrated that telemedicine approaches are well suited to support CHWs' routine health services in rural communities. Call centers provide CHWs with quick, free access to the expertise of health professionals who answer questions and provide advice on diagnosing, referring, and treating patients.CHWs feel well-informed, less isolated, and express support for helping them provide better care. This is also the status quo in many countries in sub-Saharan Africa, where CHWs play an important role in providing basic care in rural and remote areas.

In addition to that, during the epidemic, Uganda also applies technology to support testing, contact tracing and surveillance, as well as risk communication and community mobilization. Technology also supports supportive surveillance, training and maintenance of basic health services.

Tab.12 Use of technology in Uganda'S COVID-19 response[26]

Aspect of COVID-19 response	Application of technology
Testing	Instant access to COVID-19 laboratory results, their dispatch and management to support quick action.
Contact tracing and surveillance	Communication of results and follow-up of COVID-19-positive clients.
	Registration and payment of testing fees such as at the airport.
	Verification of results and traceability to the

	laboratory test centre.
	Reporting of testing data by facilities.
	A mobile phone application supported the issuance of COVID-19 digital certificates.
	Tracing of contacts.
Risk communication and community mobilisation	Transmission/sharing of data such as daily situational reports from the lower levels to the centre or within the same levels.
	Conduct surveillance such as using the Electronic Integrated Disease Surveillance and Response System.
	Screening, clearance and tracking of travellers at border districts.
	Website with dashboard providing updates on surveillance.
	Develop multilingual information and communication campaigns.
Supportive supervision and training	Share COVID-19 information and messages through mobile phones and social media.
	Citizen engagement for feedback and data collection on important COVID-19 impacts.
	Obtain and monitor incidents, beliefs and opinions about the pandemic.
	Supportive supervision and mentorship of health workers.
Maintenance of essential health services	Training health workers on COVID-19 prevention and management and other services.
	Communicate guidance on the maintenance of health services and other guidelines.
	Mobile applications facilitated adherence to the MOH COVID-19 guidance by community health workers.
	Phones supported improved communication between community health workers and health facilities.
	Communication campaigns about adjustments to critical services delivery and encourage continued access to health services.
Maintenance of essential health services	Provision of information about services, conduct triage and appropriately refer clients.
	Reach out to clients with scheduled clinic visits such as through phone calls.
	Electronic logistics management information

	system facilitated the procurement process for COVID-19 commodities.
	Provision of health services including health information remotely including consultations, mental health and psychosocial support, and laboratory testing.
	Ordering and delivery of health products and commodities.
	Providing instructions such as through videos and follow-up of clients to ensure medication adherence and reduce lost to follow-up.
	Reach out to district or health authorities to avail transport for critical services such as delivery
	Establishment of toll-free telephone numbers for victims of gender-based violence to access services.
	Training youths to use social media platforms to advocate for services utilisation, such as contraceptives

Challenges to the use of digital technologies in Uganda in terms of concrete implementation include:
(1) Duplication of efforts due to different digital tools and health information systems；
(2) Limited access to and coverage of digital tools and poor data quality;
(3) Data inaccessibility;
(4) Inability to support data manipulation, analysis and visualization;
(5) Inadequate technical support systems, e.g., weak Internet/electricity infrastructure

In this regard, the centralized storage, management, and sharing of image information by patients in digital imaging centers can significantly assist healthcare digital technology in decision-making and precision treatment on image big data, thus improving the challenges of ii and iv in digital technology in Uganda.

In the post epidemic era, under the National Development Plan 2020/21/21-2024/25 (NDPIII) and the Ministry of Health's Strategic Plan 2020/21-2024/25, which prioritizes the achievement of Universal Health Coverage (UHC), the goal is to increase UHC coverage between 2020-20 and 2025 from 48% to 65%. A number of health information and digital health system challenges remain, posing a threat to the failure of UHC's stated goals, as without quality data, health programs cannot measure progress and timely program improvement decisions are

hampered. The Uganda Health Information And Digital Health Strategic Plan 2020/21-2024/25 proposes that by 2025, Uganda's health sector needs to institutionalize the use of patient-level digital systems at the point of care and establish a functional collaborative mechanism at the MoH that supports research and innovation in health information and digital health implementation.

Over the past 5 years, digital health development in Uganda has been focused on implementing patient-level EMRs (e.g., Uganda EMR, iHFMIS, Clinic Master, eIDSRS, Covid-19 Vaccination Register). However, the operability of these patient-level digital systems is primarily low-scale and falls short of the digitization needs of the national health sector. Due to the broad nature of the digitization process, the deployment of EHRs in 2023 will be implemented in four phases:
(1) Implementation to July 2023 (23 national/regional referral hospitals and MoH data centers);
(2) Starting July 2023 to November 2024 (70 hospitals and regional data centers);
(3) Starting Nov 2024-July 2025 (183 hciv)
(4) From July 2025 (over 2064 HCIIIs)

As of 2023, EHR have been deployed in 15 hospitals (5 hospitals, 6 hospitals and 4 hospitals). In addition to this, a key priority of the current MoH-developed Strategic Plan 2020/2021-2024/25 is the strengthening of health information systems. Health information systems provide an opportunity to realize some of the core objectives of health information management and provide a basis for critical decision making. MoH is committed to strengthening its implementation at the community level with a focus on prevention and health promotion. As part of this process, MoH is implementing a Community Health Information System (eCHIS) for use by Village Health Teams (VHTs) as a digital job aid in service delivery. In the post-pandemic era, the Government of Uganda is committed to improving the use of digital health technologies, which have played a fundamental role in facilitating the provision of timely and quality health information and the delivery of improved health services.

A representative project of this period is digital health Uganda, whose goals include overhauling Uganda's healthcare system using cutting-edge technologies such as artificial intelligence (AI), cloud computing, 3D printing, and blockchain to improve patient outcomes while lowering overall healthcare costs. It also aims to streamline and automate hospitals, clinical data, and disease management across the entire patient care continuum.

The first product of the project is NextGen HIMS. it is a modular platform for disease surveillance, risk factor assessment, diagnosis, treatment, management, and public engagement. Key elements of the product include image analysis using artificial intelligence and the use of data science to provide insights for disease diagnosis and hospital management. The Medical Imaging Center, a key data

source for NextGen HIMS, is pivotal in the product's patient information management system, PIMS. PIMS needs medical imaging centers to provide it with data support, and it can in turn provide it with more relevant patient history and personal circumstances, thus helping it to better synthesize its analysis. For the patients themselves, it allows them to visualize their diagnoses, making it easier to understand their condition and reduce commuting costs, enhancing the implementability and efficiency of telemedicine. In addition, medical imaging centers can also use NextGen HIMS as a medium to integrate the imaging information systems of various medical institutions, ultimately realizing the centralized management and interconnection of patient examination information and imaging data.

The second product of the project is ONCIMS (Advanced Integrated Oncology Information Management Platform), which provides hospitals with customizable electronic health record management. The development of ONCIMS also advances medical imaging technology. It makes pap smears more accurate and reliable by developing a computer-aided diagnostic tool that can automatically diagnose and classify cervical cancer based on pap smear images.

In summary, we can see that in the post epidemic era, the development of Medical Imaging Diagnostic Centers (MIDCs) and digital healthcare are complementary to each other. Digital healthcare needs the development of Medical Imaging Centers to provide it with a more accurate and efficient source of data; and Medical Imaging Centers need to leverage on digital platforms to increase the popularity of their medical services.

Currently, digital health and imaging center collaborations include, but are not limited to, the following forms:
(1) The integration of telemedicine + digital imaging centers can help patients located in rural areas to avoid the inconvenience of commuting to provincial cities;
(2) The integration of patient bio-database + digital imaging center can provide Medical Imaging Center with more reference data when issuing diagnostic imaging opinions, making its program more accurate;

The digital platform also makes it possible to connect data from public and private digital imaging centers, breaking down the isolation of Uganda's regional healthcare institutions, further improving the quality of medical services, and facilitating access to patients, thus ultimately helping Uganda to achieve sustainable development of "Good Health and Well-being" (SDG 3).

- **Development in Africa on Medical Imaging Center**

The development of the Medical Imaging Center coincides with the involvement of African countries, represented by Uganda, in global health themes and programs,

such as the Sustainable Development Goals (SDGS). The development of the Radiation Safety in Africa (RSA) campaign has raised awareness of imaging quality and safety in Africa. And partnerships with organizations such as professional associations, global institutions, etc. have also fostered interest in the development of related fields. If Uganda is to achieve the SDGs, there is a need to increase the number of devices per million population by providing different radiological devices throughout the country.

At the same time, the past decade has seen a growing interest in imaging quality and safety in Africa. This interest can be attributed to participation in global health themes and programs such as the Basic Safety Standards (BSS), the Bonn Call to Action (BCA), Universal Health Coverage (UHC), and the launch of the African Radiation Safety Campaign. This has been further exacerbated by shifts in the burden of disease due to neglected tropical diseases, maternal and childhood diseases, non-communicable diseases, trauma, cancers, HIV, tuberculosis, and the recent change in trend of the COVID-19 pandemic. The launch of the African Radiation Safety Campaign has raised awareness, mobilized and focused consciousness in Africa on the quality and safety of imaging. In addition, partnerships and collaborations with professional associations, global institutions and organizations such as WHO and IAEA have promoted interest in quality and safety.

Healthcare technology, including diagnostic imaging, is recognized as an essential component of any healthcare system. Essential medical diagnostic imaging services such as radiographs and ultrasound are necessary for effective primary healthcare for patients.

If Uganda is to satisfactorily achieve the SDGs, there is need to increase the number of equipment per million population through the provision of different radiological equipment throughout the country. This calls on the Ministry of Health in collaboration with other stakeholders to increase funding to enable Uganda reach the WHO recommended figures. It is well documented that this relates to the provision of effective primary health care, which is very important for the achievement of Universal Health Coverage (UHC) and also affects Uganda's ability to achieve the Sustainable Development Goals (SDGs).

2.1.2 Existing market size

- **Digital Health Market**

According to a report by statista, the digital health market in Uganda is expected to generate revenue of $176.30millions in 2023. The largest of these markets will be digital fitness & wellness with a total revenue value of $108.70millions in 2023. The second largest market is followed by digital treatment & care. customers in

the digital health market are increasingly looking for solutions that enable remote access to healthcare services, such as telemedicine and remote patient monitoring. They also prefer digital solutions that provide personalized and proactive healthcare, such as wearables and mobile health apps.

One of the major trends in the digital health market is the adoption of telemedicine services. Telemedicine allows patients to consult healthcare professionals remotely, thereby reducing the need for in-person visits and providing convenience. Between 1980 and 1982, Uganda undertook a telemedicine project in collaboration with international organizations to plan for technology implementation. With the increasing popularity of e-health and m-health technologies, especially during the period 2012-2016, there has been a rapid growth of telemedicine services in the Uganda region. In 2019, Uganda is focused on upgrading current telemedicine services to realize their full potential in smaller rural communities, and providing triage and referral services to the public through the establishment of call centers and online health to enhance the continuity of patient healthcare.

In summary, the digital health market is growing rapidly due to customer preference for convenient and accessible healthcare solutions. Medical Imaging Centers, as standalone facilities applying modern imaging technologies such as X-rays, CTs, MRIs, and ultrasound to examine the human body and combine them with medical history, clinical signs, symptoms, and other ancillary exams, comprehensive analyses, and diagnostic imaging opinions, are also an important data source component of digital healthcare. It is also an important data source for digital healthcare, and its market demand is increasing with the development of telemedicine services in Uganda.

- **Development of radiology**

Teleradiology, as a branch of telemedicine under digital health, involves taking images and data to another radiologist in another location for medical interpretation for diagnosis and analysis, and is an equally important source of data for Medical Imaging Centers. At the same time, diagnostic imaging systems can be designed to significantly improve the quality of care and the efficiency of clinical workflow. 2021 A related investigation using St. Francis Hospital Nsambya in Kampala, Uganda, as a study site, showed that patient turnaround time was dramatically reduced from an average of 22.65 minutes to 4.8 minutes by sharing radiology images directly over the network and making them available on a general PC-based display system in the emergency room. In similar studies, electronic delivery of medical images has been shown to improve radiology workflow. Digital imaging is therefore key to emergency care, such as acute case management, allowing rapid access to diagnostic information critical to making clinical decisions and adherence to Digital Imaging and Communications in

Medicine (DICOM) standards.

In this area, back in 2016, Uganda had developed advanced institutions such as the Uganda Heart Institute and Mulago Hospital associated with Makerere University, which have successful programs in several clinical and surgical specialties. Both institutions already had CT scanners and digital radiography equipment, which were acquired with the help of the Government of Uganda and international entities such as the United States Agency for International Development. This technology brings the potential for comprehensive training and education of healthcare workers to provide better quality clinical services to the community; and by 2019, the Artificial Intelligence Laboratory at the Lord Makerere University in Uganda had begun experimenting with research on AI and breast cancer. Research on contrast elastography, machine learning and AI in ultrasound is already underway in Uganda at this time.

In 2023, the Ministry of Health established a Teleradiology Center at the National Referral Hospital in Mulago to assist in the transmission of digital radiology images through CT scanners located at the regional referral hospitals. The local Uganda Radiological Society, which has been in existence for five years, has provided technical support to Ugandan hospitals in the use of improved diagnostic and therapeutic techniques in medical imaging, radiology, and allied sciences, and as of today the society has 500 specialist doctors and 115 members.

- **Number of healthcare facilities**

According to the Uganda Health Facility Registry, as of February 2023, there were a total of 6,937 healthcare facilities in Uganda. 1,200 clinics, 1,017 health centers and 50 referral hospitals. Of these, about 3,483 (50 %) were publicly owned, while about 2,935(42%) were privately owned.

- **Healthcare and trade regulation environment**

The government is working to promote access to affordable and quality healthcare services, while also promoting innovation and investment in the healthcare sector. The NDA also regulates the medical supplies in Uganda. Importers must obtain import permits from the NDA and comply with quality control standards. Exporters must comply with regulations set by the Ministry of Trade, Industry, and Cooperatives. Uganda is a member of the East African Community (EAC) and the Common Market for Eastern and Southern Africa (COMESA), which have free trade agreements and harmonized regulatory systems. Uganda also has trade agreements with other countries like the United States and China.

- **Analysis of the distribution of Medical Imaging Centers**

For the current distribution of Medical Imaging Centers's facilities in Uganda, a total of 32 medical imaging centers in Uganda can be seen on the FASTBASE website. The addresses of 20 of these can be found online. Of these 20, 9 of them are in Kampala. The map shows that Uganda's medical imaging centers are mainly located in the northeast and southwest of Uganda, and more along Lake Victoria. In terms of population distribution in Uganda, the total population in each region does not vary much. However, the northern part of the country is vast and therefore has a lower population density.

Fig.13 Distribution of Medical Imaging Centers in Uganda on Google Maps in 2023 (Source: Google Map)

However, we can find mixed reception of services in Medical Imaging Centers. Take Kampala Imaging Center (KIC) - Kololo in Kampala as an example. It is a private healthcare company founded by a group of medical consultants with the aim of providing specialized medical imaging services. The imaging center is equipped with a 16-slice optima CT 520 series. It has three branches in Kampala. However, local residents on google don't really recognize its service capability for reasons such as:

(1) Uneven attitude of the staff at the reception of the organization;
(2) Low correctness rate of scanning results;
(3) Long waiting time for the results, more than 4h;
(4) Bad order of queuing and frequent queue jumping;
(5) Lack of customer care;
(6) Not so good website updating and maintenance (contact information can't be communicated to the hospitals) and so on.

Therefore, the current development of the Medical Imaging Center market in Uganda is characterized by three problems: the distribution of Medical Imaging Centers resources between urban and rural areas is not very even; the service capacity of Medical Imaging Centers's needs to be improved; and the efficiency of

Medical Imaging Centers‘s work is too low.

2.1.3 Competition

- **Uganda-China cooperation on Medical Imaging Centers**

Recently, Uganda and China have collaborated in the field of imaging medicine. Hunan Shanshui Group is working with local practitioners in Uganda to provide specialized skills training for medical staff in 2023. Meanwhile, the two sides will jointly focus on radiation protection measures to ensure the safety of patients and medical staff. It also plans to start construction work on the medical imaging center in the coming year. The project will be carried out in two phases: the first phase is infrastructure construction, including equipment procurement, installation and commissioning; the second phase is operation and management, including technical training, equipment maintenance and updating. Meanwhile, in order to ensure the smooth progress of the project, Shanshui Silk Road will work with the Ministry of Health of Uganda to solve technical and management problems that may arise during the implementation of the project. Meanwhile, both sides will also regularly evaluate the operation and effectiveness of the project to ensure that the medical imaging center truly plays its role in diagnosing and treating diseases.

In addition, Mindray Medical also entered the African market in 2002 and has cumulatively provided medical equipment to 50 countries, basically covering the entire African continent. At present, Mindrayhas set up offices in South Africa and Nigeria, and has more than 40 local employees in Africa, which promotes the localization and construction work in Africa. In addition, Mindray has actively built a platform for medical academic exchanges in Africa, setting up a total of 16 training schools in Africa, contributing to the training and exchanges of grassroots doctors. It cooperates directly with the distributors.

- **Uganda and other foreign companies on Medical Imaging Centers**

In Africa, it is mainly foreign healthcare companies, including SIMENS and GE, that have already made significant gains in digital imaging healthcare.
SIMENS has joined the "Make IT Alliance" of the German Federal Ministry for Economic Cooperation and Development to promote start-ups and technology companies on the African continent. The agreement was signed in the presence of Guenter Nooke, the German Chancellor's Personal Representative for Africa at the Ministry.

In terms of equipment provision for medical devices, companies such as SIMENS and Philippe offer cost-effective basic setups that capture the larger medical infrastructure market. Taking SIMENS as an example:

(1) Offering ultrasound machines and ultrasound equipment such as ACUSON NX3, it provides cutting-edge echocardiography technology, advanced OB/GYN solutions, and applications ranging from 2D imaging to advanced 4D and elastography. Thus, helping medical structures with the clinical versatility and functionality needed for accurate patient diagnosis;
(2) Offering digital X-ray systems, thus providing African healthcare organizations with innovative technology at a price level that is within their budget;
(3) Offering a portfolio of CT scanners, which includes a range of CT scanners covering 2-slice to 128-slice data acquisition as well as dual-source CT scanners to meet the needs of basic entry-level scans as well as advanced cardiology and instantaneous scans；
(4) Offering magnetic resonance imaging (wide range of field strengths from 0.35 Tesla to 7 Tesla) and portable X-ray machines；
(5) Offers a portfolio of mammography products. SIMENS Wide Angle Breast Tomosynthesis is a breakthrough technology in breast cancer detection with 50° image acquisition and 3D volumetric reconstruction for accurate diagnosis with increased depth resolution and clarity. With 50° image acquisition and 3D volumetric reconstruction, it enables accurate diagnosis with increased depth resolution and clarity；
(6) Provides reduced operating costs from 2-in-1 fluoroscopy and X-ray systems to remote control systems and height-adjustable table and patient-side control systems；
(7) Provides infrastructure related to molecular imaging. to meet the needs in cardiology, neurology, oncology and radiology. Covers PET/CT, SPECT and hybrid SPECT scanners (SPECT/CT).

In contrast, GE's market expansion in Africa presents a more systematic character. In addition to providing infrastructure, it has:
(1) Opening a local diagnostic center.In 2021, GE's first diagnostic center opened in Kampala, Uganda. The center is equipped with GE equipment including CT scanners, digital mammography, X-rays, BMD, ultrasound, and life care solutions in the areas of women's health, neonatal care, cardiology, internal medicine, HIV, infectious diseases, and COVID-19. This is a regional project between GE Healthcare and AFRIPHARMA, bringing together global partners to strategize, design and execute the facility, including operations and processes, with one goal in mind: to provide better patient care in Uganda, East Africa and Sub-Saharan Africa.
(2) Provide training for employed staff. More than 100 radiologists and radiographers from Kenya, Uganda and Tanzania attended the "Interventional Radiology" conference. This GE-provided educational program allowed practitioners to learn about the latest techniques and technologies in medical imaging and to recognize the value of intraoperative imaging.

As for GE, back in 2013, the Ugandan government had partnered with GE

Healthcare to modernize the country's hospitals by providing robust medical equipment, long-term training, long-term maintenance of machines, and bringing in funding.

- **Analysis**

To summarize, foreign-funded private medical enterprises have abundant capital and a strong technological base, which can help them develop more cost-effective products suitable for the local African market, thus providing them with competitiveness in the African market. In terms of policy support, due to the large scale of the above-mentioned foreign-funded private medical enterprises, they can directly obtain policy support at the national level, which reduces the obstacles arising from the lack of information exchange in the process of project promotion. In addition, these companies have a large number of high-quality medical labor resources, which enables them to occupy the African medical market more easily and systematically and increase the market penetration rate. Finally, companies like Siemens and GE are highly recognized, which makes more local private hospitals in Uganda willing to trust their equipment and deepen their willingness to cooperate with them.

2.1.4 Advantage assessment

2.1.4.1 Better design

- **Public Health Emergency Management System**

According to the findings of the second joint external evaluation exercise, which assessed the country's capacity to detect, prevent and respond rapidly to public health emergencies in accordance with the International Health Regulations (2005), Uganda has one of the best emergency preparedness and response systems in Africa. The country has also been commended for its robust surveillance system, which enables early detection of outbreaks. In addition, the public health emergency management system is strong, as evidenced by the existence of the Public Health Emergency Operations Center. This provides a better base of medical capacity for the development of medical imaging centers for digital healthcare in Uganda.

- **Health system**

At the same time, Uganda's health system has its own unique model. A patient's first point of contact in the health system is usually the Village Health Team (VHT), who are responsible for primary healthcare interventions in local communities and villages. The VHTs will refer patients to higher level facilities depending on the complexity of the services required. Higher level facilities tend to be located in

urban centers, with the National Referral Hospitals (NRHs) being located in Kampala, while lower level health facilities are more widely distributed in rural communities, with 75% of the population living within 5km of a health facility according to the Government of Uganda's Health Sector Development Plan (HSSDP) 2015/16-2019/20, with the goal of reaching coverage by 2020 of 85%.

- **Accessibility of medical services**

Frome 10-Year Roadmap for Government of Uganda's Health Supply Chain Self-Reliance (2021/2022 – 2031/2032), estimated 90.7% of the population can access a health facility within 5 KM, a rise from 83% in 2014 and 86% in 2017, showing improved accessibility of health services

Also, According to a study, the percentage of Ugandan residents who can walk for one hour to reach the nearest secondary health center is 71.73%, and this increases to 90.57% by bicycle.

- **Health supply chain**

Health care supply chain management is the regulation of the flow of medical goods and services from manufacturer to patient or point of final use.

In Uganda, as with the health system as a whole, the health supply chain system is organized into four levels to support Essential Medicines and Health Supplies(EMHS) distribution. The supply chain system includes several other stakeholders involved in procurement, importation, wholesaling, distribution, retailing and various other functions to ensure that the commodities reach the end-users in the various health facilities in the country. The structure of the system used for distribution of EMHS includes a centralized warehouse at the national level, district level stores and health facility stores. The structure of the health supply chain system has a significant impact on the performance of the health system at all levels. Previous studies have shown that the condition and performance of health supply chain systems are poor These studies have highlighted lack of staff knowledge and skills, inadequate equipment and infrastructure, and poor management.

Tab.13 Health supply chain system in Uganda: assessment of status and of performance of health facilities in 2022 [27]

Level of care	No.of Public health facilities	No.of PNFP health facilities	Total Noh of health facilities	(%)
Health centre Ⅱ	15	9	24	18.8
Health centre Ⅲ	25	10	35	27.3
Health centre Ⅳ	28	3	31	24.2
General Hospital	8	15	23	18.0

National Referral Hospital	2	0	2	1.6
Regional Referral Hospital	13	0	13	10.2
Total	91	37	128	100

This indicates that the health supply chain system is underperforming in several processes and functions at all levels of care. This is manifested in inadequate qualified human resources in the supply chain, weak infrastructure and systems to support the Health Management Information System (HMIS), and persistent stock-outs of EMHS at all levels of care in the country.

2.1.4.2 Price

Impact of national budgetary adjustments for health services, with a large number of local institutions to work with that can contribute to lowering labor and facility.

Uganda's healthcare facilities are attracting U.S. investors, especially in the private healthcare and oncology sectors. The health sector receives 24% of the national budget for 2023, but donor funding accounts for nearly 80% of resources. The government is increasingly considering public-private partnerships for healthcare investments, where the government provides the land and private investors build and operate the facilities. This also opens up more possibilities for the financing component when developing digital healthcare in Uganda.

2.1.4.3 Location

Most of Uganda's medical institutions are located in the cities, which are more mature and have more resources; the villages have potential for development and need to work with the government.

2.1.4.4 Effective partnership

Effective public-private partnerships in radiology exist in Uganda and should continue to be supported and strengthened. This may support privately owned radiology facilities, help to reduce inequality and unequal distribution of imaging services, and enable access to more sophisticated imaging techniques.

2.2 Obstacles in Developing Quality Health Services in Uganda

2.2.1 Capital requirements

In health care financing, The Uganda Ministry of Health (MOH) coordinates the purchase of government-funded health services through central and local

government institutions. As the manager of the health sector, the MoH oversees many of the procurement decisions at the central level through the annual work planning, resource allocation, and budgeting processes. The design of Uganda's decentralized governance structure decentralizes the management of the health system to local district and municipal governments, but they actually enjoy limited decision-making autonomy. Many key procurement and resource allocation decisions remain a central government function, which, combined with budgetary shortfalls, limits the ability of the local level to meet local needs and priorities. A notable exception is Kampala, where the city government has greater autonomy in procurement for public health facilities and some faith-based private non-profit health facilities (PNFPs), which are few among the many private health facilities (PHPs) in the city.

The Uganda National Minimum Health Care Package (UNMHCP) was developed by the Ministry of Health in 1999 to serve as a reference for government purchasing of services.The UNMHCP serves as the basis for definitions and standards of service delivery in the public sector, both in terms of purchasing services from the private health care sector and in terms of the ongoing efforts to apply these standards to the private health care sector. However, underfunding of the health sector and inefficiencies in the health system have led to many gaps in service delivery in public facilities. This has stimulated private sector development, which in turn has increased out-of-pocket expenditures.

The Government provides subsidies to private health care providers to reduce user fees, but the subsidies cover 10-20 per cent of operating costs.

2.2.2 Availability

- **Discontinuity of medical care**

There is a disconnection of health services thereby discouraging the local population from accessing health services. It is observed that there is a significant difference in the management performance of primary health care facilities in Uganda. Facilities categorized as hospitals and health center IV scored higher on management than "lower level" facilities, while privately managed facilities showed better management performance than public health facilities. A majority of the population has access to health facilities and services—72% live within 5km of a health facility—but there are vast disparities between those who live in rural areas versus the capital city of Kampala.

Many women bypass the nearest health facility and seek care in hospitals and private facilities, while also paying more out-of-pocket to access these facilities. Similar patterns of access may occur in Uganda, where wealthier individuals seek care at better-managed "higher level" health facilities and pay additional fees, such as transportation costs, to cover the cost of the visit.

These differences can exacerbate inequalities in health services and outcomes. Particularly for underserved populations in rural and low-income communities, better-managed health facilities may be inaccessible to those who cannot afford to pay for care in those locations.

- **Procurement of equipment**

In the case of equipment purchasers, most research laboratories have autonomous or semi-autonomous administrative structures and substantial donor funding to enable rapid procurement of required spare parts, consumables and contracting of skilled human resources to increase the utilization of medical equipment. Public hospitals, on the other hand, have a permanent bureaucratic structure for the procurement process and very little funding to support the maintenance of medical equipment. This is mainly due to the fact that 7% of the medical equipment observed in this study was purchased or donated but never put to use due to lack of space for installation, lack of consumables or incompatibility with existing infrastructure and resources. In addition, hospitals seem to be eager to purchase medical equipment at a low initial cost without taking into account the life/hidden costs of medical equipment such as the cost of consumables, the cost of maintenance and the cost of required utilities.

- **Follow-up maintenance of infrastructure**

In addition to this, the maintenance of infrastructure in the Uganda region is also an issue. The trained professionals who perform the relevant repairs or maintenance are mainly Biomedical Engineering Technicians (BMETs) or Biomedical Engineers. Laboratory equipment in hospitals and research laboratories are usually provided with service contracts by local dealers. The dealers are tasked with user training, regular preventive maintenance (usually 6 months) and corrective maintenance in case of failure. The study found that on average, 37% of the medical equipment found in Ugandan hospitals is not in use, needs repair, and is completely non-functional. The research laboratory had manuals for all its medical equipment, while all the hospitals surveyed did not have manuals for more than 50 percent of the equipment, implying a lack of technical support from the hospitals in terms of proper use, maintenance and repair.

Apart from this, 68% of the medical equipment in the hospitals do not have manuals. Without these guides, equipment maintenance becomes very difficult, especially in Uganda where almost all medical equipment is imported and access to manufacturers is limited. Failure to follow routine maintenance procedures can lead to escalation of equipment failures. When comparing this workload to the number of devices identified and the number of manufacturers supplying each hospital, on average, each BMET is responsible for maintaining 167 devices and 51 variant manufacturers, each of which provides a unique model of medical

equipment. In addition, BMETs in regional referrals are expected to maintain medical equipment in lower level health facilities. With little funding, lack of spare parts, manuals, and limited technical support from manufacturers, these BMETs are truly overwhelmed. Fortunately, however, considerable efforts have been made to train medicine locally; as of March 2021, seven teaching institutions train biomedical engineers and technicians at all levels, with Makerere University as a pioneer.

2.2.3 Affordability

For patients, health insurance coverage in Uganda remains low, with private insurance coverage concentrated among individuals residing in urban areas, representing about 1% of the total Ugandan population. Uganda has about 26 community-based health insurance schemes (CBHI), most of which are located in the south of the country. However, only 5% to 10% of the CBHI scheme population is enrolled. In the absence of progressive pooling mechanisms and subsidies for the poor, the poorest Ugandans are often excluded from coverage because they cannot afford CBHI premiums. Since the abolition of user fees in 2001, government-run public health facilities have been providing health services free of charge, although informal payments may still exist. While Uganda's health financing strategy to achieve Universal Health Coverage (UHC) adopts the concept of strategic procurement, the country's roadmap for how to harmonize a range of procurement mechanisms into a more coherent and coordinated procurement ecosystem remains to be clarified.

The high cost of radiology equipment places high demands on the public sector budget. This unbalanced distribution may be addressed to some extent when government efforts are supplemented by private organizations. This may not, however, relieve the public of the burden of imaging costs or accessibility, for which the public will have to pay.

2.2.4 Effective marketing factors assessment

People are not sufficiently aware of the prevention and treatment of related diseases。Young people lack the appropriate knowledge of diseases prevalent in Africa, taking HIV as an example:

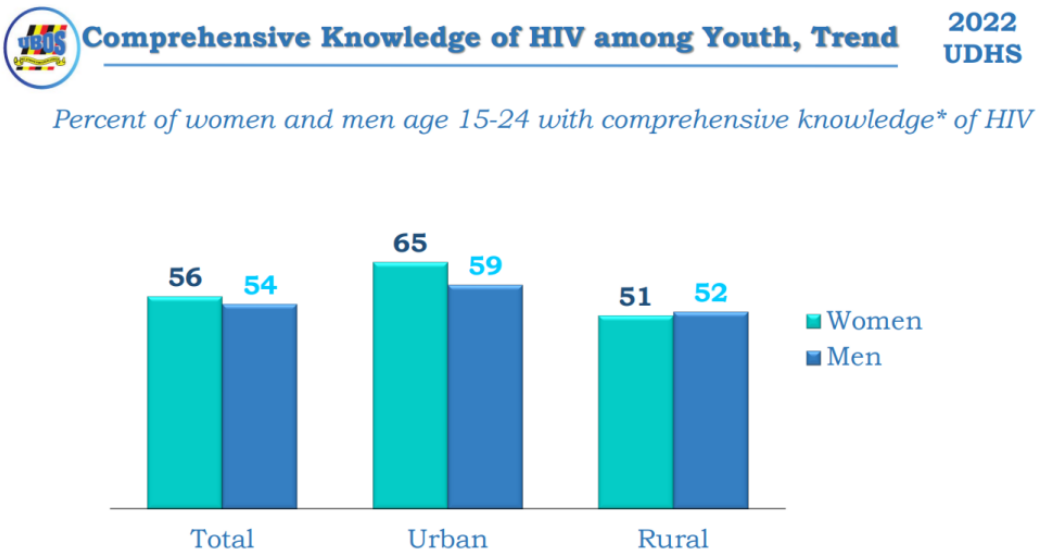

Fig.14 Percent of women and men age 15-24 with comprehensive knowledge* of HIV in 2022· （Source:UDHS）

Moreover，the proportion of residents using mobile medical platforms is small, making it difficult to promote them online.

2.3 Technical feasibility and costs involved in setting up a medical imaging center, operating and maintaining it.

2.3.1 Equipment

PR： Overall in the Uganda region, PR (radiographic) equipment is the most numerous, accounting for 63.52% (397/625) of all equipment. The private sector owns 52.6% of the PR equipment. The majority of this is in the Central Region at 42.8%. Almost half of the PR equipment serves 25% of the population.

The Central Region has the highest density (15.2 per million population) in PR, but it is still below the threshold recommended by WHO. The rest of the region lies halfway between the central region.

Fluoroscopy: There is a 5-fold difference in fluoroscopy in the Central region compared to the rest of the region, with 62.5% (20/32) in the private sector, leaving only 37.5 (12/32)% for the public sector. Mammography: The majority of mammography facilities are located in the Central region with 75% (15/20) of them, of which 60% (12/20) are in the private sector. There is only one mammography machine in the Western Region with a population of 100,000 or 26% of Uganda's population.

Computed tomography: of the 25 CTs, 25 (18%) were in private centers, 72% (52/13) were in the central region and none in the northern region. There is a

significant difference between public and private 25:7. Other modalities: Positron emission tomography (PET-CT) and digital subtraction angiography (DSA) are not available.

Comparison with South Africa, Tanzania and Zimbabwe: Tanzania has the lowest equipment density per capita, followed by Uganda, Zimbabwe and South Africa, with densities above the WHO recommended threshold.

Tab.14 Number of radiology equipment (units) by region, modality and health sector in Uganda in 2020[28]

		Central	Eastern	Northern	Western	Total
FPR	**Total**	86	39	32	42	199
	Gov't	21	14	11	12	58
	Private	65	25	21	30	141
MPR	**Total**	84	31	33	50	198
	Gov't	17	3	4	6	30
	Private	67	28	29	44	168
DR	**Total**	89	10	6	15	120
	Gov't	14	6	3	8	31
	Private	75	4	3	7	89
CA	**Total**	21	1	2	4	28
	Gov't	8	1	0	4	13
	Private	13	0	2	0	15
CT	**Total**	19	3	0	3	25
	Gov't	6	0	0	1	7
	Private	13	3	0	2	18
MM	**Total**	15	2	2	1	20
	Gov't	3	0	0	0	3
	Private	12	2	2	1	17
FL	**Total**	20	4	5	3	32
	Gov't	6	2	2	2	12
	Private	14	2	3	1	20
RT	**Total**	3	0	0	0	3
	Gov't	0	0	0	0	0
	Private	3	0	0	0	3
Fixed Plain Radiography (FPR), Mobile Plain Radiography (MPR), Dental Radiography (DR), C-Arm (CA), Computed Tomography (CT), MM Mammography, Fluoroscopy (FL) and Radiotherapy (RT)						

Most of Uganda's radiological equipment is in good functional condition, which is commendable because, like most low-income countries, Uganda has few biomedical engineers to maintain and the equipment is in good condition.

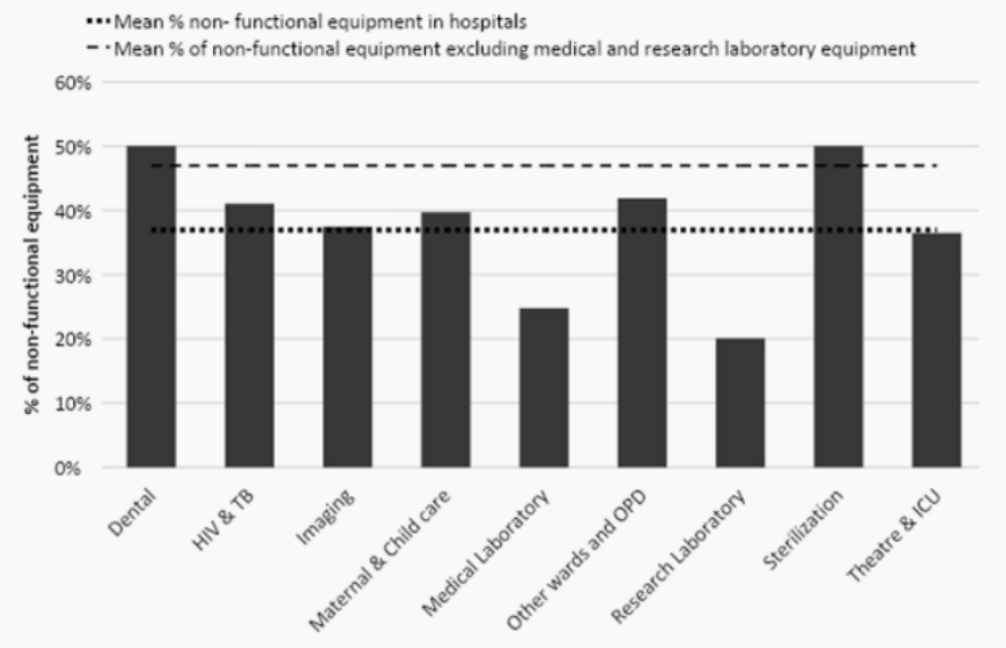

Fig.15 Equipment in Ugandan medical institutions in 2022[28]

2.3.2 Facility location and design

The majority of radiology equipment is located in the central region (the capital region), followed by the western region. This uneven distribution is not only for equipment but also for human resources in radiology, whose availability depends on the availability of equipment. This is likely to lead to an unequal distribution of service delivery, i.e., only a few of those who need the services are able to access them.

It is noteworthy that the most expensive equipment for high-end technology such as Computed Tomography (CT), Fluoroscopy (FL) and Radiotherapy (RT) equipment are located in the Central Region. This may be due to the fact that most medical schools, tertiary hospitals and major referral hospitals and institutes are located in the Central Region. For example, there is only one cancer institute in Uganda that is located in the Central Region and therefore all the radiotherapy units are located in the Central Region. Also, the equipment is government owned.

The uneven distribution of radiology equipment means that a significant number of people may not be able to access radiology services, especially if they require high-tech radiology examinations. Therefore, the Ministry of Health needs to ensure that equipment is distributed equitably in all regions of the country. Equipment distribution may be affected by limited funding. It may therefore be difficult to distribute high-end equipment evenly across all districts.

2.3.3 Cost of personnel

Radiology and imaging manpower is also associated with availability and utilization, which may well reflect the availability of radiologists and imaging specialists. There are differences in the distribution of imaging and manpower resources, with the Central region having disproportionately more human resources compared to other predominantly rural regions.

2.3.4 Supply availability

Concerning the equipment distributor in Uganda, firstly,in cooperation with local facilities, Pacific Diagnostics is a Premium Partner and official SIMENS Healthcare distributor in Uganda. It has offices not only in Uganda but also in several other countries in Africa.

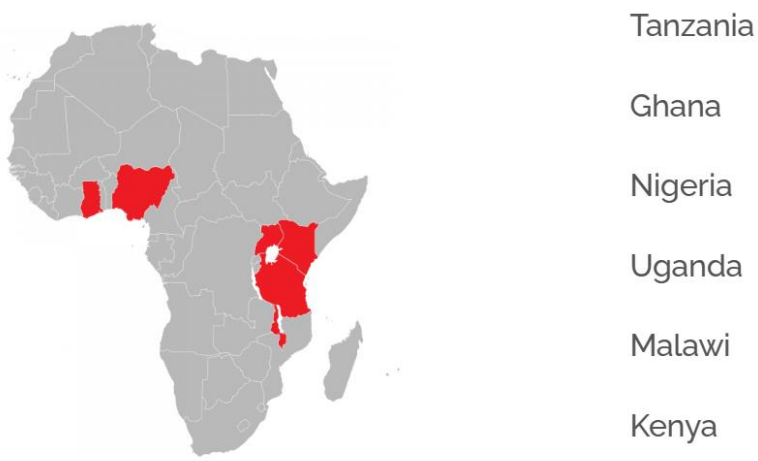

Fig.16 Pacific Diagnostics Locations in Africa in 2023
(Source: https://pacificuganda.com/)

The services they provide include: equipment, local service support and technical team for installing the equipment, providing user training on the equipment, providing application training and advanced training as per the offer, providing warranty support, providing project management and project solutions to ensure project implementation.

Tab.15 An overview of some of Pacific Diagnostics' collaborations in the Uganda region in 2022

Name	Nature	Location	Features	Facilities provided
Nsambya Hospital	Private	Kampala	Catholic Mission Hospital	High-quality Siemens equipment
Children's Hospital of Uganda	Private	Mbale	Leading Pediatric Hospital for Brain Surgery	High-quality CT scanners and follow-up maintenance

			and Treatment of Neurological Disorders	
Lubaga Hospital	Private	Lubaga	Second oldest hospital in Uganda	State-of-the-art C-arm, Siemens CT scanning
Nakasero hospital	Private	Kampala	One of the city's five private, upscale hospitals	Helped establish a state-of-the-art imaging center to provide full-spectrum imaging in all modalities

In addition to these, there are Labtech Medical Supplies (LMS), Yogi, Palin Corporation, Flexi Healthcare, Medical Street, Joint Medical Store, and more than a dozen other equipment distributors in Uganda, most of whom are located in Uganda's capital city, the Kampala region, and all of whom share the same objective of providing quality branded medical equipment and supplies to Ugandan medical facilities and hospitals at reasonable prices. Most of them are located in the Kampala area, the capital city of Uganda, and share the same objective of providing high quality branded medical equipment and supplies to Ugandan healthcare institutions and hospitals at affordable prices.

2.4 Impact on the health system and communities in Uganda

Based in Uganda, the Last Mile Health program works with governments to build strong community health systems where professional community health workers provide essential primary health care services to the world's most remote communities.

The project invests in skilled, salaried, supplied, and supervised community health workers who are part of a national program that operates on a large scale and is supported by strong data and financing systems.

Chapter 3 Angola

3.1 Holistic analysis of quality health services and advantage assessment in Angola

3.1.1 Needs for quality health services

Angola is a country located in the southwest of Africa with a population of over 30 million people. Angola is bordered to the north by the Republic of the Congo and the Democratic Republic of the Congo, to the east by Zambia, and to the south by Namibia. It is one of the key maritime gateways in central and southern Africa and is a member of the Southern African Development Community (SADC) [29]. The country is divided into 18 provinces and 164 cities, with the capital city of Luanda, located in the Luanda province, serving as the political, economic, cultural, and transportation hub of the nation (Fig.17).

Fig.17 Map of Angola

Angola practices a market economy and, while it has a foundational industrial and agricultural base, the 27-year-long civil war that began in 1975 severely damaged much of its infrastructure [30]. After the end of the civil war, Angola's economy was primarily based on oil exports. With the continuous rise in international crude oil prices, Angola's economy grew rapidly, becoming the third-largest economy in

sub-Saharan Africa and one of the top recipients of foreign investment [31]. However, post-2008, due to the global financial crisis and a significant drop in international crude oil prices, Angola's economic growth noticeably slowed. Consequently, in an effort to reduce the national economy's reliance on the oil industry, the government promoted economic diversification, achieving some success in the process. In recent years, although Angola's economy has warmed up with the resurgence of international crude oil prices, it still faces various economic challenges [32]. As a major oil-producing country, Angola is China's third-largest source of oil imports, a primary market for foreign contracted projects, and an important labor cooperation partner [33].

Angola is classified as a lower-middle-income country. Even though the middle and high-income population constitutes 50% of its total populace, there is a significant wealth disparity and serious social inequality. In 2018, Angola's GDP stood at 108.2 billion USD, with a per capita GDP of 3,698 USD. 64.8% of the population resides in urban areas, and 37% live below the poverty line [34]. In 2017, Angola received close to 300 million USD in aid. The International Development Association provided the most substantial portion of this aid, contributing 64.18 million USD, followed by the United States with 56.75 million USD. The European Union, Global Fund, African Development Fund, South Korea, and the United Nations Children's Fund also provided financial support. Approximately 24% of these funds were allocated to health and population development [35].

On January 12, 1983, China formally established diplomatic relations with Angola. In 2010, China and Angola established a strategic partnership [36]. The two countries not only have close political ties with active interactions and exchanges at the government's senior levels, but their economic relations have also rapidly developed. Subsequently, Angola's GDP began to grow rapidly, as shown in Fig.18.

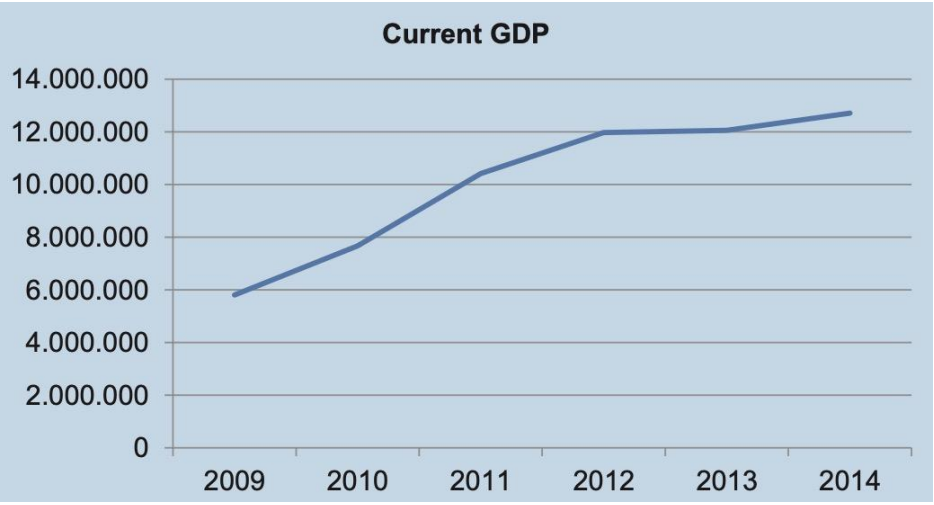

Fig.18 Current GDP trends in Angola (in millions of kwanzas)

In 2018, the trade volume between China and Angola reached 27.7 billion US

dollars. Currently, China is Angola's largest trading partner, and Angola is China's second-largest trading partner in Africa. Furthermore, China has provided extensive infrastructure to Angola, significantly aiding in the country's post-conflict reconstruction [37]. Besides economic assistance, there's also a close collaboration in cultural and educational areas between the two nations. With China's support, Angola has opened a Confucius Institute [38]. As both China and Angola enter new developmental phases, driving the transformation and upgrading of their collaboration and seeking new development opportunities will become new objectives in their bilateral relations.

- **Existing Health Problem**

Although the economy rapidly grew after the end of the civil war, the country's high poverty rate, high infant mortality rate, and social inequalities have not seen significant improvement [39]. Angola's infant and child mortality rates are significantly higher than other countries in sub-Saharan Africa. In Angola, on average, 50 out of every 1,000 live births result in infant deaths, with the mortality rate being even higher among the poorest households and male infants [40]. Due to substantial information gaps in healthcare indicators, the decision-making processes in the country are also difficult for the public to understand. Moreover, the vast disparities in health outcomes and healthcare utilization rates among different populations highlight Angola's lag in health equity [41]. In 2017, the average life expectancy in Angola was only 65.30 years, nearly 20 years less than that of Singapore, the country with the highest life expectancy of 84.79 years [42]. Angola's health and development indicators are poor, and its high morbidity, high mortality, and low life expectancy all reflect the limited opportunities for its people to access health services [43]. The population suffers from poverty, malnutrition, and poor sanitary conditions. For instance, in Angolan cities, 25% of the population lacks access to clean water sources, a figure that rises to 60% in rural areas. Similarly, 84% of the urban population lacks access to improved sanitation facilities, while this percentage is relatively lower in rural areas, standing at 44% [44].

Apart from high neonatal mortality rates and poor sanitation, malaria, HIV/AIDS, diarrhea diseases, lower respiratory infections, and tuberculosis are also significant causes of death in Angola. The number of positive tuberculosis cases rose from 7,379 in 1999 to 21,793 in 2011, becoming a major public health concern [45]. Moreover, non-communicable diseases like ischemic heart disease and strokes have been increasingly leading to deaths [46]. Notably, in recent years, the incidence of new cancer cases in Angola has been on the rise, with about 9,000 cases reported by 2012. This includes esophageal cancer, prostate cancer, breast cancer, and stomach cancer, with an overall mortality rate exceeding 80% [47]. The high mortality rate is primarily due to Angola's lack of capabilities for early screening, diagnosis, and treatment. This highlights the necessity for medical

imaging centers and the significant shortfall Angola has in this area. Therefore, it is imperative to improve sanitary conditions in Angola and promote more advanced sanitary facilities to enhance the overall health status of the country.

- **National Health System Structure**

Angola's healthcare system is divided into three regulatory tiers: national, provincial, and municipal levels [48]. The national healthcare system is overseen by the Ministry of Health, which encompasses national institutions and central support units under the minister and secretariat office. Its main responsibilities include formulating health system policies, ensuring medical industry standards, cultivating talent, implementing public health projects, and procuring essential drugs. The provincial healthcare system is supervised by provincial health command units and is responsible for coordinating municipal health units. The municipal health system covers cities and communities and is managed by regional health administration teams [49].

The National Health Service (NHS) is comprised of three levels of care (Figure 3):
（1）The first level offers low-complexity services, primarily provided by health stations, health centers, doctor's offices, nursing stations, and district hospitals.
（2）The second level offers medium-complexity services and is catered for by general hospitals and unitary hospitals.
（3）The third and highest level offers higher complexity services and is provided by central hospitals and specialty hospitals. These levels are interconnected through various mechanisms to ensure comprehensive and continuous support for patients [48].

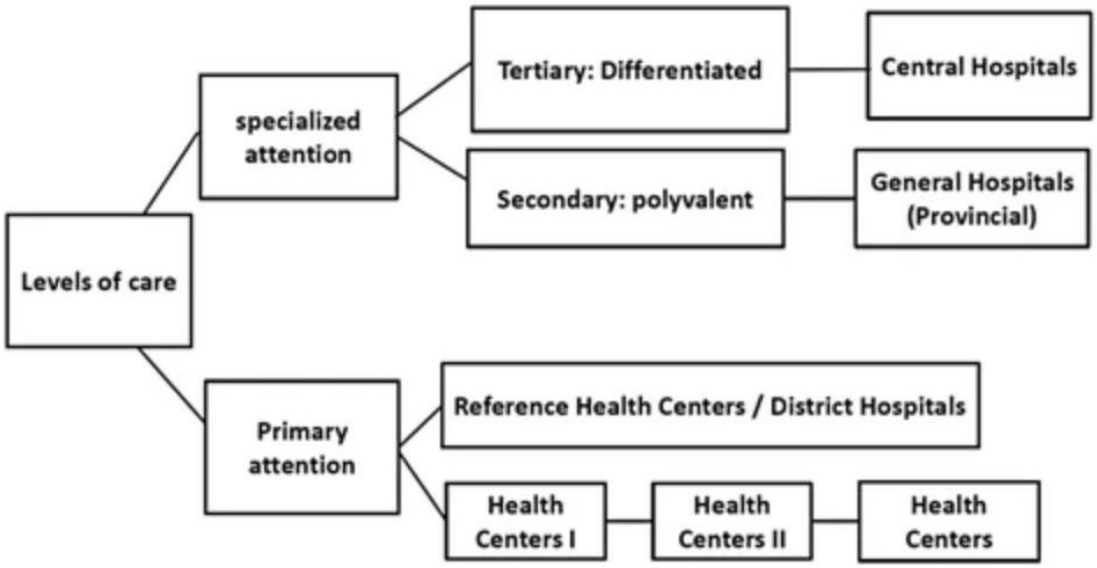

Fig.19 Health Service Delivery Levels in Angola

In Angola, provincial governors appoint the medical administrative chiefs for each region and delegate administrative and financial authority to these regional

medical administrative chiefs. The entire health management department is appointed by the medical administrative chief, who guides and supports their specific tasks. This regulatory structure gives the Angolan health system strong executive capacity [50]. Influential authorities and tribal leaders within communities serve as intermediaries between grassroots and government departments, and they also belong to the health management department. As the foundational financial unit of the entire health system, regions have discretion over medical funds and do not need approval from higher-level institutions [51].

The National Health Policy, passed in 2010, explicitly outlines that the primary objective for Angola's health development up to 2025 is to promote free primary medical services for all by strengthening the municipal health system. This is to be implemented across various fronts, including raising awareness of health issues, improving service quality, training new professionals, procuring health infrastructure, and developing health information systems [52]. Similarly, the National Health Development Plan for 2012-2025 also emphasizes the absolute priority of primary health care. Through a series of interventions, it aims to combat diseases, provide healthcare to communities, develop a human resource management model, finance model, and develop a national health system. Furthermore, it aims to transition the health system from being government-funded to being financed through multiple channels [53]. However, due to Angola's internal conflicts, national poverty, underdeveloped infrastructure, and volatile international oil prices, it will still take a long time for the Angolan government to achieve this goal.

- **Public Healthcare System**

Angola implements free public healthcare, with a coverage rate of about 44% [54]. The public healthcare system is also divided into three levels: national, provincial, and municipal. The national level institutions include central hospitals equivalent to tier-three hospitals; provincial level institutions, such as general hospitals, primarily provide secondary care; while municipal level institutions, including health posts, clinics, referral centers, and municipal hospitals, mainly provide primary care [55]. This level is the most crucial part of the entire health-care system. These institutions form the backbone of Angola's primary diagnostic network, capable of addressing fundamental public health issues, thereby ensuring basic health protection for the people.

The Angola National Development Plan 2013-2017 and the National Health Strategy 2012-2025 both clearly highlight the renovation and expansion of public healthcare facilities' infrastructure as the government's primary objective for healthcare system development. Strengthening the training of specialized medical talents, such as introducing personnel capable of operating X-ray machines, and

enhancing the service capabilities of public institutions, are development goals for Angola's public healthcare. Specifically, the National Development Plan 2013-2017 proposes that from 2013 to 2025, the Angolan government would invest approximately 5.2 billion US dollars annually in the public healthcare system construction. However, due to the volatility of international oil prices and national poverty, whether this goal can be achieved remains to be seen [55].

- **Private Healthcare System**

Angola's private healthcare system is primarily composed of private clinics funded by large financial conglomerates and funds, and smaller clinics funded by individual investors. The quality of healthcare services in Angola's private clinics surpasses that of public hospitals, but the costs are high. Furthermore, most private facilities are located in the capital, making it challenging for the lower socioeconomic populace to access [56]. Despite the high costs and limited accessibility, the majority of Angola's middle class and higher social strata still opt for private healthcare services. This preference is largely due to the outdated facilities, staff shortages, and referral difficulties encountered in public health institutions. Wealthier individuals even travel abroad for specialized private healthcare to countries such as Namibia, Cuba, South Africa, Spain, and Portugal. However, due to the recent financial crisis, foreign exchange controls in Angola, and travel restrictions due to COVID-19, seeking medical care abroad has become challenging. As a result, more people from the higher socioeconomic state (SES) are choosing to receive medical services in private clinics in the Luanda region, Angola's capital. In the Luanda area, over a quarter of the patients opt for private healthcare institutions, a percentage significantly higher than in other cities and regions of Angola [55].

- **Healthcare Financing System**

From 2009 to 2014, Angola's health expenditure was on an upward trend (Figure 4). However, by 2015, total health expenditure in Angola accounted for only 2.9% of its GDP, still significantly below the average level of the member countries of the Organization for Economic Co-operation and Development (OECD), which is around 9%. Per capita health expenditure was $108.6, approximately one-fifth of China's, with the out-of-pocket expenditure per capita at$33.4 and declining annually. Compared to other Sub-Saharan African countries, Angola relies less on financial donations, with external resources constituting only 3.4% of the total health expenditure, much lower than the African regional average of 22% [57]. The National Health Development Plan 2012-2025 plans to transition the national health system from a government-funded model to a multi-channel financing model.

- **Health Expenditure**

Health expenditure in Angola is divided into government health spending and private health spending. Government funds account for two-thirds of the national total health budget. The government health funds mainly come from natural resources and a small amount from taxation within the national system. Given that the main income (53%) of the entire Angolan government derives from oil, and with the recent volatility in oil prices, future government investment in health is not expected to increase significantly. The private sec-tor's funding constitutes one-third of the national health budget, mainly coming from private enterprises, insurance companies, and out-of-pocket payments, with personal out-of-pocket expenditure comprising 73% of the private portion. Private health insurance companies have been present in Angola since 2009, primarily concentrated in the Luanda region, providing employee insurance for large private and public institutions. Such insurance does not cover AIDS and preventive medical services. In the long term, private insurance companies can provide a practical data foundation for future risk and case management through an increase in the number of insured persons and an expansion of the coverage population, as well as offer insurance services to service providers. All these will, in the future, support the national social health insurance.

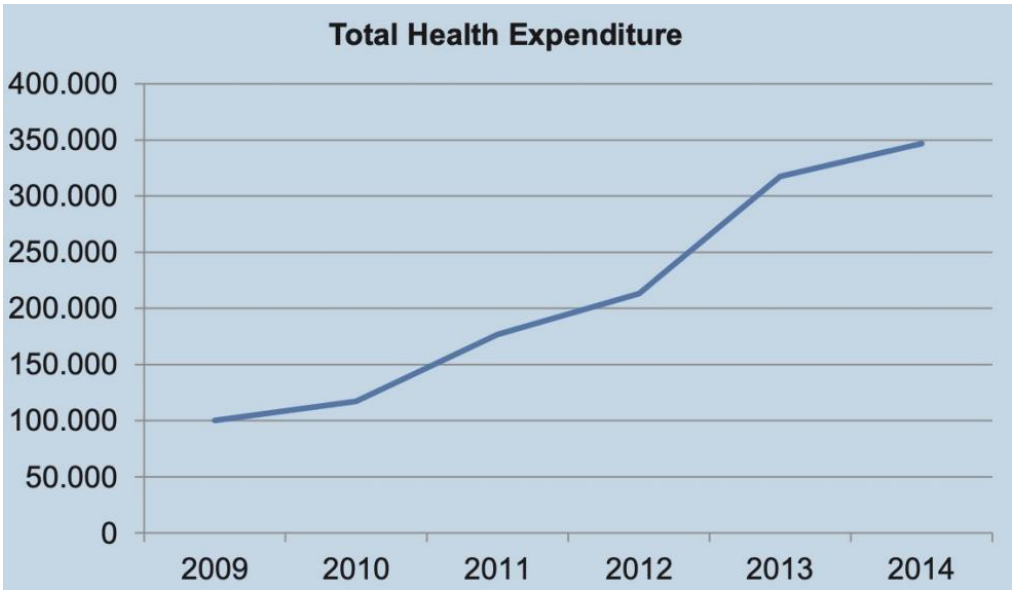

Fig.20 Total health expenditure trends (in millions of kwanzas)

- **Health Human Resources**

The distribution of health human resources in Angola is asymmetric, primarily concentrated in major urban centers. In 2005, Angola had only 849 doctors and

16,037 nurses. By 2009, these numbers increased to 2,956 doctors and 29,592 nurses, nearly more than double [49]. Additionally, in 2009, 5,435 technicians were equipped [52]. The overall ratio of public sector health workers to every 1,000 inhabitants in Angola is close to the World Health Organization's thresh-old of 2.28 qualified health workers per 1,000 people, which is necessary to ensure the provision of 80% of essential services [43]. There is a significant disparity in the number of health workers per 1,000 inhabitants among the provinces (Fig.21).

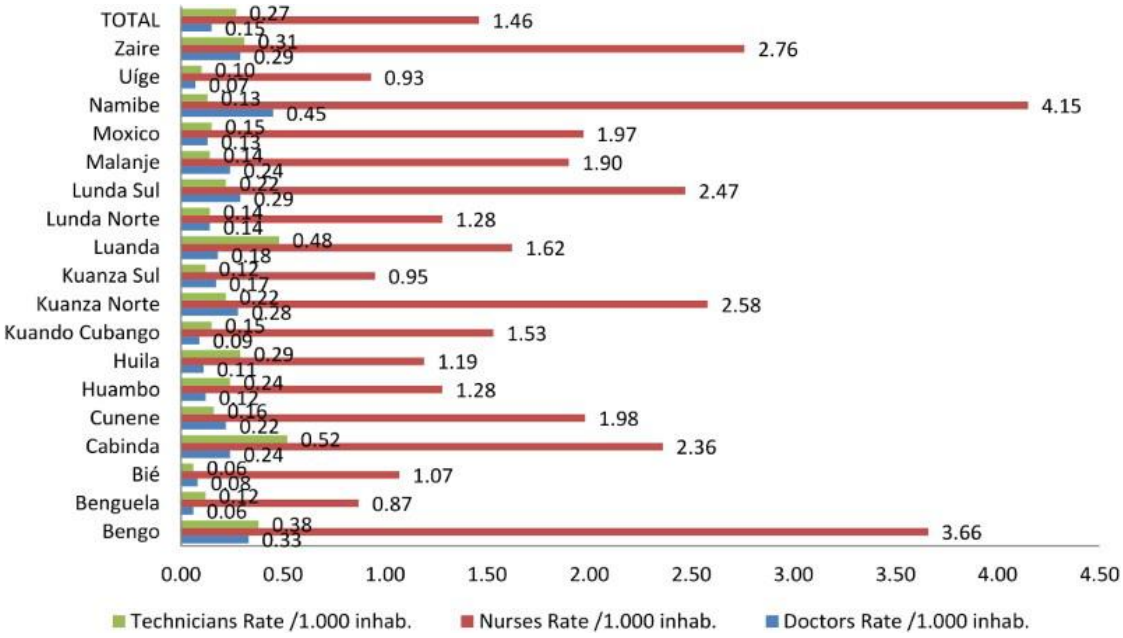

Fig.21 Angola – Staff of the National Public Health System (rate per 1000 inhabitants)

- **Public System**

In Angola, there are approximately 0.1 hospital bed for every 1,000 people, a total of 3,700 doctors (or about 0.08 doctor per 1,000 inhabitants, while the World Health Organization recommends an average of 1 doctor per 1,000 people), 34,300 nurses, and 6,400 diagnostic and therapeutic technicians [58]. The country has only five medical schools and a number of nursing schools, producing about 200 new doctors annually. The government plans to increase this figure to 1,000 doctors per year by 2020. The majority of foreign medical professionals in Angola come from Cuba, Brazil, and Portugal. Cuban doctors make up about half of the doctors in the entire country of Angola, but a significant number are gradually leaving due to the reduction in the country's foreign exchange income.

- **Private System**

All doctors in private medical service institutions must be registered with the Angolan Medical Council and provide information on their place of practice; however, this information is not publicly available, making it impossible to know the number of service providers. Nonetheless, according to disclosures from related parties, the number of qualified private medical service providers is low and concentrated in urban areas. In some remote regions, there are health facilities operated by private nurses, but there are also other facilities whose operators may not have received formal medical training.

- **Main Issues**

Over 80% of the healthcare workforce, including doctors, nurses, and other professionals, are concentrated in the city of Luanda and other provincial capitals, leaving other regions with fewer and lower-quality medical staff, resulting in uneven distribution. To address this issue, on one hand, the Angolan government plans to increase the number of domestic medical graduates from 500 to 1,000 per year. On the other hand, it actively imports foreign doctors from countries such as Cuba, Brazil, and Portugal. However, due to the significantly lower income in public health institutions compared to private ones, and the "brain drain" effect, many doctors switch to the private healthcare sector. Further-more, Angola lacks training programs for medical personnel, and the quality of existing programs cannot be assured. The health supervision and service quality monitoring systems are also not well-established, leading to poor oversight of healthcare service quality.

3.1.2 Digital Health

Digital health is defined as "the use of information and communication technology in a cost-effective and safe manner to support health-related fields, including healthcare services, health education, health literature, health monitoring, and more [59]." Universal health coverage is a primary concern in global health, and digital health is an indispensable part of achieving this goal [60]. However, currently in Africa, less than a quarter of the population is utilizing facilities provided by the internet. For the development of digital health in Africa and the widespread application of digital medicine, there is still a long way to go.

Medical imaging in digital health plays a significant role in the diagnosis and treatment of diseases [61]. Medical imaging broadly includes technologies such as X-rays, scanning technologies (CT), Magnetic Resonance Imaging (MRI), and ultrasound. However, due to severe shortages of equipment and facilities, a lack of skilled personnel, and limited funding, medical imaging in Angola is still in a preliminary stage of development. This results in diseases not being diagnosed in

time, leading to delays in treatment and severely affecting patients' health. Beyond the lack of hardware, the absence of standardization is also one of the main reasons hindering the advancement of medical imaging in Angola. Overuse of imaging equipment or its underutilization and being left idle are consequences of this lack of standardization.

3.1.3 Impact of COVID-19

COVID-19 poses a significant challenge to public health and has severely disrupted health systems worldwide. With Angola already having limited opportunities for basic health interventions, COVID-19 has had a profound impact on its population's health [62]. Digital health can effectively assist Angola in addressing the health system challenges posed by COVID-19, such as adopting telemedicine via phone calls and using drones to promote health education to unreachable populations [63]. Digital health in Angola has already taken initial steps, but it still needs time to develop and integrate into the traditional health-care system. The effectiveness of digital health has been demonstrated during the COVID-19 period, but its widespread adoption still faces many challenges. Digital health heavily relies on the internet, and many traditional Angolan residents may resist or reject digital advancements [64]. Furthermore, funding is a significant barrier to development. Inadequate power supply and a lack of clean water resources are also primary obstacles to digital health progress. Overall, digital health played a vital role in safeguarding the health of the Angolan population during COVID-19. For the long-term development and effective implementation of digital health in the future, issues related to infrastructure, human resources, and funding must be addressed. Therefore, collaboration with stakeholders who can provide sustainable funding and commitment, as well as political commitment to workforce training, is crucial for the development of digital health in Angola post-COVID-19.

3.2 Medical Imaging in Angola

Radiology plays a crucial role in addressing chronic and acute diseases such as pneumonia, tuberculosis, and AIDS, especially in resource-scarce settings like Angola. However, the limited infrastructure and shortage of technical personnel result in restricted opportunities for Angola to access radiology services of acceptable quality. Moreover, there is a significant disparity in the radiological services provided between public and private healthcare services [65]. In resource-limited settings like Angola, the most common method of acquiring X-rays is through screen-film technology. However, in such low-resource environments, the image quality of X-rays produced by screen-film can often be compromised due to various factors, such as insufficient equipment and materials (films, chemicals, etc.), a shortage of professionals with knowledge in film development and

processing, and the inability to use post-processing features. Furthermore, film images generated by screen-film cannot be directly saved as files, which limits their use for duplication, distribution, patient follow-up, external consultations, and training purposes. These issues result in a lower-than-standard quality of screen-film X-ray images, which hinders timely and accurate disease diagnosis, ultimately leading to an increase in mortality rates [66]. Digital imaging is a novel medical technology that not only addresses the need for film development and processing required by traditional X-rays but also enables instant reporting through tele-radiology, with specific advantages illustrated in Fig.22. Digital imaging could be a solution for Angola to address the issues inherent in traditional X-ray methods [67]. However, due to the complexity and high costs associated with digital radiology, as well as limited infrastructure, most digital radiology services are confined to the private sector or pilot projects.

GENERAL ADVANTAGES OF DIGITAL X-RAY
Better image quality
Lower cost
Timeliness
Increased dynamic range
No film-developing
No need for water or ventilation for film developing
No hardcopy storage disadvantages
Real-time transferability over long distances
Remote consultation and training
Availability of post-processing functions
ADDITIONAL ADVANTAGES OF POC 130 OR SYMILAR DIGITAL SYSTEMS
User-friendly
Compact size
Robustness
High temperature and humidity resilience
Self-diagnosis of internal problems

Fig.22 Advantages of digital X-ray

As early as 2001, the IRCCS Burlo Garofolo Institute for Maternal and Child Health was providing support and assistance to Angola's Hospital Divina Providencia (HDP). HDP serves a population of 1 million in the suburbs of Luanda, with a focus on pediatric care [67]. While Angola's economy showed signs of recovery after the civil war, infant and child mortality rates remained high. There was a scarcity of medical equipment in Angola, and specialized radiologists were in short supply. By 2011, there was only one doctor for every 10,000 Angolans on average [68]. In

2010, HDP began offering radiological services, but the hospital still lacked specialized radiologists. Additionally, there were no external consultation services like tele-radiology, and doctors had to rely solely on their personal experience to interpret X-rays. Therefore, starting in November 2010, IRCCS Burlo began providing external support to HDP to improve its radiology services [67].

A feasibility study in Angola assessed whether digital radiology could effectively improve the quality of care [67]. The primary equipment included a computed radiography system and a sufficient number of photo-sensitive fluorescent screens, with the POC 130 chosen for the computed radiography system due to its simplicity, robustness, and low maintenance requirements and costs. The computers used for operation were also ensured to be simple and user-friendly. The digital radiology technology was implemented locally by a team consisting of external radiologists, radiology technicians, and local IT engineers. HDP provided a ten-day training for local staff, using materials written in the local language. From November 2010 to December 2012, over a span of more than two years, local staff at HDP took a total of 20,564 X-ray images using the digital system. All X-ray images were taken without any technical issues, indicating that there was no further need for additional training and on-site supervision. Digital X-rays are suitable for both adults and children and can completely replace traditional X-rays. Before digitization, the annual average number of X-rays taken had a 95% CI of (8,043 to 12,497). After digitization, the annual average number of X-rays taken had a 95% CI of (8,885 to 11,679). The overall numbers are not significantly different. However, after implementing digitalization, the quality of the images obtained from X-rays significantly improved. Using traditional screen films, out of every 100 images, 15 were of good quality, 43 were satisfactory, and 42 were of poor quality. After using digital X-rays, out of every 100 images, 79 were of excellent quality, and 21 were of good quality ($p < 0.0001$) (Fig.23).

	VERY GOOD	GOOD	SUFFICIENT	POOR
SCREEN FILM X-RAYS	0	15	43	2
DIGITAL X-RAYS	79	21	0	0

Fig.23 Quality of X-Rays

Fig.24 more vividly demonstrates the enhancement of image quality by digital imaging. On the left is the most original X-ray image, while on the right is the same X-ray after digital image processing. It is evident that the overall brightness has increased and the clarity has improved, making it easier for doctors to diagnose.

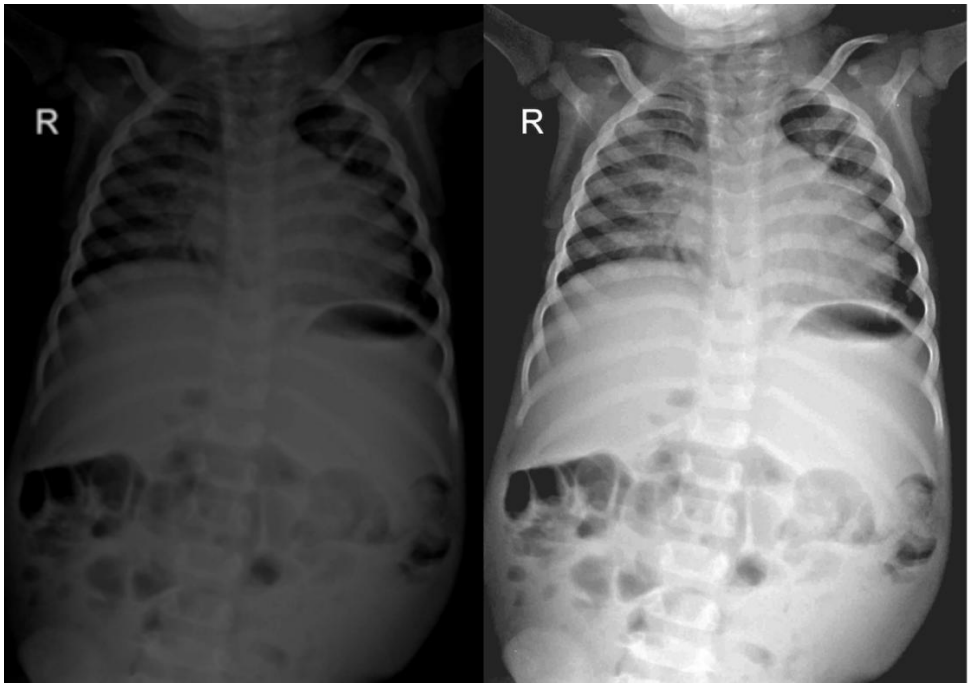

Fig.24 Post processing functions with Digital X- Rays

In addition to the digital medical services within HDP, the project also incorporated remote consultations. Pediatric X-rays diagnosed as "complex" by local pediatricians were sent out for external consultation. The consulting physicians included two doctors working at HDP and a senior pediatric radiologist from IRCCS Burlo. Out of 1,671 pediatric X-rays, 127 cases (7.6%) were sent for external consultation. External consultations varied from a few minutes to 24 hours but did not exceed 24 hours. The vast majority (93.7%) were chest X-ray examinations. In summary, this report shows that digital medicine is still feasible even in resource-limited environments like Angola. However, development should consider starting with the introduction of low-cost digital medical equipment. And imaging systems, like the digital radiology in this project, significantly improved local work quality, providing better services for patients. Digital radiology eliminates the need for additional time and effort to convert images into files, thus, compared to traditional screen film radiology, it greatly enhances diagnostic efficiency and makes remote consultations viable. However, Angola's digital imaging system is still in its early stages, and its subsequent development and proliferation will need to overcome many challenges.

3.2.1 China's Medical Assistance to Angola

China's assistance to Angola in the field of healthcare dates back to 2009 when Sichuan Province began to send medical teams to support the Luanda General Hospital, which was built with Chinese aid. By the end of 2015, Sichuan had dispatched three medical teams, totaling 46 members. The Luanda General

Hospital, which the medical teams assisted, is located in the northern suburb of Camama area in Belas city, Luanda Province, the capital of Angola. It is a comprehensive public hospital built with the assistance of the Chinese government and offers services free of charge. The hospital was completed in February 2015. It currently has 350 beds, about 320 staff members, including 202 nurses, 23 nursing aides, and 95 doctors. Among the 95 doctors, there are 10 Chinese doctors and 20 Cuban doctors. The hospital can accommodate more than 800 patients daily. It has various departments including internal medicine, surgery, obstetrics and gynecology, pediatrics, ICU, operating rooms, radiology, and laboratories. It is equipped with advanced medical equipment such as 64-slice CT scanners, gastrointestinal contrast imaging, gastroscopes, DSA, and cardiac color ultrasound. With its elegant environment, central air conditioning, comprehensive facilities, and advanced medical equipment, Luanda General Hospital is one of the largest and best-equipped comprehensive hospitals in Angola.

Despite the fact that the hospital is one of the best-equipped in Angola, its radiology department's digital radiography (DR) room often cannot perform examinations due to lack of materials or power outages. The situation with the CT scanner is even more serious, mainly because there are no radiology technicians or doctors to operate these facilities. Cardiac color ultrasound, gastroscopy, and DSA are also not yet in use. Therefore, it can be seen that equipping facilities is only the first step in the development of medical imaging in Angola. More efforts need to be made in terms of training personnel and optimizing conditions.

3.2.2 Recent Developments in Medical Imaging

As a professional and leading provider of medical imaging solutions in China, Shenzhen Blue Charm Medical Imaging Co., Ltd. has also provided certain assistance to the development of medical imaging in Angola. In order to improve medical conditions in Angola, the Chinese government has established health center construction projects in five cities of Angola's Lunda Norte province: Dundo, Lucapa, Cuilo, Cuango, and Capenda. Among these, the high-quality Muses mini U-arm DR from Blue Charm Medical Imaging was successful in the bidding process for the projects. In June 2016, five Muses mini units, along with equipment from other manufacturers, departed from Qingdao Port in China and were shipped to Angola. After more than two months of travel, they finally arrived in Lunda Norte province. Upon inspection, the five Muses mini units were fortunate to maintain a 100% qualification rate, and their packaging was intact. However, Angola's challenging outdoor environment and primitive cargo-handling equipment made the transportation of goods to the hospitals exceedingly difficult. Transporting nearly a ton of machinery from an open space a hundred meters from the hospital, along a muddy path without the aid of cranes or fork-lifts meeting the specifications, was a major challenge. Our engineers could only resort to laying down old wooden planks to pave a path, leading local workers and using the only

available mini forklift, they managed to transport the equipment safely into the hospital with sheer manpower. After moving the machines into the machine room, an even greater challenge presented itself. The radiology examination room in this hospital, apart from a freshly applied protective layer, was practically an unfinished room (Fig.25). It lacked lead glass for radiation isolation, shielding doors, and an electrical supply that met the installation requirements of the equipment.

Fig.25 The Early Stage Radiology Department

Despite the local infrastructure being severely damaged due to years of civil war, agricultural development halted, rampant inflation, soaring prices, impoverished living conditions of the people, and a severe shortage of supplies, there was only one examination room that was completely non-compliant with the installation standards for radiological equipment. However, engineers from Blue Charm Imaging, in support of the development of medical imaging in Angola, stayed to continue advancing the radiology department. For instance, they worked in an environment with potential X-ray radiation harm, temporarily modified electrical connections to meet the DR installation requirements, and acted as human models to generate images.

In May 2017, engineers from Blue Charm Imaging returned to the five cities of Lunda Norte Province to train local doctors on how to use the equipment (Fig.26). Fortunately, the five Muses mini units were operating stably and performing well in all five hospitals, earning unanimous praise from the local doctors. By the end of June 2017, the President of Angola was expected to personally visit the hospitals to participate in the ribbon-cutting ceremonies, and medical imaging in the five cities of Lunda Norte Province was officially put into use. Today in Angola, the Muses mini is advancing further on the path of helping local residents obtain more

accurate diagnoses, marking a significant progress in the development of medical imaging in Angola.

Fig.26 The Muses mini is generating images

On December 14, 2020, Angola's blood dialysis center, named Sol, officially commenced operations. Located in the Benfica district of Talatona city, the center is reported to be equipped with 70 machines for medical infrastructure, capable of operating in three shifts, thereby serving at least 210 patients daily. The dialysis center is outfitted with the latest technology and is considered one of the largest blood dialysis centers in the country. Prior to this, the dialysis center at the General Hospital of Benguela was the largest facility, associated with the private sector, and was recently nationalized by the authorities. The initiation of this center has increased the capital's capacity to treat renal patients, supplementing the work previously done at the Josina Machel and Prenda hospitals. Fig.27 shows the interior of the blood dialysis center, where it is apparent that a certain level of medical imaging equipment is in place, and the overall hardware facilities are quite commendable.

Fig.27 Interior of the Blood Dialysis Center

3.3 Challenges and Recommendations

3.3.1 The obstacles to the advancement of medical imaging in Angola

As observed in the current state of Angola's digital medical infrastructure, numerous issues such as local radiology examination rooms resembling bare rooms, significant obstacles in the transportation of goods, a shortage of technical personnel, and insufficient electrical resources, all represent challenges that need to be addressed in the development of medical imaging centers in Angola. This chapter has briefly discussed the obstacles to the advancement of medical imaging in Angola and has proposed some potential solutions.

Water resources are a basic need for hospitals and are an indispensable component for medical imaging, especially in radiology departments. Water serves as a solvent and a crucial component of the processing tanks, playing a key role in the composition of developer solutions, and is vital for the washing and printing of radiological films. Therefore, the development of radiology cannot proceed without a reliable water supply and timely drainage [69]. For many regions in Angola that suffer from a lack of water supply, employing instantaneous dry processing methods might be a viable solution [70]. Computer Radiography (CR) or Digital Radiography (DR) systems are other modern solutions.

Electricity is also one of the basic needs of hospitals, yet in remote areas, it is difficult to obtain a stable electricity supply [69]. For instance, due to the high cost of fuel, hospitals may only be able to provide electricity for a short time at night [71]. However, in radiology, operating X-ray equipment and the cooling systems for X-ray processing tanks both require electrical support [72]. Utilizing X-ray

equipment with an independent power supply may be a viable solution to this problem. The World Health Organization has developed two types of battery-powered X-ray equipment, the WHO Basic Radiology System (WHO-BRS) and the World Health Imaging System for Radiography (WHIS-RAD), to address the issue of unstable power supplies [73]. Beyond the issue of unstable supply, power surges and voltage fluctuations are also challenges faced by the power supply. System overloads in custom equipment can easily lead to equipment meltdown and fires, which are common issues. The use of surge protectors and voltage regulators to protect radiological equipment can effectively resolve this problem [74].

The scarcity of water and power resources often coincides with a lack of public infrastructure such as roads and railways, yet these infrastructures are crucial for healthcare facilities [75]. Public infrastructure ensures that equipment and consumables can be transported into hospitals, and that maintenance companies can access the facilities when imaging equipment is in place. Without these public amenities, as in the rural areas of Angola, the cost for advanced equipment suppliers to transport their products becomes prohibitively high. The previously mentioned WHO-BRS and WHIS-RAD can also help alleviate this problem. The WHO-BRS is low-maintenance, user-friendly, and meets cost-effectiveness standards [76]. WHIS-RAD requires maintenance only for the X-ray tube, generator, and collimator [77]. Additionally, some CR readers are designed to be lightweight and can be shipped as complete units for repairs. However, these methods do not address the root issue of lacking public infrastructure. Developing the railway and road networks in Angola, especially for rural areas, is an urgent necessity for the advancement of medical imaging.

The extreme climate of Angola could also potentially impact the equipment. Angola experiences a rainy season from October to April, with an average temperature of 33°C, and a dry season from May to September, with an average temperature of 24°C. The average annual precipitation is about 400 millimeters, ranging from a high of 1500 millimeters in the northeastern highlands to a low of 50 millimeters in the southwestern desert regions, with high humidity levels. In high-temperature environments, algae can accumulate in processors and cause equipment failure [74]. More seriously, if not properly controlled, temperature and humidity can also have adverse effects on film and even workers. Films must be used within a temperature range of 19-28°C and a humidity range of 40-50%, which is a challenge in Angola's environment [78]. High temperatures can also damage emulsions, causing fogging and contrast loss. Films can be somewhat protected from humidity by using sealed containers. The optimal temperature for processing solutions is 20°C; below 16°C, the activity of the reducing agents is inhibited, and temperatures that are too high can produce blurry radiographs. Adequate ventilation of the solutions might be a way to address this issue [72].
In addition to the severe shortage of equipment, the lack of human resources also poses a significant barrier to the development of medical imaging in Angola.

According to surveys, there are 14 African countries without any radiologists, and the majority have fewer than 30 radiologists in total. Angola is among these countries. Data indicates that there are only 20 radiologists available in Angola, with half of them located in the city center of Luanda, 7 in Maianga, Luanda, 2 in Mar¸cal, Luanda, and 1 in Rangel, Luanda. There is a critical shortage of radiologists in Angola. A shortage of medical technicians, coupled with a heavy disease burden, leads to an enormous workload for physicians. A survey on the current state of health human resources in the province of Kwanza Sul in Angola indicates that, in urban areas, doctors, nurses, and diagnostic therapeutic technicians (DTTs) work an average of 8 hours per day [79]. However, in rural areas, nurses work an average of 11.5 hours per day, DTTs only 5.5 hours, and doctors just 4.5 hours. This may be due to the limited equipment and the relatively simple variety of diseases that can be addressed in rural settings. In terms of employee satisfaction, 20.8% of medical staff in urban healthcare institutions reported low satisfaction, whereas this figure reaches 70.8% in rural areas, which is related to poor working conditions, low wages, and long working hours.

3.3.2 Tele-radiology may be a solution to address shortages of equipment, personnel, and resources

Tele-radiology may be a solution for developing countries like Angola to address shortages of equipment, personnel, and resources. Tele-radiology services not only enable instant reporting but also eliminate the need for film development and processing. Mobile radiography imaging units are suitable for patients who cannot leave their beds, such as those in intensive care units, and are cost-effective and highly mobile [80]. However, due to the need for various environmental equipment adjustments, many NGOs in developing countries do not support the use of such mobile devices. Therefore, the widespread adoption of mobile radiography imaging units necessitates the expansion of trained radiology technicians. A drawback is that most of these devices are underpowered and thus can only be used for radiographic examinations of the limbs and skeletal system.

The example of the Swinfen Charitable Trust can serve as an approach to addressing the challenges of tele-radiology. Swinfen operates a low-cost telemedicine service, connecting doctors in hospitals of developing countries with surgical consultants and medical professionals who offer advice free of charge. Using internet access and equipment such as digital cameras, doctors in remote areas can send clinical photographs, medical histories, and any other materials (such as X-ray images) for diagnosis by surgical consultants. Currently, the Swinfen group allows doctors in 181 remote hospitals immediate contact with 458 consultants covering all medical and surgical specialties [72]. However, only a small portion of the work done by the Swinfen team can be classified as tele-radiology. More complex solutions have also begun to emerge. It is now possible to use tele-ultrasound systems for real-time imaging in resource-limited environments [81].

Utilizing open-source software and commercial off-the-shelf hardware, tele-ultrasound technicians can connect with radiologists. Another recent initiative is Tele-radiology sans Frontières (TSF; Tele-radiology Without Borders), a Luxembourg-based enterprise involving radiology experts and high-end technology based on the Power Server PACS system developed and donated by RamSoft. Users log into the WEB-PACS via a standard computer over the internet. With just the click of a button, images are transmitted to the data center, and radiologists interpret the images sent to them. Everything is centrally stored and available online. If a computer is lost or damaged, the images can easily be recovered on any other computer using a web browser. Thanks to TSF's WEB-PACS, large files no longer need to be split up [82]. The PACS can seamlessly transmit large files that are uploaded in the background, typically while the reader is completing their regular workload. This also helps to avoid the drawbacks of hard copy storage and the time and space-consuming retrieval (Fig.28). Ordinary radiographs can also be taken and recreated in JPEG (Joint Photo-graphic Experts Group) format [83]. Then the JPEG images can be converted to DICOM (Digital Imaging and Communications in Medicine) format; the PACS conversion facility is crucial for this process. The remote reading service is free of charge and is currently available in parts of French-speaking Africa. Mature private tele-radiology entities like Nighthawk have also participated in NGO pilot projects, reporting X-rays from rural health centers free of charge.

Fig.28 Manual storage and retrieval of hardcopy radiographs

3.3.3 China has provided assistance in public health and digital health development in Angola

- **Chinese Aid Activities in the Country**

In the field of healthcare assistance to Angola, China's efforts commonly include the construction of hospitals, provision of equipment, donation of medicines, fundraising, and dispatching medical teams. In terms of infrastructure and equipment, China has been involved in eight projects in various regions, including the renovation of the Luanda General Hospital, the Malaria Center, and the Benguela Central Hospital. Alongside the participation in construction projects, China has also supplied medical equipment to hospitals such as the Luanda General Hospital to enhance their capacity for medical services. Specific details are presented in Tab.16.

Tab.16 The summary of Chinese government aid to Angola in hospitals and medical equipment

Project Content	Time	Project Status	Funding Source	Nature of the Project
Renovation and Equipment Provision for Luanda General Hospital by China	January 2011 - June 2015	Completed	Chinese Government Department	Donation
China-funded Malaria Control Center	October 23, 2009	Completed	A department of the Chinese Government	Donation
China renovated and re-equipped the Benguela Central Hospital	May 2007 - August 2008	Completed	The Export-Import Bank of China	Donation
China upgraded the Caculama Health Center to a Municipal Hospital	October 2006 - November 2008	Completed	The Export-Import Bank of China	Donation
China's construction aid for three health centers in Malanje and provision of equipment	August 2006 - August 2007	Completed	The Export-Import Bank of China	Donation
China's Construction Aid for the Hospital in Namibe Region	April 2006 - February 2008	Completed	The Export-Import Bank of China	Donation
China's Aid for Construction and Equipment Provision of Huíla	May 2006 - June 2008	Completed	The Export-Import Bank of China	Donation

Hospital and Health Center				
Renovation and Equipment Provision for the Huambo Regional Hospital by China	August 2006 - August 2007	Completed	The Export-Import Bank of China	Donation

- **Activities of China's Private Sector in Health Construction in Angola**

In recent years, Chinese investments in Angola have led to the establishment and operation of hospitals including the Zhongyan Hospital, Zhongtai Hospital, China Railway Group Four Local Hospital, the Angola Luanda Provincial General Hospital, Shaorimu Hospital, and the Public Hospital over Kwanza River Bridge. Impacted by the financial crisis in recent years, the exchange rates for converting Angolan Kwanza to U.S. dollars, Renminbi, and other currencies have surged dramatically. The government has imposed strict restrictions on foreign exchange outflows, causing difficulties in capital repatriation for businesses and impacting the normal operations of Chinese-funded hospitals. Furthermore, many Chinese-funded hospitals face issues such as incomplete or imperfect procedures for medical qualifications and physicians' practice licenses, leading to frequent and disruptive inspections by Angolan local regulatory authorities (including the Ministry of Health, Disease Control Centers, Immigration Bureau, Tax Bureau, Private Investment Bureau, and Police Department, etc.). As of August 2018, with the mass departure of Chinese nationals from Angola in recent years, some Chinese-funded hospitals, due to incomplete qualifications and operational management issues, are mostly facing operational difficulties or have already been shut down or transferred. Specific details are presented in Tab.17.

Tab.17 Summary of Medical and Health Construction Activities by the Chinese Private Sector in Angola

Project Name	Time	Investor	Project Description
Establishment of Zhongyan Hospital, the first comprehensive private Chinese hospital in Angola	June 2015	Jiangsu Zhongxing Construction (Angola) Co., Ltd.	Zhongyan Hospital is the first comprehensive hospital in Angola, aiming to provide high-quality medical services to local residents, Chinese enterprises in Angola, and the Chinese community of over 200,000 people. The creation of Zhongyan Hospital is in response to the transformation needs of Chinese-funded enterprises in Angola and is also a gesture of goodwill to give back to the Angolan society. The main building of Zhongyan Hospital has three floors, with a total investment of 10 million US dollars. The hospital

			currently employs over 100 medical and nursing staff from China, Cuba, and Angola. It has 87 beds and offers various departments including pediatrics, obstetrics and gynecology, internal medicine, and surgery. The hospital has obtained a business license and operating permit issued by the Angolan Ministry of Health.
Huawei Healthcare Establishes a Digital Hospital in Angola	2012	Huawei Angola Company	Huawei Healthcare has established a model digital hospital in Angola, promoting paperless, wireless, and filmless hospital administration, utilizing HIS, LIS, PACS, and other information systems to enhance the efficiency of doctors' work, reducing the average waiting time for patients by 1 hour per day. The hospital network is equipped with Gigabit access and ten Gigabit to the core. In 2018, Huawei Group plans to increase its investment in Angola in the area of information technology and technical solution supply.
Tasly Pharmaceuticals Provides Compound Danshen Dripping Pills and Other Basic Traditional Chinese Medicine Health Products	2008	Tasly Holding Group	Tasly has established subsidiaries, offices, and specialty stores in Angola, leading with direct sales to drive distribution and forming a multi-level marketing system. The main products are basic traditional Chinese medicine health products, combining Chinese herbs with local herbs as well as traditional medicine with technology, paving the way for traditional Chinese medicine to reach international markets.

Chapter 4 Policy Recommendations

To advance medical imaging services and promote digital health development in countries like Ethiopia, Uganda and Angola, a comprehensive set of efforts need to be done in systematic ways. New policies that support innovation and create space for ideas, new technology or tools that address challenges of equipments, personnel and resources, new financing models that make it possible to balance quality, affordability and scale at the same time, are all necessary elements of achieving this goal.

In terms of new policies, the government should set up incentives to encourage the private sector in developing programs and products that are beneficial for the overall growth of the industry. Among all the policy tools, tax reduction and subsidy provision will be certainly a powerful one. However, it is more important to remove the barriers (including hidden barriers) that prevent the industry from growing, such as transparency of procurement, social security issues, etc. The government can also encourage public-private partnerships to innovate financing tools for highly expensive equipments and facilities.

For new tools and technology, tele-radiology may be a solution for countries like Ethiopia, Uganda and Angola. It has great potential in addressing shortages of equipment, personnel, and resources. Tele-radiology services not only enable instant reporting but also eliminate the need for film development and processing. For those patients in intensive care units, mobile radiography imaging units are suitable when the patients cannot leave their beds. In addition, utilizing open-source software and commercial off-the-shelf hardware, it is possible for tele-ultrasound technicians to connect with radiologists, to reduce the need for on-site personnel in the hospitals.

Last but not least, governments, foundations and donors can work together with supplier agents and social marketing agents, to create innovative financing models for the procurement and maintenance of the equipments. By providing public funds for private suppliers or marketing agents, the agents can purchase higher quantatity of equipments with lower average costs, or with lower prepaid costs. Through such partnerships, more equipments can be potentially deployed into the market, and with good maintenance, as well as models such as pay-as-you-go, economic sustainability and affordability could be strengthened at the same time. There have been global partnerships such as The Global Fund and GAVI, which utilize similar models to fight against infectious disease; with similar efforts in innovative financing, global partnerships in medical imaging and digital health services can also be created, to diagnose and cure other deadly diseases that severely affect the wellbeing of population in countries like Ethiopia, Uganda and Angola.

Appendix

Appendix 1: Medical imaging related enterprises shown in the text

Number	Enterprise name	Scope	Content in Ethiopia
1	GE Healthcare https://www.gehealthcare.com/	Primary Service (1)Advanced Visualization (2)Cardiology IT (3)Command Centers (4)Cybersecurity (5)Digital Health Platform (6)Enterprise Imaging (VNA) (7)Imaging Operations (8)PACS and AI Orchestration (9)Pharmaceutical IT (10)Software & Apps Marketplace	GE has been doing business in Africa for 120 years plus and in Ethiopia for over 10 years investing in the healthcare, aviation and power sectors and driving capability and capacity building for local talent.
2	Philips N.V. https://www.philips.com/global	Primary Service (1)Medical Devices (2)Design & Engineering (3)High-PrecisioHigh-Precision Engineering (4)Electronic Systems & IoT (5)Philips MEMS & Micro Devices (6)Manufacturing Systems & Industry 4.0 (7)Design for Reliability Solutions (8)Industry Consulting (9)Environment, Health & Safety	Memagi Medical Imports PLC is the distributor of renowned healthcare equipment brands Philips Healthcare & Carl Zeiss in Ethiopia. It specializes in the import, installation, as well as after-sales service of MRIs, CT Scans, Ultrasounds, C-Arms, Digital X-Rays, Ophthalmic devices, etc.
3	Siemens Healthineers https://www.siemens-	Primary Service (1)Medical Imaging (2)Laboratory diagnostics	The German Development Cooperation and Siemens Healthineers

	healthineers.com/	(3)Point-of-Care Testing (4)Clinical fields (5)Point-of-care testing	partner up to support the Ethiopian healthcare system through ultrasound technology in 2022.
4	Canon Medical Systems Corporation https://global.medical.canon/	Primary Service (1)Collaborative imaging (2)AI (3)Oncology (4)Lung Cancer (5)Screening (6)SportsMed (7)CT Dynamic Volume (8)Cardiology (9)Efficient Workflow	
5	Mindray Medical International https://www.mindray.com/cn	Primary Service (1)Mindray Medical laboratory (2)Digital integrated operating room system (3)Overall solution of digital medical imaging	Mindray set up a distributor in the Ethiopian capital and provided employment opportunities for local residents.
6	Esaote https://esaote.com.cn/	Primary Service (1)Benchtop ultrasound (2)Portable ultrasound (3)Laser (4)Probe (5)Animal medicine	ESAOTE biomedical products set up distributors in Addis Ababa, Ethiopia to carry out exchanges and cooperation.
7	Hologic, Inc. https://www.hologic.com/	Primary Service (1) Tests (2) Cytology (3) Molecular Diagnositics (4) Collection Devices (5) Screening Technology	
8	Koning Corporation https://www.koninghealth.com/zh-cn/	Primary Service (1)Koning Vera CT (2)Female health	

Appendix 2:

Other enterprises shown in the text

Number	Enterprise name
1	Kenya Cooperative Bank
2	Cadilhac Vascular
3	Polarean
4	Toshiba
5	Amazon
6	National Bank of Ethiopia
7	Amhara Bank
8	Zamzam Bank
9	Hijra Bank
10	Commercial Bank of Ethiopia

Government or organization in the text

Name	Organization name
1	Ethiopian government
2	Ethiopian Ministry of Health
3	Ethiopian Drug Supply Bureau
4	Ethiopian Control Authority
5	World Health Organization

Appendix 3: Ethiopian health system

Level of Health System	Current State	Mechanisms to Influence Quality	Future State
National	• Existence of policies, guidelines and some tools to assess quality • Existence of regulatory bodies (FMHACA) developing minimum standards and guidelines (e.g. EHRIG, standards, key performance indicators) • No common understanding or vision of quality among leadership • Inadequate mechanisms to ensure timeliness and availability of supplies and procurement and maintenance of equipment • Integrated Supportive Supervision (ISS) is provided to facilities who do not meet Lots Quality Assurance Sampling (LQAS) assessment criteria • Defined protocols exist, but enforcement of standards is inconsistent and punitive measures have not been defined • Government, rather than partners, is main driver of quality initiatives, leading to unified understanding of needs and goals	**Quality Planning** • Policy development • Planning process for programmatic implementation **Quality Control** • Standards and regulations development and enforcement • Qualification, licensing, training and accreditation of laboratories, professionals, facilities **Quality Improvement** • Strategize with NGOs to drive nationwide QI initiatives	• Harmonized standards (e.g. hospital) with institutionalized quality control mechanisms to ensure minimum standards are met • Standards and action plans or punitive measures enforced consistently for underperforming facilities • Leadership within the health system has a common definition and vision for quality and is knowledgeable in quality assurance and improvement approaches • Quality structures will be instituted and strengthened at all levels of the health care system • Necessary and appropriate equipment, medicines and reagents are readily available with systems in place to mitigate stock-outs of supplies and breakdown of equipment • Successful quality improvement programs scaled to cover facilities beyond hospitals nationwide(e.g. EHAQ, initiatives for priority conditions and diseases)

Regional, Zonal and Woreda	• Recognition of well-performing facilities, leading to sharing of best practices at regional (and national) forums • Supportive supervision provided to facilities • Difficulty in driving initiatives in settings with minimal management support or commitment; need for strong champions and quality mentoring	**Quality Planning** • Regional priority setting • Resource distribution • Ensure system for providing capacity and capability to drive quality **Quality Control** • Clinical audits and inspections of health facilities • Licensing for private hospitals • Data and reporting standards and requirements development **Quality Improvement** • Supportive supervision as a QI mentoring and learning system • Focused improvement efforts around high priority topics using QI methods and learning systems	• Strengthened leadership across regional, zonal and woreda levels of the health system, trained in quality improvement methods • Insurance claims data is used to identify quality challenges • Leverage two-way data feedback loop to develop focused quality improvement activities • Financial and technical assistance may be provided for public and private facilities to implement quality improvements
Facility Based Care	• Some facilities and centers successfully implemented EHRIG standards and established quality structures • Hospitals performing well based on KPIs and clinical audits chosen as LEAD hospitals and provide mentorship to EHAQ member hospitals	**Quality Control** • External Quality Assurance • Collecting, analyzing and reporting data **Quality Improvement** • Best practice sharing • Conducting QI peer-learning sessions • Workforce motivation and training • Designing activities	• Sharing best practices with EHAQ member hospitals lead to sustained increased performance and quality in the selected focus areas assessment data • Facilities have low turnover and more satisfied employees • All facilities have uniform mechanisms to

	• Inadequately staffed facilities due to staff attrition / turnover, absenteeism, lack of motivation or incentives	based on community involvement and feedback	capture and act on patient feedback
Community and Patients	• The improvement of community awareness has led to the demand for • Members of the Health Development Army (HDA) in the community are important link between patients and health extension workers. • Patients do not have access to rankings/ grades of facilities they plan to visit, based on quality	**Quality Control** • Patient Feedback **Quality Improvement** • Leveraging HDA as quality improvement teams • Leveraging HDA to educate patients and community around quality care	• HDA act as QI teams • Continuous Quality Improvement is institutionalized through public forums facilitated by the HDA • All patients and communities have access to quality health care, information (e.g. service availability) and clear communication with providers and facilities • Community Endorsement Groups, comprised of citizens that assess areas that impact quality, linked with the HDAs

Appendix 4 Potential partners in Ethiopia

1. Addis Ababa Silk Road General Hospital

See the introduction in main body of the report. The research team was able to visit the hopital in Addis Ababa.

2. Huawei Ethiopia

The research team visited Huawei Ethiopia's digital solutions department in Addis Ababa. The chief of the department mentioned the Huawei team has been exploring to develop digital solutions for the Ministry of Health and all the public hospitals in Ethiopia, to assist the country in digitize health information for the vast population. The project is still in development stage, and would love to partner with the program team for future opportunities.

3. Arba Minch University

The research team interviewed Arba Minch University's professor in health research. Arba Minch University is one of the top universities in Ethiopia, with high-level staff and facilities in Ethiopia for health services, including medical imaging services. The university can also be considered as a kep partner for any future programs.

Appendix 5 Potential partners in Uganda

1. Joint Medical Store

The Joint Medical Store (JMS), is a non-government organisation in Uganda, mandated to procure, store and distribute human medication and health-related consumable items to health units. It is owned by the Uganda Catholic Medical Bureau and the Uganda Protestant Medical Bureau, the two entities who own the NGO. JMS offers free installation, servicing and maintenance on equipment purchased from JMS or any of their authorized distributor. In December 2017, they began manufacturing nutritional supplements, clinical oxygen and medical sundries. The research team visited JMS in Kampala. It can be considered as a potential partner in Uganda for follow-up programs.

Contact: the research team has direct contact with JMS's staff members.

2. Uganda Virus Research Institute (UVRI)

Government research organization. It is a WHO-accredited regional reference laboratory for yellow fever, and the only accredited reference laboratory for yellow fever in East Africa: also has research on AIDS, malaria, etc.
Possibility for a win-win situation by reducing the cost of medical personnel through collaboration: they can get more data from imaging centers, etc.; imaging centers can also further reduce hiring costs and improve quality.

directoruvri@uvri.go.ug / +256-414-320385/6

3. Health Development Partners (HDPs)

The diverse group of non-governmental buyers plays an important role in Uganda's external financing.
Financial help may be available in promoting projects on the ground.

Britt.A.Cruz@HealthPartners.com /952-883-5632

4. Mulago National Referral Hospital (MNRH)

2023 The Ministry of Health has established a Teleradiology Center at the National Referral Hospital in Mulago to assist in the transmission of digital radiology images through CT scanners located at the regional referral hospitals.
This center is a recent creation with the latest teleradiology technology and may be able to provide assistance and cooperation possibilities for the Digital Medical Imaging Center project.

admin@mulagohospital.go.ug / +256-414-554008/1

5. Uganda Society of Radiology

Established for five years, the Society has provided technical support to Ugandan

hospitals in the use of improved diagnostic and therapeutic techniques in medical imaging, radiology and allied sciences, and to date has 500 specialist doctors and 115 members.
It is possible to learn from this body about the latest advances in medical imaging in Uganda and related collaborateons in hospitals.

admin@sruganda.org / two@gmail.com / +256773260091

6. Healthy Entrepreneurs
Sustainable healthcare systems, providing business opportunities for community health workers to improve healthcare in hard-to-reach rural communities, emphasizing the role of Community Health Entrepreneurs (CHEs) - using telemedicine platforms to share instantaneous test results with healthcare professionals, which in turn provide electronic consultations and prescriptions.
Interviews and collaborations are possible in telemedicine.

tj.kuipers@healthyentrepreneurs.com/ +31 6 52058809

7. Digital health Uganda
The company's NextGen HIMS integrated hospital information management system brings artificial intelligence to medical image analysis. There are many stakeholders involved (private and public healthcare centers/clinics/hospitals etc.) .
Therefore collaboration possibilities can be obtained by contacting the company and more local digital healthcare stakeholders in Uganda can also be established with the company.

+256755856420

8. Labtech Medical Supplies
There is a partnership with Joint Medical Stores, which we researched offline in Uganda.

labtechmedicalsupplies@gmail.com/ 0777166742/0773763728/ 0702570750

9. John Snow
A digital platform for targeted customer communications, including appointment reminders for healthcare providers for ANC, eMTCT, VMMC and PLHIV. Health information on the program's thematic areas is disseminated through mobile SMS, and teleconsultations are conducted through a toll-free hotline and WhatsApp platform aimed at providing specialized medical imaging services.
There is already a mature digital healthcare platform and telemedicine practice base, and interviews can be conducted to understand the development of local digital healthcare in Uganda and seek collaboration possibilities.

https://www.jsi.com/

10. Makerere University

Makerere University College of Health Sciences was established in 1924 known as Makerere University Medical School, till 2007 when it became Makerere University's premier constituent College. It is the oldest medical training University unit in East Africa; having been in the business of training medical and health professionals for over 80 years. This history has earned it an enviable position in Uganda and the East and Central African region.

In 2008 Makerere University began a major institutional change that led to the creation of Makerere University College of Health Sciences (MakCHS) as the University's first constituent college. The research team visited Makerere University's professor in health sciences in Kampala. It can be considered as a potential partner in Uganda for follow-up programs.

Contact: the research team has direct contact with staff members of Makerere University College of Health Sciences.

Appendix 6 Introduction of companies with digital medical practices/medical equipment supplies in Uganda

Name	Project	Scope	Content	Partners	Progress
Uganda companies					
Streamline Health Tech Company https://streamlinehealth.org/	Stre@mline	Expected to grow to Kenya and then the rest of sub-Saharan Africa.	Technology infrastructure for rural hospitals. Providing: (i) electronic medical records; (ii) A digital insurance platform for rural communities with $0.50 premiums; (iii)AI-based anonymized clinical data aggregation, processing and analysis	Developed by a team of doctors at Kisiizi, a private non-profit hospital.	Completed
Healthy Entrepreneurs https://www.healthyentrepreneurs.nl/	Call Center	Sub-Saharan countries	Sustainable Healthcare Systems, which provides business opportunities for community health workers to improve healthcare in hard-to-reach rural communities, emphasizes the role of Community Health Entrepreneurs	Uganda Local Consortium and Ministry of Health	Completed. The goal is to have 90,000 CHEs delivering health products to more than 100 million people in 10 countries/ regions by 2027.

			(CHEs) - using telemedicine platforms to share instantaneous test results with healthcare professionals, which in turn provide e-consultations and prescriptions.		
Digital health Uganda https://digitalhealthuganda.org/	NextGen HIMS	Uganda	Integrated hospital information management system that brings artificial intelligence to medical image analysis. Involves many stakeholders (private and public healthcare centers/clinics /hospitals, etc.)	USAID,WHO	Completed
	ONCIMS		Customizable EHR management for digital oncology workflows with manual and automated support for PAP-Smear image analysis	Digital Health Center of Global Auto Systems LTD Uganda	Completed
	PAPSI		A Digital Platform for Cervical Cancer Diagnosis &	USAID , Digital health Uganda,	Completed

			Management,Of these, CerviMIC provides remote viewing and diagnostics	University of Strathclyde Glasgow	
Compelling Works https://compelling.works/	E-health elec-tronic system & AlSuite	Uganda Health Center III	Deployment of an eHealth system for Health Center III in Uganda, which operates at the rural stage/level. Monitoring and evaluation was also carried out using AlSuite as a project management system.	MIFUMI Health center	Completed
UgandaNational Health Laboratory Services https://www.cphl.go.ug/	Reference Laboratory Information System	Health centers IV, general hospitals, regional referral hospitals	The system is used for data acquisition, processing and generation of laboratory test results for the UNHLS-CPHL viral load and EID programs.	Centers for Disease Control (CDC),etc	Completed
Uganda Makerere University https://new.mak.ac.ug/taxonomy/term/1870	UgandaEMR(OpenMRS)	Buikwe district of Uganda. Kampala Metropolitan Area Kisoro and Zombo districts covers over 19 Districts/ branches	Patient-level electronic medical record systems for healthcare organizations	UCSF，HISP Uganda	Completed

		in Uganda.			
Living Goods https://livinggoods.org/	SmartHealth App in Uganda	Buikwe district of Uganda. Kampala Metropolitan Area Kisoro and Zombo districts covers over 19 Districts/ branches in Uganda. across the country.	Created a robust suite of mobile and web-based tools to support Living Goods-assisted Community Health Workers (CHWs). Provided key data to government to better plan and budget for community-level interventions	Bill and Melinda Gates Foundation (BMGF) , Gavi, The Vaccine Alliance	Completed The 2022-2026 program will work to improve the health of at least 9.7 million people in three African countries and support the transition to substantial government ownership of community-based health services.
	Medical Records and Data Reporting System - A digital platform to capture health data at facility level linked to the DHIS2		A digital platform for capturing critical patient information for the day-to-day operations of health organizations.	Ministry of Health and Social Services , Ministry of Health	
Pacific Diagnostics https://pacificuganda.com/	Medical Equipment Distributors	Uganda	Specializes in diagnostic imaging, endoscopy, surgical, emergency and ICU equipment; offers	SIMENS 、Local hospitals in Uganda	/

			diagnostic imaging and endoscopy training courses, user training and application training		
Labtech Medical Supplies https://lms.co.ug/contact/			Procurement and distribution of highest quality branded medical equipment and supplies to medical institutions and hospitals in Uganda at reasonable prices.	Joint Medical Stores，CIPLA Quality Chemicals, etc	/
Yogi https://www.yogilimited.org/			Manufacturers, importers and distributors offering medical, hospital and laboratory equipment, hospital furniture, surgical instruments and laboratory diagnostics.	/	/
Palin Corporation https://palineurope.com/about-us/			Currently represent the industry's most premium brands which include among others: Mettler Toledo, Esco	/	/

			Biosafety instrumentations,		
Medical Street https://www.medicalstreet.biz/			Leveraging artificial intelligence to provide personalized product recommendations, efficient order management and real-time inventory tracking	/	/
Joint Medical Store https://jms.co.ug/			Uganda's leading privately owned pharmacy serving at least 3,000 health facilities. Engaged in importation, warehousing, exportation, wholesaling and distribution of pharmaceuticals and related medical supplies. As well as health commodity value chain activities such as health worker training, infrastructure development,	Joint venture between Uganda Catholic Medical Board and Uganda Protestant Medical Board.	/

			maintenance of medical equipment, etc.		
U.S. Companies					
GE	Medical Diagnostic Center	Kampala,	Equipped with GE equipment and a regional project between AFRIPHARMA	Local medical organizatio nsAFRIPHARMA	Completed
John Snow https://www.jsi.com/	USAID RHITES-N, Lango	The Lango region of Uganda	Digital platform for targeted customer communications, including appointment reminders for ANC, eMTCT, VMMC and PLHIV providers. Dissemination of health information on program subject areas through mobile SMS and tele-consultation through toll-free hotline and WhatsApp platform. Aiming to provide professional medical imaging services	USAID,The Medical Concier Group,etc	Completed
Chinese companies					
Hunan Shanshui Group http://w	Medical Imaging Center	Uganda	Aims to provide professional medical imaging	Local medical institutions	In progress

ww.ssjtchina.com/company.html			services, build a platform for medical academic exchanges in Africa, and promote the training and exchanges of primary care physicians		
Mindray Medical https://www.mindray.com/en	/	Africa	Promote localization and construction work in Africa; build a platform for medical academic exchanges in Africa and set up 16 training schools; and work directly with distributors.	Local distributor in Uganda	/
German company					
SIMENS https://www.siemens.com/ug/en.html	Medical Device Distributor	Uganda	Providing cost-effective medical equipment	Pacific Diagnostics	/
Netherlands company					

Philips https://www.philips.co.uk/healthcare/solutions/customer-service-solutions/customer-care-center/distributors-africa	Medical Device Distributor	Uganda	Provision of infrastructure	Local distributor in Uganda	/

Appendix 7: The specific details of China's investment in Angola's healthcare infrastructure in the private sector

Company Name	Headquarters	Year Founded	Business Scope	Website
China Jiangsu Zhongxing Construction (Angola) Co., Ltd.	Jiangsu, China	1984	Construction engineering, including construction of housing engineering, municipal public engineering, mechanical and electrical installation engineering, architectural decoration engineering, garden ancient architecture engineering, and lifting equipment installation engineering; real estate development; contracting overseas projects and domestic international bidding projects; export of equipment and materials required for the above-mentioned overseas projects; dispatching labor personnel required for the implementation of the above-mentioned overseas projects.	http://www.jszxjs.net
Huawei Angola Company	Shenzhen, China	1987	Communication technology, including research and development, production, sales, and services in the fields of network equipment, terminals, cloud computing, big data, Internet of Things, smart homes, car networking, and digital cities.	https://www.huawei.com/cn/corporate-information
Tasly Holding Group	Hunan, China	1994	Traditional Chinese medicine manufacturing, including Chinese medicinal material planting, Chinese medicine preparation production, Chinese medicine slice production, Chinese medicine injection production, Chinese medicine health product production, Chinese medicine new drug research and development, and Chinese medicine trade.	https://www.tasly.com/

Appendix 8: Potential Partners in Angola's Healthcare Sector

1. Ministry of Health, Angola (Ministério da Saúde)

Introduction:This is the government body responsible for public health policy, healthcare programs, and medical regulations in Angola.
Contact: info@moh.gov.ao
Website: http://www.minsa.gov.ao

2. World Health Organization (WHO) - Angola Office

Introduction: The WHO's country office in Angola works on health-related initiatives, providing technical support and collaborating on health projects.
Contact: afwcotgwho@who.int
Website: https://www.afro.who.int/countries/angola

3. Doctors Without Borders (Médecins Sans Frontières) - Angola

Introduction: An international humanitarian medical NGO known for its projects in war-torn regions and developing countries, focusing on emergency medical aid.
Contact: office@brussels.msf.org
Website: https://www.msf.org/angola

4. International Red Cross - Angola Delegation

Introduction: Part of the global Red Cross network, providing humanitarian aid, disaster relief, and health services in Angola.
Contact: luanda@icrc.org
Website: https://www.icrc.org/en/where-we-work/africa/angola

5. PATH - Angola Office

Introduction: An international health organization driving transformative innovation to save lives, with a focus on strengthening health systems and advancing health equity.
Contact: info@path.org
Website: https://www.path.org/countries/angola/

6. Universidade Agostinho Neto (UAN) - Faculty of Medicine

Introduction: Angola's premier university offering extensive medical education and research, playing a crucial role in training healthcare professionals.
Contact: reitoria@uan.ao
Website: http://www.uan.ao

7. African Development Bank - Angola

Introduction: A financial institution supporting socio-economic development in Africa, including healthcare infrastructure and services in Angola.
Contact: afdb@afdb.org
Website: https://www.afdb.org/en/countries/southern-africa/angola

8. China International Development Cooperation Agency (CIDCA)

Introduction: A Chinese government agency coordinating foreign aid and promoting international development and cooperation, with investments in various sectors including healthcare.
Contact: cidca@cidca.gov.cn
Website: http://www.cidca.gov.cn

References

[1] Marcus, Harold G et al. "Ethiopia". Encyclopedia Britannica, 31 Oct. 2023, https://www.britannica.com/place/Ethiopia. Accessed 10 November 2023.
[2] D, Tewuhibo et al. "Availability of Essential Medicines in Ethiopia: A Systematic Review." Journal of Community Medicine & Health care (2021): n. pag.
[3] Manyazewal, T., Woldeamanuel, Y., Blumberg, H.M. et al.The potential of digital health technologies in the African context: a systematic review of evidence from Ethiopia. NPJ Digit Med. 2021 Aug 17;4(1):125.
[4] Nigatu, A.M., Yilma, T.M., Gezie, L.D.et al.Medical imaging consultation practices and challenges at public hospitals in the Amhara regional state, Northwest Ethiopia: a descriptive phenomenological study. BMC Health Serv Res 23, 787 (2023).
[5] Magge H, Kiflie A, Nimako K, Brooks K et al. The Ethiopia healthcare quality initiative: design and initial lessons learned. Int J Qual Health Care. 2019 Dec 31;31(10):G180-G186.
[6] Berhanu, E., Factors that Affect the Quality of Healthcare Services in Ethiopia. Science Journal of Business and Management, 2021. 9(3): p. 186-196.
[7] Woldemichael A, Takian A, Akbari Sari A, Olyaeemanesh A. Inequalities in healthcare resources and outcomes threatening sustainable health development in Ethiopia: panel data analysis. BMJ Open. 2019 Jan 30;9(1):e022923.
[8] Degefa, T. and K. Hoelscher, Development aid and health equity in Ethiopia. Development Studies Research, 2020. 7(1): p. 83-92.
[9] Debie, A., Khatri, R.B. & Assefa, Y. Contributions and challenges of healthcare financing towards universal health coverage in Ethiopia: a narrative evidence synthesis. BMC Health Serv Res 22, 866 (2022).
[10] Merga, B.T., Balis, B., Bekele, H. et al. Health insurance coverage in Ethiopia: financial protection in the Era of sustainable development goals (SDGs). Health Econ Rev 12, 43 (2022).
[11] Tiwari, A., Urban Infrastructure Research A Review of Ethiopian Cities. 2016.
[12] Population and Health in Developing Countries: Population, Health and Survival at INDEPTH Sites Archived 2006-02-13 at the Wayback Machine. ISBN 0-88936-948-8
[13] "One Hundred Ways of Putting Pressure", p. 17. Human Rights Watch report, released 10 March 2010
[14] Vértesy, L. and T. Lemango, Comparison of local governments in Hungary and Ethiopia. 2022.
[15] Shigute, Z.; Mebratie, A.D.; Sparrow, R.; Alemu, G.; Bedi, A.S. The Effect of Ethiopia's Community-Based Health Insurance Scheme on Revenues and Quality of Care. Int. J. Environ. Res. Public Health 2020, 17, 8558.
[16] Zemene, A., Kebede, A., Atnafu, A. et al. Acceptance of the proposed social health insurance among government-owned company employees in Northwest

Ethiopia: implications for starting social health insurance implementation. Arch Public Health 78, 104 (2020).
[17] Tahir, A., Abdilahi, A.O. & Farah, A.E. Pooled coverage of community based health insurance scheme enrolment in Ethiopia, systematic review and meta-analysis, 2016–2020. Health Econ Rev 12, 38 (2022).
[18] Degefa, T. and K. Hoelscher, Development aid and health equity in Ethiopia. Development Studies Research, 2020. 7(1): p. 83-92.
[19] Reeves CA Bednar DA. "Defining quality: alternatives and implications''. Academy of Management Review, 1994; 19 (3): 419-445.
[20] Redman A. 'Assessment and accountability'. Journal of Health Services Research and Policy, 2009; 14 (4): 249–250.
[21] Ladhari R. 'A review of twenty years of SERVQUAL research'. International Journal of Quality and Service Sciences, 2009; 1 (2): 172-198.
[22] McLaughlin, C. P. and Kaluzny, A. D. Continuous Quality Improvement in Health Care. 3rd ed. Sudbury, MA: Jones and Bartlett Publishers, 2006.
[23] Eiriz V Figueiredo JA. 'Quality evaluation in healthcare services based on customer provider relationships'. International Journal of Healthcare Quality Assurance, 2005; 18 (6): 404-12.

[24]Lugada, Eric et al. "Health supply chain system in Uganda: assessment of status and of performance of health facilities." Journal of pharmaceutical policy and practice vol. 15,1 58. 5 Oct. 2022, doi:10.1186/s40545-022-00452-w

[25] Liang, Li et al. "A Locally Developed Electronic Health Platform in Uganda: Development and Implementation of Stre@mline." JMIR formative research vol. 2,2 e20. 24 Sep. 2018, doi:10.2196/formative.9658

[26] Ndejjo, Rawlance et al. "Harnessing digital technology for COVID-19 response in Uganda: lessons and implications for future public health emergencies." BMJ global health vol. 8,Suppl 6 (2023): e013288. doi:10.1136/bmjgh-2023-013288

[27]Jordanwood, Tapley, et al. "How Primary Health Care Services Are Financed in Uganda: A Review of the Purchasing Landscape. 1-27." (2020).

[28] Kiguli-Malwadde, Elsie et al. "An audit of registered radiology equipment resources in Uganda." The Pan African medical journal vol. 37 295. 2 Dec. 2020, doi:10.11604/pamj.2020.37.295.22046

[29] Guus Meijer and David Birmingham. Angola from past to present. Accord: from military peace to social justice? the Angolan peace process, pages 10– 15, 2004.
[30] Jeremy Ball. The history of angola. In Oxford Research Encyclopedia of African History. 2017.
[31] Jedrzej George Frynas and Geoffrey Wood. Oil & war in angola. Review of African political economy, 28(90):587–606, 2001.

[32] John L Hammond. The resource curse and oil revenues in angola and venezuela. Science & society, 75(3):348–378, 2011.
[33] Indira Campos and Alex Vines. Angola and China: a pragmatic partnership. Royal Institute of International Affairs, 2008.
[34] Yacouba TELLY and LIU Xuezhi. Analysis of the impact of renewable energy use on gdp and employment in angola: An error correction model approach. Journal of Economics and International Finance, 15(1):22–36, 2023.
[35] Pauline N Njoroge. The Impact Of Foreign Aid On Development In Africa: A Comparative Study Of Ghana And Angola. PhD thesis, University of Nairobi, 2020.
[36] Lukasz Jure´nczyk. Analysing china's "angola model": A pattern for chinese involvement in africa? The Strategic Review for Southern Africa, 42(2):43– 61, 2020.
[37] Kevin Acker and Deborah Brautigam. Twenty years of data on china's africa lending. Technical report, Briefing Paper, 2021.
[38] Siyuan Li. China's confucius institute in africa: a different story? International Journal of Comparative Education and Development, 23(4):353–366, 2021.
[39] Luigi Segagni Lusignani, Gianluca Quaglio, Andrea Atzori, Joseph Nsuka, Ross Grainger, Maria Da Concei¸cao Palma, Giovanni Putoto, and Fabio Manenti. Factors associated with patient and health care system delay in diagnosis for tuberculosis in the province of luanda, angola. BMC infectious diseases, 13(1):1–11, 2013.
[40] Gebretsadik Shibre. Social inequality in infant mortality in angola: Evidence from a population based study. Plos one, 15(10):e0241049, 2020.
[41] Caryn Bredenkamp, Adam Wagstaff, Leander Buisman, Leah Prencipe, and Devon Rohr. Health equity and financial protection datasheets. 2012.
[42] Xinxi Cao, Yabing Hou, Xinyu Zhang, Chenjie Xu, Peng Jia, Xiaomin Sun, Li Sun, Ying Gao, Hongxi Yang, Zhuang Cui, et al. A comparative, correlate analysis and projection of global and regional life expectancy, healthy life expectancy, and their gap: 1995-2025. Journal of global health, 10(2), 2020.
[43] World Health Organization. The world health report 2006: working together for health. World Health Organization, 2006.
[44] Abraham Charnes, William W Cooper, and Edwardo Rhodes. Measuring the efficiency of decision making units. European journal of operational research, 2(6):429–444, 1978.
[45] Maria Lusia Aznar, A Rando-Segura, MM Moreno, ME Soley, ES Igual, C Bocanegra, EG Olivas, A Ninda Eug´enio, A Zacarias, D Katimba, et al. Prevalence and risk factors of multidrug-resistant tuberculosis in cubal, angola: a prospective cohort study. The International Journal of Tuberculosis and Lung Disease, 23(1):67–72, 2019.
[46] Jeni Klugman. Human development report 2011. sustainability and equity: A better future for all. Sustainability and Equity: A Better Future for All (November 2, 2011). UNDP-HDRO Human Development Reports, 2011.
[47] Lygia Vieira Lopes, Ana Vaz Concei¸c˜ao, Jo˜ao Blasques Oliveira, Ant´onio Tavares, Clarinha Domingos, and Lucio Lara Santos. Cancer in angola, resources

and strategy for its control. Pan African Medical Journal, 12(1), 2012.
[48] Mar´ılia Marcondes Campoamor. Prevalˆencia e fatores associados a` toxoplasmose em gestantes de um munic´ıpio do interior do estado de S˜ao Paulo. PhD thesis, Universidade de S˜ao Paulo, 2021.
[49] Isabel Craveiro and Gilles Dussault. The impact of global health initiatives on the health system in angola. Global Public Health, 11(4):475–495, 2016.
[50] Palesa Sekhejane and Moeketsi Modisenyane. Use of system innovation for sustainable health system in angola. OIDA International Journal of Sustainable Development, 7(05):71–84, 2014.
[51] Isabel Craveiro and Giles Dussault. Effect of global health initiatives on the health services system in angola: perspectives of civil servants, donors, and non-governmental organisations. The Lancet, 380:S13, 2012.
[52] World Health Organization et al. Who country cooperation strategy 2015-2019: Angola. 2016.
[53] Camilo Lombana Cordoba, Luis A Andres, Lucrecio AM Da Costa, Crystal Fenwick, et al. Diagnosing angola's wash sector. Technical report, The World Bank Group, 2021.
[54] Maria Teresa Concei¸c˜ao Vicente, Rodrigo Daminello Raimundo, Ligia Ajaime Azalis, Virginia Berlanga Campos Junqueira, and Fernando Luiz Affonso Fonseca. Analysis of quality indexes of the provided health services in public and private services of angola. Journal of Human Growth and Development, 26(2):228–233, 2016.
[55] Yogesh Rajkotia, Ya-Shin Lin, and Paula Figueiredo. Angola health system assessment. 2005.
[56] Dawa Gyeltshen, Shuaibu Saidu Musa, Josephine Ndapewoshali Amesho, Samuel Chukwuebuka Ewelike, Alex Vandy Saffa Bayoh, Christophe Al-Sammour, Angel Anthony Camua, Xu Lin, Mat Lowe, Attaullah Ahmadi, et al. Covid-19: a novel burden on the fragile health system of angola. Journal of Global Health, 11, 2021.
[57] Emily Vardell. Global health observatory data repository. Medical reference services quarterly, 39(1):67–74, 2020.
[58] World Health Organization. Global tuberculosis report 2013. World Health Organization, 2013.
[59] Gertjan van Stam. Conceptualization and practices in digital health: voices from africa. African Health Sciences, 22(1):664–72, 2022.
[60] World Health Organization et al. Global diffusion of eHealth: making universal health coverage achievable: report of the third global survey on eHealth. World Health Organization, 2017.
[61] Nicholas Aderinto. Diagnosing the disparities: an analysis of the current state of medical imaging in africa and strategies for improvement: a correspondence. IJS Global Health, 6(3):e138, 2023.
[62] Gaby Ooms. Covid-19 and it's far-reaching health impacts in sub-saharan africa. Health Action International, 2020.
[63] Naz Karim, Ling Jing, J Austin Lee, Ramu Kharel, Derek Lubetkin, Camille M Clancy, Doris Uwamahoro, Ernest Nahayo, Joseph Biramahire, Adam R Aluisio,

et al. Lessons learned from rwanda: innovative strategies for prevention and containment of covid-19. Annals of global health, 87(1), 2021.
[64] Yidnekachew Girma Mogessie, Blaise Ntacyabukura, Dawit Tesfagiorgis Mengesha, Mohamed Babiker Musa, Marie-Claire Wangari, Nsabimana Claude, Nit Buntongyi, and Don Eliseo Lucero-Prisno III. Digital health and covid-19: challenges of use and implementation in sub-saharan africa. Pan African Medical Journal, 38(1), 2021.
[65] Savvas Andronikou and Victor Mngomezulu. Paediatric radiology seen from africa. part ii: recognising research advantages in a developing country. Pediatric radiology, 41:826–831, 2011.
[66] L Jarvis and B Stanberry. Teleradiology: threat or opportunity? Clinical radiology, 60(8):840–845, 2005.
[67] Floriana Zennaro, Joaquim Ant´onio Oliveira Gomes, Armando Casalino, Magda Lonardi, Meta Starc, Pierpaolo Paoletti, Daniele Gobbo, Chiara Giusto, Tarcisio Not, and Marzia Lazzerini. Digital radiology to improve the quality of care in countries with limited resources: a feasibility study from angola. PloS one, 8(9):e73939, 2013.
[68] Brett Saperstein. Angola: Country profile. 2015.
[69] E Samuel and PE Palmer. X-ray equipment for routine investigations– the who basic radiological system. South African Medical Journal= Suid-afrikaanse Tydskrif vir Geneeskunde, 67(7):248–251, 1985.
[70] Elizabeth A Krupinski. Clinical assessment of dry laser-processed film versus traditional wet-processed film with computed tomography, magnetic resonance imaging, and ultrasound. Academic Radiology, 3(10):855–858, 1996.
[71] Helina Kotilainen. Rehabilitation of the hospital infrastructure in a developing country. World Hospitals and Health Services: the Official Journal of the International Hospital Federation, 37(2):25–8, 2001.
[72] Savvas Andronikou, Kieran McHugh, Nuraan Abdurahman, Bryan Khoury, Victor Mngomezulu, William E Brant, Ian Cowan, Mignon McCulloch, and Nathan Ford. Paediatric radiology seen from africa. part i: providing diagnostic imaging to a young population. Pediatric radiology, 41:811–825, 2011.
[73] AI Korolev, IN Mirzoyan, and VB Chelnokov. Equipment for fast radiography with diffusion-transfer photographic materials. Biomedical Engineer-ing, 24(1):31–32, 1990.
[74] Stephen RC Howie, Sarah E Hill, David Peel, Momodou Sanneh, Malick Njie, Philip C Hill, Kim Mulholland, and Richard A Adegbola. Beyond good intentions: lessons on equipment donation from an african hospital. Bulletin of the World Health Organization, 86:52–56, 2008.
[75] Robert A Malkin. Design of health care technologies for the developing world. Annu. Rev. Biomed. Eng., 9:567–587, 2007.
[76] JM Kitonyi. The basic radiological system experience in kenya. East African medical journal, 70(12):793–796, 1993.
[77] Sinisa Haberle and Charles Maxfield. Pediatric imaging in global health radiology. In Radiology in Global Health: Strategies, Implementation, and

Applications, pages 205–217. Springer, 2014.
[78] Michael R Galarneau, Kevin J Mahoney, Paul J Konoske, and Kristee E Emens-Hesslink. Development of a model for predicting medical supply requirements at the forward echelons of care: Preliminary findings for Ech-elon II laboratory and x-ray ancillaries. Naval Health Research Center, 1997.
[79] Damas Macaia and Lu´ıs Velez Lap˜ao. The current situation of human resources for health in the province of cabinda in angola: is it a limitation to provide universal access to healthcare? Human resources for health, 15:1–9, 2017.
[80] PD Simpson, CJ Martin, CL Darragh, and R Abel. A study of chest radiography with mobile x-ray units. The British Journal of Radiology, 71(846):640–645, 1998.
[81] Josh Pyke, Michael Hart, Veljko Popov, Robert D Harris, and Susan Mc-Grath. A tele-ultrasound system for real-time medical imaging in resource-limited settings. In 2007 29th Annual International Conference of the IEEE Engineering in Medicine and Biology Society, pages 3094–3097. IEEE, 2007.
[82] Agnieszka Szot, Francine L Jacobson, Samson Munn, Darius Jazayeri, Edward Nardell, David Harrison, Ralph Drosten, Lucila Ohno-Machado, Laura M Smeaton, and Hamish SF Fraser. Diagnostic accuracy of chest x-rays acquired using a digital camera for low-cost teleradiology. Interna-tional journal of medical informatics, 73(1):65–73, 2004.
[83] Peter Corr, Ian Couper, Stephen J Beningfield, and Maurice Mars. A simple telemedicine system using a digital camera. Journal of Telemedicine and Telecare, 6(4):233–236, 2000.

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