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ADVANCES IN MEDICAL IMAGING AND IMPLEMENTATION CHALLENGES IN AFRICA

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ABSTRACT

Introduction
The integration of advanced imaging technology into healthcare systems across Africa presents both significant challenges and promising opportunities. While the global field of medical imaging continues to evolve rapidly, many African countries have lagged in adopting these advancements, hindered by systemic, financial, and infrastructural barriers. Nevertheless, with focused efforts at both local and international levels, these obstacles can be addressed.

Purpose
This paper highlights current advances in medical imaging and related implementation challenges for healthcare systems in Africa. It examines the challenges surrounding the acquisition and integration of advanced imaging technologies, including financial, infrastructural, and systemic barriers. The paper emphasizes the need for locally informed policies, increased health sector investment in imaging, and the development of a well-trained workforce through comprehensive education and training programs. It also highlights the importance of research, innovation, and strategic collaborations among international organizations, professional bodies, and local stakeholders. By addressing these key areas, the paper provides actionable insights to guide African countries in advancing medical imaging for improved healthcare delivery and patient outcomes.

Keywords: *Medical Imaging Advances, Medical Imaging in Africa, Future of African Healthcare, Medical Imaging Implementation, Medical Imaging Challenges*
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INTRODUCTION

Medical Imaging technology uses ionizing and non-ionizing radiation for diagnosis, treatment, and monitoring of disease conditions(1). Healthcare professionals select specific imaging modalities based on symptoms presented to help diagnose and manage a range of conditions(2). The advancement in medical imaging techniques plays a crucial role in standardizing screening, diagnosis, reporting, and management of protocols for both communicable and non-communicable diseases. Emergent conditions and epidemics such as COVID-19 have benefited from technological advancements such as telemedicine and artificial intelligence, which have increased the effectiveness of medical imaging practices(3).

The Introduction of cutting-edge medical imaging technology in Africa confronts many challenges, including but not limited to skill set disparities, human resource limitations, and the dynamic landscape of evolving diseases(4). Notably, the continent grapples with a pronounced scarcity of advanced medical imaging equipment(5, 6), precipitating diminished levels of accessibility and utilization(7), adversely impacting the overall quality of imaging services.

The paper seeks to give a nuanced understanding of the current status, barriers, and potential pathways forward in medical imaging across the African continent through a comprehensive examination.

HISTORY AND ADVANCES OF MEDICAL IMAGING TECHNOLOGY

Medical Imaging stands as one of the most revolutionary innovations in the medical field, with a captivating 128-year history that includes the pivotal developments in x-ray, Ultrasound (US), Magnetic Resonance Imaging (MRI), Computed Tomography (CT) and functional imaging using Nuclear Medicine (NM) technology; Positron Emission Tomography (PET) and Single Photon Emission Tomography (SPECT).

The accidental discovery of X-rays in 1895 by Dr. Roentgen has revolutionized healthcare, especially in detecting various medical conditions (8). In Africa, X-rays were introduced in countries like South Africa (1896), Egypt (1906), Uganda (1907), Nigeria (1913), and other regions(9). However, the adoption of advanced imaging technology in Africa has been slower compared to the rest of the world(10). Digital x-ray technology in Africa has seen gradual progress since the 1980s, though still underutilized due to a lack of training of the existing human resource(11).

Diagnostic ultrasound was introduced in the 1960s, using high-frequency sound waves and detection of echoes for imaging from various layers of tissues(12, 13). The modality has gone through a series of advancements, including one of the latest as Real-time Virtual Sonography (RVS), which enhances the accuracy of breast lesion detection when utilized alongside MRI(14). It is not known whether some African countries have acquired this yet, as many still face significant challenges in acquiring and utilizing these ultrasound advances(15).

MRI was introduced in the 1970s in the UK, and it provides superior soft tissue contrast of the human anatomy non-invasively(12). MRI operates on the principle of nuclear magnetic resonance of protons in the presence of strong magnetic fields and an applied RF pulse, resulting in the difference in the relaxation rates observed between different tissues, leading to the excellent soft tissue contrast(16). Africa has seen a slow pace in acquiring MRI systems, with less than a third of African countries having, on average, one machine per one million people(17). Even those installed with new advances, like basically functional MRI and neuroimaging, are not fully utilized because of limited availability to education and training resources(18, 19).

CT was first developed by Hounsfield in 1969(20). It generates cross-sectional anatomical images by capturing a sequential series of slices, which are then reconstructed by a computer to visualize internal structures(21). It has seen a series of advancements to the current generation of photon-counting CT detectors that are still limited to the developed world. These have exceptionally high spatial resolution, minimal electronic noise, and enhanced contrast-to-noise surpassing the capabilities of current CT detectors(22, 23). Over the past two decades, African countries have significantly increased their acquisition and utilization of CT equipment for various medical conditions(24). However, technological advancements in CT scanners are still underutilized in African nations because of a lack of trained personnel and high operation costs(19)

NM is a gold standard for functional imaging using PET and SPECT. NM has been in use since the 1990s, with a resurgence in recent years with combined usage of CT or MRI to enhance localization(12, 21). Over the past 50 years, NM has become crucial in managing public health issues worldwide because of advances in its technology, software, radiopharmacy, and instrumentation. This progress has highlighted NM importance in diagnosing and treating diseases like cancer, heart disease, gastrointestinal, neurological disorders, among others. Africa has seen developments in NM over the last three decades, with South Africa and North African countries showing growth similar to developed nations. However, in many other African countries, NM growth has been limited to basic clinical services using ^{99m}Tc studies and iodine-131 treatments(25).

CONTRIBUTIONS OF MEDICAL IMAGING TO AFRICAN HEALTHCARE

Medical imaging has revolutionized the healthcare sector, offering unprecedented insights, driving research, and achieving practical milestones in the past few decades(26).

Although technological advancements have been slow in developing countries, emerging conditions and epidemics have accelerated progress(27). Covid-19 highlighted the crucial role of medical imaging, leading to increased use of CT scans for screening and diagnoses due to their high sensitivity compared to X-rays and easily accessible ultrasound(28). Countries like Uganda seized this opportunity to equip regional health facilities with more imaging modalities in readiness for future preparedness(29). Additionally, emergent conditions like cancers have prompted the procurement of recent models of CTs, PET scanners, and the application of Artificial Intelligence in Africa, with variability of implementation and a huge workforce shortage(30).

Furthermore, global initiatives like "Making Pregnancy Safer" and "End TB" have promoted the use of obstetric ultrasounds for better maternal and newborn outcomes. This global move has seen the introduction of portable PoCUS probes and 3D ultrasound systems in low-resource settings that are used to confirm intrauterine pregnancy, fetal viability, and a number of fetuses (31, 32). The initiative to end TB by 2030 has led to the installation of equipment in low-income communities and the integration of chest X-rays in routine TB screenings in South African countries like Lesotho, Malawi, Mozambique, and Zambia, and East African countries like Uganda, Kenya, Tanzania, and Ethiopia(33). This effort has also spurred the use of artificial Intelligence (AI) techniques, such as WHO's CAD-TB, with scientists developing machine learning datasets and algorithms for early TB detection in underserved areas(34, 35). However, little is still known

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about AI's applicability to community-based active case findings for TB(36)

MEDICAL IMAGING MODALITIES CURRENTLY IN AFRICA

Advanced imaging technologies are limited in the African healthcare sector compared to that of the developed world(37), and the equipment coverage varies from country to country. Except for South Africa, most African countries lack the minimum number of medical imaging equipment recommended by the WHO(7). *Table 1* illustrates the under-distribution of imaging equipment in Africa. Most of the data were obtained from recent publications, with the remainder sourced from statistics provided by authors from their respective countries. *Table 1* highlights the most widely used and the least available modalities, with conventional X-ray being the most utilized and NM and bone densitometry being the scarcest. While data were obtained from 12 out of the 54 countries, this selection provides a valuable representation of the broader trends across the region. These 12 countries were chosen based accessibility of data, diversity in healthcare infrastructure, and availability of a contributor to this statistical data, which allows for meaningful analysis and comparison.

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Table 1: Statistical distribution of medical imaging equipment, as of 2024

Country	Population	#MRI	#CT	# Co-X-ray	# Fluoro	#Mammo	#Ultra	#IR	Dental	NM	Bone Densitometry
Ghana(38)	31,478,523	18	46	454	47	37	--------			3	--------
Uganda	45,850,000	10	27	653	117	12	--------	7	82	1	1
Kenya	56,600,000	87	1018	5433	679	283	86	45	36	6	4
Ethiopia	129,719,719	28	140	1208	10	35	633	132	373	4	4
Nigeria(17, 38-40)	228,394,504	100	150	------	-----	50	-------	8	-------	3	-------
South Africa(17, 38, 40, 41)	59,890,000	243	282	>1450		117	-----	-----	-------	107	--------
Egypt(17, 38, 40)	114,235,107	277	725	>2500	------	~185	-------	622	(app) 3000	139	---------
Tanzania(17, 38, 40)	69,128,496	17	21			21		400		3	
Morocco(17, 38, 40, 42, 43)	38,160,034	119	360	>4500	--------	110	99	60	-----	34	-------
Rwanda(17, 44)	14,368,827	5	7	52	5	5	------	---	-------	0	0
Zambia	21,052,273	7	13	235	9	20	84	0	53	2	1
Zimbabwe(38, 40, 45)	16,969,458	6	22	401	18	10	------	----	------	2	3
Malawi	21,375,000	3	11	134	0	4	128	0	83	0	0
Sudan	43,849,260	15	30	875	82	40	200	23	38	13	2

CURRENT ADVANCES OF MEDICAL IMAGING IN AFRICAN HEALTHCARE

In Africa, the integration and advancement of medical imaging technologies have seen notable progress over the past two decades, despite persistent infrastructural and resource-related challenges. A growing body of literature underscores the continent-wide transition from analog to digital radiography, largely driven by the increasing affordability of digital systems and the demand for enhanced image quality and operational efficiency(46, 47).

Ultrasound remains the most widely accessible imaging modality, particularly in rural and resource-constrained settings, due to its portability, widely accessible, non-ionizing nature, and cost-effectiveness(48). Its application in obstetric care, abdominal imaging, and point-of-care diagnostics is well documented. More recently, the deployment of handheld ultrasound devices has extended diagnostic capabilities to remote areas, with promising results in maternal health and emergency care(49).

Advancements in CT and MRI are increasingly evident in Africa. CT has gained prominence in trauma and oncology care, while MRI is being used for neurological and musculoskeletal imaging(50-52). However, access remains uneven, with many rural and secondary healthcare facilities still lacking these modalities.

Tele-radiology has emerged as a transformative tool for addressing the acute shortage of radiologists on the continent(53). Several studies report successful tele-radiology collaborations between African institutions and international partners, significantly improving diagnostic turnaround times and access to specialist interpretation(53, 54). This trend is complemented by the gradual adoption of Picture Archiving and Communication Systems (PACS), which enhance workflow efficiency and data management in hospitals.

AI and computer-aided detection (CAD) systems are being piloted in countries like Kenya, South Africa, and Uganda, particularly in tuberculosis screening and breast cancer detection(55). These innovations aim to augment the capacity of overstretched radiology services, although challenges related to infrastructure, regulatory frameworks, and data privacy persist.

A case in point is; despite the challenges, the future of medical imaging in African healthcare is promising. Emerging technologies such as AI in diagnostics(56-58), portable imaging devices(6), and innovative telemedicine platforms(59) offer new opportunities for improving access to quality care. These advancements, coupled with ongoing efforts to build a skilled workforce and improve healthcare infrastructure(60), could significantly enhance the capacity for early disease detection and treatment across the continent.

CHALLENGES TO ADVANCING MEDICAL IMAGING IN AFRICA

The WHO estimates that 2/3 of the global population lack access to radiology services, a disparity particularly pronounced in developing countries. Despite accounting for 84% of the world's population, these regions contribute only 12% to global health spending(45, 61, 62). While advanced imaging modalities such as CT, MRI, and PET are increasingly available globally, their adoption in Africa is uneven due to persistent challenges.

Government Policies

The policy landscape in many African countries presents significant barriers to the effective acquisition and implementation of advanced medical technologies. Service planning, sustainability, and the availability of adequate data to inform future strategic planning, policy development, standards, and guidelines are lacking in developing countries(63). In Nigeria, policies neglect key areas like information technology (IT), requiring changes to enhance awareness and competence. Unfavorable government policies impede civil service employment, compromising the healthcare system(64). Uganda's Health Sector Development Plan (HSDP) 2015-2020 recognizes medical equipment importance however, the 2009 Uganda National Medical Equipment Policy limits low-level centers to ultrasound and general radiography at health center IV. Additionally, the plan does not specify the required technology for these facilities(62). In Africa, policies for integrating telemedicine and AI in healthcare infrastructure are lacking(65), yet these new advances have the full potential of changing the future of medical imaging on the continent.

Investment Plans

HealthTech investments yield financial returns and positive social impact by enhancing healthcare accessibility and affordability in developing countries. Insufficient investment plans and device procurement processes, perceiving imaging as peripheral to healthcare delivery in developing countries, pose challenges, with low budget allocations being the major issue. Imaging has been neglected in healthcare planning for decades due to its complexity and resource requirements(6, 63, 66, 67).
In Nigeria, inadequate investment plans restrict access to new technologies. Scarcity of equipment relative to the population, coupled with affordability, is exacerbated by the prevalent practice of clients paying out of pocket, with minimal health insurance access. Similarly, in Uganda, the health budget has declined relative to GDP and overall government expenditure, impacting resource allocation for addressing health needs(62). Governments in developing countries prioritize cost savings, imposing budgetary constraints on health systems(68). Additionally, Governments in developing countries lack strategic plans that can guide health sector investments. Lack of continuity and failure to capture critical lessons during plan implementation have been emphasized in the Malawian Health Sector Strategic Plan II 2017-2022(69).

Implementation Costs

The high cost of acquiring and maintaining advanced imaging equipment, as well as the expenses associated with training personnel and upgrading infrastructure, can be prohibitive for healthcare facilities in Africa with limited resources(66). High sustainability costs, encompassing purchase, skill acquisition, operations, and maintenance, constitute a substantial portion of the total expenses. The pervasive issue in all countries is the scarcity of funds for healthcare, with even HICs facing challenges in coping with escalating costs amid ongoing economic downturns(64). Limited financial resources hinder the growth and acquisition of the latest technology in Africa. The continent heavily depends on donated equipment, with 40% not fully functional, donated at the end of their lifespan with limited availability of spare parts(63), lack of user manuals, no service contract or warrantee, no local qualified service Engineer, and often donated without vendor assistance(7). Additionally, vendors offer service contracts for the equipment bought from them, yet they are included in less than 40% of the purchases(7). In Nigeria, the major challenge is the exorbitant cost linked to the acquisition of medical imaging, stemming from the country's economic struggles(70). The capital-intensive nature of the equipment and infrastructure, and the highly skilled personnel required, present insurmountable barriers for developing countries(71).

Poor Leadership and Management

Effective leadership from healthcare professionals is crucial, however, it is frequently lacking in the medical imaging industry(72). A major challenge to come will be identifying and nurturing leaders equipped for the complexities of healthcare systems, driven by rising demands. African leadership in healthcare is often scrutinized and considered a contributing factor to the region's health challenges, including adaptation to technological changes(73).

Human Resource

The workforce to operate imaging modalities remains insufficient. A clear example: the number of radiologists in four selected teaching hospitals in Boston exceeds the total count for the entire West Africa(7). The high burden of disease, especially in sub-Saharan Africa, has been exacerbated by various factors, including a shortage of a skilled workforce that is largely attributed to brain drain(3, 74, 75). Even if advanced imaging technology were largely available in Africa, the scarcity of skilled and trained biomedical engineers poses a challenge in maintaining such equipment in optimal working conditions(62), in addition to a lack of adherence to equipment servicing practices(4). The status of staffing in some African countries is shown in Tables *2 and 3* below. Data was obtained from recent publications and Authors from different countries.

Table 2: Number of skilled health professionals in medical imaging by profession in selected countries in East and North Africa

Regions		East Africa					North Africa		
Countries		**Ethiopia**	**Kenya**	**Rwanda**	**Tanzania**	**Uganda**	**Egypt**	**Morocco**	**Sudan**
Population (million)		129.72	56.60	14.37	69.13	45.85	114.24	38.16	43.85
Number of Skilled Health Professionals	Radiologists	475	430	11	60	113	1250	338	**85**
	Medical Physicists	14	37	0	4	11	374	61	38
	Radiographers	2500	1,700	-------	1200	770	------	------	727
	Biomedical Engineers	4004	480	-------	350	> 1000	-------	------	108
Skilled Health Professional Density/10,000		0.50	0.45	--------	0.23	0.41	------	-------	0.22

Table 3: Number of skilled health professionals in medical imaging by profession in selected countries in Southern and West Africa

Regions		Southern Africa				West Africa		
Countries		**Malawi**	**South Africa**	**Zambia**	**Zimbabwe**	**Cameroon**	**Ghana**	**Nigeria**
Population (million)		21.38	59.89	21.06	16.97	27.29	31.48	228.39
Number of Skilled Health Professionals	Radiologists	2	1007	12		176	93	335
	Medical Physicists	4	136	6	9	2	114	100
	Radiographers	263	7910	870	386	380	340	3221
	Biomedical Engineers	41	300	90	--------	---------	--------	> 5000
Skilled Health Professional Density/10,000		0.15	1.60	0.46	--------	--------	-------	0.38

(9, 40, 43, 76-78)

In comparison to developed countries, like the United States, UK, and Canada that generally have a higher ratio of radiologists, radiographers and medical physicists to their populations, the U.S. has around 10-12 radiologists per 100,000 people, UK has 8.6, Canada has 6.9 and Australia has 8.4, while European countries have similar ratios as cited by Ko, C.-H., et al. 2024 (79). Additionally, they often have more medical imaging technologists and support staff. This strongly draws a thick line between developed and developing countries concerning human resources.

The success of Medical Imaging relies on a well-trained workforce, encompassing technologists, radiologists, medical physicists, and biomedical engineers. The impediment to this success is a lack of local training programs, training institutions, and the necessary infrastructure(74, 80, 81). Table 4 depicts the scarcity in terms of the number of training institutions for different medical imaging professionals in thirteen countries in Africa. The selection of countries provides a valuable representation of the broader picture across the region.

Training

Table 4: Number of institutions facilitating the training of medical imaging skilled medical professionals in selected countries in Africa

No	Country	Radiographers	Radiologists	Medical Physicists	Biomedical Engineers
1	Uganda	4	3	0	3
2	South Africa(74)	9	6	5	--
3	Egypt(40)	11	5	8	
4	Ethiopia	7	4	0	5
5	Nigeria(40)	7	27	10	--
6	Ghana	6	4	1	3
7	Kenya	5	11	1	7
8	Tanzania(74)	2	2	1	--
9	Morocco(40)	8	6	1	
10	Zambia	3	1	0	2
11	Zimbabwe(40, 74)	3	1	2	2
12	Malawi(74)	2	0	0	2
13	Sudan	5	4	2	4

Despite the significant evolution of medical imaging curricula over the years(82), developing countries face curricula update challenges, impeding alignment with rapid field advancements(83). Moreover, a shortage of qualified professionals to teach medical students imaging principles has widened the gap in radiology education(84).

Limited user personnel training in developing countries reduces confidence, as many buyers rely on third-party distributors for both new and refurbished equipment(7). This significantly contributes to a shortage of trained healthcare workers to operate such equipment. Similarly, in Zambia, it was reported that insufficient training for engineers and physicists in equipment safety and maintenance is evidenced in public hospitals as they resort to a trial-and-error approach and suboptimal machine utilization(85).

PROPOSED SOLUTIONS TO THE CHALLENGES

Developing countries' healthcare systems require innovative solutions to overcome the current challenges. Without addressing these challenges, achieving the WHO's Sustainable Development Goals (SDGs) of Universal Health Coverage (UHC) by 2030 is unlikely.

Informed Policies

Public health sustainability relies on a multifaceted approach, encompassing effective healthcare policy, robust regulatory frameworks, procurement policies, innovation strategies, and an intellectual property (IP) system. Establishment and reinforcement of national policies are crucial for acquiring appropriate medical imaging technologies, supporting primary care and specialty services, and contributing to overall population health improvement. Neglecting technical experts' input in procurement processes due to gaps in policies leads to acquiring outdated imaging technology(3).

Implementing an innovative framework for a tiered diagnostic imaging service that adapts to the varying resources in different contexts and settings may empower local technical experts to contribute to decision-making processes, support national policies, adhere to norms and standards, and participate in cost-effectiveness studies that can inform future policies(3).

The presence of strong regulatory policies ensures consideration of advanced imaging technologies during procurement processes. The policies may guide training, utilization, and maintenance of these technologies. For instance, Kenya has a policy on medical imaging for the practice and licensing of imaging facilities. Enhancing African regulatory bodies with policies for periodic surveillance ensures the use of new technology and the decommissioning of outdated ones. Similarly, Uganda's National Advisory Committee on Medical Equipment regulates and specifies purchases for various health center levels. Beyond technology acquisition, the government may consider subsidizing access costs for the broader population, necessitating the development of relevant policies. Furthermore, Algeria has a free access to health care policy in which all its citizens have benefited, a policy that each African country may need for the improvement of access to healthcare, including medical imaging services for a broader population.

Health Budget (Prioritize Health)

Governments may consider relocating funds from low-impact programs to higher impact as medical imaging(86). Increasing health budgets and implementing universal healthcare insurance for all citizens are also important measures(62, 64, 80, 86). For instance, Algeria has prioritized its health budget by acquiring several PET CTs and distributing advanced imaging equipment across the country. Similarly, Uganda boosted its training budget for professionals and has equipped all regional hospitals with state-of-the-art CT technologies.

Investing in a reliable power supply and network connectivity is essential to support the implementation of new imaging technology(3). Strengthening public-private partnerships is vital to reducing inequalities and improving access to advanced technologies(62). Kenya and Egypt have taken steps to decentralize imaging facilities, improve accessibility, and invest in national health insurance systems, ensuring affordable access to imaging technology for workers and their dependents. Additionally, planning for the maintenance budget of new technology is critical to avoid underestimation. Including service contracts in the initial purchase agreements and budget considerations helps ensure a comprehensive and sustainable financial plan for the full lifecycle of the technology(87).

Leadership and management

Strong leadership is essential for transforming technological changes into opportunities, requiring a problem-solving mindset and a team-based approach(88). A collaborative leadership model is widely recommended for maintaining quality improvement in medical imaging(68, 89, 90). As technological advancements continue, leadership from both professionals and organizations plays a key role in guiding the successful integration and management of these changes, requiring careful planning to address the growing complexity of medical imaging technology and its associated challenges(91). Leaders in medical imaging must adapt to address challenges in quality assurance, adaptability, and human resource management. Health leaders may need to evolve and broaden their skills to navigate the current healthcare landscape effectively.

Train and train more to enhance the workforce.

Health systems may benefit from prioritizing the recruiting and retention of qualified staff, especially those with advanced training and skills(3, 66). Establishing comprehensive training programs focused on specialized education in imaging areas could enhance capacity in developing countries(92). Collaboration with both public and private training institutions in HICs, as well as partnerships with NGOs, could also support these efforts(6, 66). A case in point, the IAEA has collaborated with a number of institutions in Africa to provide training to professionals in the medical imaging field.

Ghana hosts an IAEA Regionally Designated Center (RDC) for Medical Physics Education and Training. The program includes a 2-year master's degree (MPhil) and a two-year clinical internship, as well as a 4-year PhD degree program. Medical Physicists are trained within the country to ensure a sufficient workforce for the country and the African sub-region.

Uganda has a limited number of training institutions catering to Radiographers, Sonographers, Radiologists, and Biomedical Engineers, along with active societies that provide CMEs. Egypt has a comprehensive human resource development plan for medical imaging professionals, including national fellowships, professional diplomas, MScs, PhDs, and MDs.

Invest in Local Maintenance Training Programs

Investing in local maintenance training programs can cultivate a workforce of skilled technicians who are proficient in maintaining and repairing medical imaging equipment. This not only reduces dependence on expensive foreign experts but also promotes self-reliance and strengthens local healthcare infrastructure. Furthermore, local maintenance solutions ensure faster turnaround times for equipment repairs, minimizing disruptions in healthcare services.

Training programs can be designed in collaboration with international medical technology companies, universities, and local health institutions to ensure they meet global standards. Such programs can also incorporate continuous professional development (CPD) components to keep technicians updated with the latest technological advancements. In the long run, local maintenance training helps optimize the lifespan of medical equipment, improves healthcare outcomes, and contributes to the overall sustainability of healthcare systems in Africa.

Research and Innovations

Establishing research collaborations between developed and developing nations can help address medical imaging disparities, promoting global equity and enabling sustainable models for high-quality imaging services in developing countries(80). Innovations introduce new ideas and changes that extend beyond conventional technological approaches(93). In developing countries, innovative advancements in imaging technology are enhancing healthcare accessibility and significantly improving diagnostic accuracy and precision like never before (66, 94, 95). Increasing investments in research and innovation could

support the upgrading of facilities with the latest advancements, fostering global competitiveness.
The impact of AI on medical imaging in developing countries is expected to be significant, with ongoing research, development, and validation efforts contributing to its potential(66). Africa may benefit from being open to adopting emerging technologies like AI and integrating them in settings where experienced human resources are scarce(36).

Collaborations

Collaboration between governments and international organizations is essential for improving imaging infrastructure in Africa. The International Society of Radiology has proposed a comprehensive plan to enhance the role of medical imaging in global health. This plan highlights the potential of leveraging AI for imaging in low- and middle-income countries (LMICs) and recommends the establishment of the "International Commission on Medical Imaging" to increase awareness of the benefits of scaling up medical imaging in these contexts(6, 66, 96, 97). Implementing this plan will necessitate the participation of professional and international organizations. (66).
RAD-AID provides education, equipment, infrastructure, and support, offering a valuable resource for developing nations(98, 99). WHO collaborates with partners and equipment manufacturers to develop training programs for equipment users, tele-radiology, and promotes AI to improve medical imaging services in developing countries. The European Society of Radiology is collaborating with IAEA on a project to distribute the ESR iGuide, which includes imaging referral guidelines integrated into clinical decision support, aiming to enhance the appropriate use of imaging in Africa(66). Africa should embrace these opportunities.

CONCLUSIONS

Medical imaging has undergone remarkable advancements, with its evolution expected to continue at a rapid pace. In the coming years, clinicians are projected to increasingly depend on intelligent imaging technologies to support evidence-based diagnosis and treatment. However, the adoption of these innovations in Africa has lagged. Although the continent recognizes the challenges associated with acquiring and implementing advanced imaging technologies, these obstacles are not insurmountable.

Key barriers include unfavorable government policies, inadequate investment strategies, high implementation costs, weak leadership, limited human resources, and insufficient training opportunities. Addressing these challenges requires a multi-faceted approach; some solutions must be initiated locally, while others will depend on international collaboration.

Efforts to overcome these barriers must involve coordinated actions among governments, international organizations, professional bodies, and key stakeholders. Evidence shows that enhancing medical imaging services in developing countries yields substantial improvements in healthcare outcomes (100). Achieving this will require the formulation of informed policies, increased health budget allocations specific to imaging, targeted professional training, and a focus on research and innovation.
By implementing these recommendations, African nations have the potential to significantly reduce barriers to acquiring advanced imaging technologies and, in turn, strengthen healthcare service delivery across the continent.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

Not applicable.

CONSENT FOR PUBLICATION

Not applicable.

AVAILABILITY OF DATA AND MATERIAL

Not applicable

COMPETING INTERESTS

The authors declare no competing interests.

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AUTHORS' CONTRIBUTIONS

AM conceptualized the idea, wrote and reviewed the paper, ON did the literature search, wrote and reviewed the paper, and RK did a literature search and reviewed the paper after writing. MK, MPA, and KN reviewed and approved the paper, RM guided on the best way the paper can be written, and read and approved the paper.

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ABBREVIATIONS

AI – Artificial Intelligence
AR – Augmented Reality
CAD – Computer Aided Detection
CT – Computed Tomography

FDA – Food and Drug Administration
HIC – High Income Countries
IT – Information Technology
MRI – Magnetic Resonance Imaging
NM – Nuclear Medicine
PACS - Picture Archiving and Communication Systems
PET – Positron Emission Tomography
SPECT – Single Photon Computed Tomography
US – Ultrasound
VR – Virtual Reality
WHO – World Health Organization

REFERENCES

1. U.S Food and Drug Administration. Medical Imaging. 2018.
2. Huang H, Aberle DR, Lufkin R, Grant EG, Hanafee WN, Kangarloo HJAoim. Advances in medical imaging. 1990;112(3):203-20. https://doi.org/10.7326/0003-4819-112-3-203 PMid:2404446
3. DeStigter K, Pool K-L, Leslie A, Hussain S, Tan BS, Donoso-Bach L, et al. Optimizing integrated imaging service delivery by tier in low-resource health systems. 2021;12(1):1-11. https://doi.org/10.1186/s13244-021-01073-8
PMid: 34529166 PMCid: PMC8444174
4. Gadeka DD, Esena RKJJoMI, Sciences R. Barriers to quality care in medical imaging at a teaching hospital in Ghana: staff perspective. 2020;51(3):425-35. https://doi.org/10.1016/j.jmir.2020.05.002
PMid:32536512
5. Rohaya M-NJJoHIiDC. Medical imaging trends and implementation: Issues and challenges for developing countries. 2011;5(1).
6. Frija G, Blažić I, Frush DP, Hierath M, Kawooya M, Donoso-Bach L, et al. How to improve access to medical imaging in low- and middle-income countries? 2021;38. https://doi.org/10.1016/j.eclinm.2021.101034
PMid: 34337368 PMCid: PMC8318869
7. DeStigter K, Horton S, Atalabi OM, Garcia-Monaco RD, Gharbi HA, Hlabangana LT, et al. Equipment in the global radiology environment: why we fail, how we could succeed. 2019;5(1):3. https://doi.org/10.7191/jgr.2019.1079
8. Howell JDJTotAC, Association C. Early clinical use of the X-ray. 2016;127:341.
9. Iyawe E, Idowu B, Omoleye O. Radiology subspecialisation in Africa: A review of the current status. SA J Radiol 25, a2168. 2021. https://doi.org/10.4102/sajr.v25i1.2168 PMid:34522434 PMCid: PMC8424752
10. Anazodo UC, Ng JJ, Ehiogu B, Obungoloch J, Fatade A, Mutsaerts HJ, et al. A framework for advancing sustainable magnetic resonance imaging access in Africa. 2023;36(3):e4846. https://doi.org/10.1002/nbm.4846 PMid:36259628
11. Campbell S, Morton D, Grobler AJR. Transitioning from analogue to digital imaging: Challenges of South African analogue-trained radiographers. 2019;25(2):e39-e44. https://doi.org/10.1016/j.radi.2018.10.001 PMid:30955697
12. Andrew Rubin. History of Medical Imaging - A Brief Overview. 2017.
13. Kremkau FW. Sonography Principles and Instruments E-Book: Elsevier Health Sciences; 2019.
14. Uematsu T, Takahashi K, Nishimura S, Watanabe J, Yamasaki S, Sugino T, et al. Real-time virtual sonography examination and biopsy for suspicious breast lesions identified on MRI alone. 2016;26(4):1064-72. https://doi.org/10.1007/s00330-015-3892-z
PMid:26135000
15. Aliyu LD, Kurjak A, Wataganara T, De Sá RAM, Pooh R, Sen C, et al. Ultrasound in Africa: what can really be done? 2016;44(2):119-23. https://doi.org/10.1515/jpm-2015-0224
16. Westbrook C, Talbot J. MRI in Practice: John Wiley & Sons; 2018.
17. Hasford F, Mumuni AN, Trauernicht C, Ige TA, Inkoom S, Okeji M, et al. A review of MRI studies in Africa with special focus on quantitative MRI: Historical development, current status and the role of medical physicists. 2022;103:46-58. https://doi.org/10.1016/j.ejmp.2022.09.016
PMid:36219962
18. Ogbole G, Adepoju A, Ibrahim A, Togunwa T, Nkeakam F. MRI training in Africa. Annals of Ibadan Postgraduate Medicine. 2023;21(2):75-80.
19. Aderinto N, Olatunji D, Abdulbasit M, Edun M. The essential role of neuroimaging in diagnosing and managing cerebrovascular disease in Africa: a review. Annals of Medicine. 2023;55(2):2251490. https://doi.org/10.1080/07853890.2023.2251490
PMid:37643607 PMCid:PMC10496522
20. Hussain S, Mubeen I, Ullah N, Shah SSUD, Khan BA, Zahoor M, et al. Modern diagnostic imaging technique applications and risk factors in the medical field: A review. 2022;2022. https://doi.org/10.1155/2022/5164970
PMid: 35707373 PMCid: PMC9192206
21. Seeram E. Computed Tomography-E-Book: Physical Principles, Clinical Applications, and Quality Control: Elsevier Health Sciences; 2015.
22. Siemens. Photon-Counting CT.
23. Willemink MJ, Persson M, Pourmorteza A, Pelc NJ, Fleischmann DJR. Photon-counting CT: technical principles and clinical prospects. 2018;289(2):293-312. https://doi.org/10.1148/radiol.2018172656
PMid:30179101
24. Goldstein LN, Dawadi S, Viljoen IM. CT utilization in a level one trauma center in South Africa. Cureus. 2022;14(9). https://doi.org/10.7759/cureus.29041
25. Orunmuyi AT, Lawal IO, Omofuma OO, Taiwo OJ, Sathekge MM. Underutilisation of nuclear medicine scans at a regional hospital in Nigeria: need for implementation research. Ecancermedicalscience. 2020;14. https://doi.org/10.3332/ecancer.2020.1093
PMid: 33014135 PMCid: PMC7498276
26. imaging ESoRcmoJIi. Medical imaging in personalised medicine: a white paper of the research committee of the European Society of Radiology (ESR). 2015;6:141-55. https://doi.org/10.1007/s13244-015-0394-0 PMid:25763994 PMCid: PMC4376812

27. Born J, Beymer D, Rajan D, Coy A, Mukherjee VV, Manica M, et al. On the role of artificial intelligence in medical imaging of COVID-19. 2021;2(6). https://doi.org/10.1016/j.patter.2021.100269 PMid: 33969323 PMCid: PMC8086827
28. Nam BD, Hong H, Yoon SHJIiI. Diagnostic performance of standardized typical CT findings for COVID-19: a systematic review and meta-analysis. 2023;14(1):96. https://doi.org/10.1186/s13244-023-01429-2 PMid:37222857 PMCid: PMC10206568
29. Uganda HJNi. MINISTRY OF HEALTH ESTABLISHES TELE-RADIOLOGY CENTER FOR CT SCAN INTERPRETATION. 2023.
30. Frija G, Blažić I, Frush DP, Hierath M, Kawooya M, Donoso-Bach L, et al. How to improve access to medical imaging in low- and middle-income countries? EClinicalMedicine. 2021;38. https://doi.org/10.1016/j.eclinm.2021.101034 PMid:34337368 PMCid:PMC8318869
31. Leung K-YJD. Applications of advanced ultrasound technology in obstetrics. 2021;11(7):1217. https://doi.org/10.3390/diagnostics11071217 PMid:34359300 PMCid:PMC8306830
32. Recker F, Weber E, Strizek B, Gembruch U, Westerway SC, Dietrich CFJAog, et al. Point-of-care ultrasound in obstetrics and gynecology. 2021;303:871-6. https://doi.org/10.1007/s00404-021-05972-5 PMid:33558990 PMCid:PMC7985120
33. Isangula K, Philbert D, Ngari F, Ajeme T, Kimaro G, Yimer G, et al. Implementation of evidence-based multiple focus integrated intensified TB screening to end TB (EXIT-TB) package in East Africa: a qualitative study. BMC Infectious Diseases. 2023;23(1):161. https://doi.org/10.1186/s12879-023-08069-3 PMid:36918800 PMCid: PMC10013287
34. Kulkarni S, Jha SJAr. Artificial intelligence, radiology, and tuberculosis: a review. 2020;27(1):71-5. https://doi.org/10.1016/j.acra.2019.10.003 PMid:31759796
35. Qin ZZ, Sander MS, Rai B, Titahong CN, Sudrungrot S, Laah SN, et al. Using artificial intelligence to read chest radiographs for tuberculosis detection: A multi-site evaluation of the diagnostic accuracy of three deep learning systems. 2019;9(1):15000. https://doi.org/10.1038/s41598-019-51503-3 PMid:31628424 PMCid: PMC6802077
36. Okada K, Yamada N, Takayanagi K, Hiasa Y, Kitamura Y, Hoshino Y, et al. Applicability of artificial intelligence-based computer-aided detection (AI-CAD) for pulmonary tuberculosis to community-based active case finding. Tropical Medicine and Health. 2024;52(1):2. https://doi.org/10.1186/s41182-023-00560-6 PMid:38163868 PMCid: PMC10759734
37. Naik N, Hameed B, Sooriyaperakasam N, Vinayahalingam S, Patil V, Smriti K, et al. Transforming healthcare through a digital revolution: A review of digital healthcare technologies and solutions. 2022;4:919985. https://doi.org/10.3389/fdgth.2022.919985 PMid:35990014 PMCid:PMC9385947
38. Grigoryan A, Bouyoucef S, Sathekge M, Vorster M, Orellana P, Estrada E, et al. Development of nuclear medicine in Africa. 2021:1-11.
39. Adejoh T, Onwujekwe EC, Abba M, Ali AM, Imo AS, Nzotta CC, et al. Computed tomography scanner census and adult head dose in Nigeria. 2018;49(1):66-70. https://doi.org/10.1016/j.ejrnm.2017.09.001
40. Ige TA, Hasford F, Tabakov S, Trauernicht C, Rule A, Azangwe G, et al. Medical physics development in Africa: Status, education, challenges, future. 2020;3:303-16.
41. WHO. Medical devices: Total density of computed tomography units (per million population). 2021.
42. Kalagher S. RAD-AID International Country Reports. 2022.
43. Saikouk H, Ou-Saada I, Bentayeb F, Boutayeb S, Eddaoui KJMPI. Medical physics status in Morocco: education, training, and evolution. 2019;7(3):282.
44. Liu RH, Lindeborg M, Ncogoza I, Nyiraneza SE, Barrera KJ, Shaye DAJIiI. Geospatial evaluation of radiologic access in Rwanda. 2024;15(1):105. https://doi.org/10.1186/s13244-024-01624-9 PMid:38589631 PMCid: PMC11001820
45. Maboreke T, Banhwa J, Pitcher RDJPAMJ. An audit of licensed Zimbabwean radiology equipment resources as a measure of healthcare access and equity. 2019;34(1). https://doi.org/10.11604/pamj.2019.34.60.18935 PMid: 31762925 PMCid: PMC6859023
46. Nyathi T, Chirwa TF, van der Merwe DG. A survey of digital radiography practice in four South African teaching hospitals: an illuminative study. Biomedical imaging and intervention journal. 2010;6(1):e5. https://doi.org/10.2349/biij.6.1.e5 PMid: 21611065 PMCid: PMC3097796
47. Kapapa N, Bwanga O, Sichone J, Kafwimbi S, Ohene-Botwe B. Using a digital transformation framework to explore the experiences of radiographers in the use of digital radiography in a low-resource setting. Radiography. 2025;31(1):75-82. https://doi.org/10.1016/j.radi.2024.10.024 PMid:39541876
48. Rehman HU, Khan H, Rashid F, Zainab S, Khan TA, Saeed M. Exploring the Diagnostic Potential of Chest Ultrasound for Thoracic Tuberculosis: A Comprehensive Review. Pakistan Journal of Chest Medicine. 2023;29(1):115-23.
49. Organization WH. Atlas of African health statistics 2022: health situation analysis of the WHO African Region. Atlas of African health statistics 2022: Health situation analysis of the WHO African Region2022. p. 232-.
50. Jacovides CL, Udeh ND, Cannon JW, Knollmann F. The Evolving Role of Computed Tomography (CT) in Trauma Care. Trauma Computed Tomography: Springer; 2024. p. 1-9. https://doi.org/10.1007/978-3-031-45746-3_1
51. Mallum A, Mkhize T, Akudugu JM, Ngwa W, Vorster M. The role of positron emission tomography and computed tomographic (PET/CT) imaging for radiation therapy planning: a literature review. Diagnostics. 2022;13(1):53.

https://doi.org/10.3390/diagnostics13010053 PMid:36611345 PMCid:PMC9818506
52. Sneag DB, Abel F, Potter HG, Fritz J, Koff MF, Chung CB, et al. MRI advancements in musculoskeletal clinical and research practice. Radiology. 2023;308(2):e230531.https://doi.org/10.1148/radiol.230531 PMid:37581501 PMCid:PMC10477516
53. Tahir MY, Mars M, Scott RE. A review of teleradiology in Africa-Towards mobile teleradiology in Nigeria. SA Journal of Radiology. 2022;26(1):2257. https://doi.org/10.4102/sajr.v26i1.2257 PMid:35169498 PMCid:PMC8832073
54. Saleh M, Naik G, Mwirigi A, Shaikh AJ, Sayani S, Ghesani M, et al. Bridging the gap in training and clinical practice in Sub-Saharan Africa. Current Breast Cancer Reports. 2019;11:158-69. https://doi.org/10.1007/s12609-019-00322-6
55. Mkhize-Kwitshana Z, Naidoo P, Duma Z, Saini KS, Dlamini Z. Revolutionizing Breast Cancer Treatment: Harnessing the Power of Artificial Intelligence in Overcoming Drug Resistance. Overcoming Breast Cancer Therapy Resistance: From Mechanisms to Precision and AI-Powered Approaches: Springer; 2024. p. 235-57. https://doi.org/10.1007/978-3-031-52860-6_10
56. Botwe B, Akudjedu T, Antwi W, Rockson P, Mkoloma S, Balogun E, et al. The integration of artificial intelligence in medical imaging practice: perspectives of African radiographers. Radiography. 2021;27(3):861-6. https://doi.org/10.1016/j.radi.2021.01.008 PMid:33622574
57. Antwi WK, Akudjedu TN, Botwe BO. Artificial intelligence in medical imaging practice in Africa: a qualitative content analysis study of radiographers' perspectives. Insights into imaging. 2021;12(1):80. https://doi.org/10.1186/s13244-021-01028-z PMid:34132910 PMCid:PMC8206887
58. Arefin S. Leveraging AI for Healthcare Advancement in Africa. Academic Journal of Science and Technology. 2024;7(1):1− 11-1−
59. Ayo-Farai O, Ogundairo O, Maduka CP, Okongwu CC, Babarinde AO, Sodamade OT. Telemedicine in health care: a review of progress and challenges in Africa. Matrix Science Pharma. 2023;7(4):124-32. https://doi.org/10.4103/mtsp.mtsp_24_23
60. Mollura DJ, Culp MP, Pollack E, Battino G, Scheel JR, Mango VL, et al. Artificial intelligence in low- and middle-income countries: innovating global health radiology. Radiology. 2020;297(3):513-20. https://doi.org/10.1148/radiol.2020201434 PMid:33021895
61. Nigatu AM, Yilma TM, Gezie LD, Gebrewold Y, Gullslett MK, Mengiste SA, et al. Medical imaging consultation practices and challenges at public hospitals in the Amhara regional state, Northwest Ethiopia: a descriptive phenomenological study. 2023;23(1):787. https://doi.org/10.1186/s12913-023-09652-9 PMid:37488569 PMCid: PMC10367423
62. Kiguli-Malwadde E, Byanyima R, Kawooya MG, Mubuuke AG, Basiimwa RC, Pitcher RJTPAMJ. An audit of registered radiology equipment resources in Uganda. 2020;37. https://doi.org/10.11604/pamj.2020.37.295.22046 PMid: 33654516 PMCid: PMC7881928
63. Samuel SL UA, et al Challenges, opportunities and strategies of global health radiology in low and middle-income countries (LMICs): an excerpt review. Cancer Prevention & Current Research. 2022;13(1):14-20. https://doi.org/10.15406/jcpcr.2022.13.00480
64. Oleribe OO, Momoh J, Uzochukwu BS, Mbofana F, Adebiyi A, Barbera T, et al. Identifying key challenges facing healthcare systems in Africa and potential solutions. 2019:395-403. https://doi.org/10.2147/IJGM.S223882 PMid:31819592 PMCid:PMC6844097
65. Bali S. Barriers to development of telemedicine in developing countries. Telehealth: IntechOpen; 2018. https://doi.org/10.5772/intechopen.81723
66. Hilabi BS, Alghamdi SA, Almanaa M, Alghamdi Sr SAJC. Impact of Magnetic Resonance Imaging on Healthcare in Low- and Middle-Income Countries. 2023;15(4). https://doi.org/10.7759/cureus.37698 PMid:37081900 PMCid: PMC10112545
67. DeStigter K, Horton S, Atalabi OM, Garcia-Monaco RD, Gharbi HA, Hlabangana LT, et al. Equipment in the global radiology environment: why we fail, how we could succeed. 2019;5(1):e1079. https://doi.org/10.7191/jgr.2019.1079
68. Figueroa CA, Harrison R, Chauhan A, Meyer LJBhsr. Priorities and challenges for health leadership and workforce management globally: a rapid review. 2019;19(1):1-11. https://doi.org/10.1186/s12913-019-4080-7 PMid:31014349 PMCid: PMC6480808
69. Malawi GotRo. Health Sector Strategic Plan II (2017-2022). 2017.
70. Adeola OSJIJoMI. Medical Imaging System and the Health Care Delivery System in Nigeria: An Overview. 2021;9(1):45. https://doi.org/10.11648/j.ijmi.20210901.15
71. Jalloul M, Miranda-Schaeubinger M, Noor AM, Stein JM, Amiruddin R, Derbew HM, et al. MRI scarcity in low- and middle-income countries.e5022.
72. AHRA. THREE CHALLENGES IN MEDICAL IMAGING MANAGEMENT. 2019.
73. Ezeh AJTL. Leadership and health in Africa. 2015;385(9983):2141. https://doi.org/10.1016/S0140-6736(15)61010-8
74. Kawooya MG, Kisembo HN, Remedios D, Malumba R, del Rosario Perez M, Ige T, et al. An African point of view on quality and safety in imaging. 2022;13(1):58. https://doi.org/10.1186/s13244-022-01203-w PMid:35347470 PMCid: PMC8959275
75. Nigatu AM, Yilma TM, Gezie LD, Gebrewold Y, Gullslett MK, Mengiste SA, et al. Medical imaging consultation practices and challenges at public hospitals in the Amhara regional state, Northwest Ethiopia: a descriptive phenomenological study. 2023;23(1):1-15. https://doi.org/10.1186/s12913-023-09652-9. PMid: 37488569 PMCid: PMC10367423
76. Mkhize N, Tiwari R, Chikte U, Pitcher R, Chikte UMJC. Temporal trends in the South African diagnostic radiology workforce (2002-2019). 2022;14(7).

https://doi.org/10.7759/cureus.27148 PMid:36004036 PMCid: PMC9392860
77. WHO. Global Health Observatory data repository. 2018.
78. Mbashiru K. Govt to employ more biomedical engineers. 2023.
79. Ko C-H, Chien L-N, Chiu Y-T, Hsu H-H, Wong H-F, Chan WP. Demands for medical imaging and workforce Size: A nationwide population-based Study, 2000-2020. European Journal of Radiology. 2024;172:111330. https://doi.org/10.1016/j.ejrad.2024.111330 PMid:38290203
80. Matsumoto MM, Dako FJGH. Working at the Intersection of Radiology and Global Health Equity. 2023. https://doi.org/10.37549/AR2866 PMid:19930665
81. Rosman DA, Bamporiki J, Stein-Wexler R, Harris RDJCRR. Developing diagnostic radiology training in low-resource countries. 2019;7:1-7. https://doi.org/10.1007/s40134-019-0336-6
82. Pascual TN, Chhem R, Wang S-C, Vujnovic SJEJoR. Undergraduate radiology education in the era of dynamism in medical curriculum: An educational perspective. 2011;78(3):319-25. https://doi.org/10.1016/j.ejrad.2010.08.039 PMid:20864284
83. Bafaraj SM, Elkhadir AMJCE. Evaluation of Diagnostic Radiography Technology Curriculum from the Graduates' Perspective. 2021;12(01):265. https://doi.org/10.4236/ce.2021.121019
84. Serhan LA, Tahir MJ, Irshaidat S, Serhan HA, Ullah I, Mumtaz H, et al. The integration of radiology curriculum in undergraduate medical education. 2022;80:104270. https://doi.org/10.1016/j.amsu.2022.104270 PMid:36045848 PMCid: PMC9422284
85. Hinrichs-Krapels S, Tombo L, Boulding H, Majonga ED, Cummins C, Manaseki-Holland S. Barriers and facilitators for the provision of radiology services in Zimbabwe. 2023.
86. Murthi M. Sustainable financing for health: Forging a new path. 2023.
87. Agency IAE. Worldwide Implementation of Digital Imaging in Radiology: A Resource Guide: International Atomic Energy Agency; 2015.
88. DARGAN R. Managing Change is Central to Evolving Role of Radiology Leaders. 2020.
89. Aufegger L, Alabi M, Darzi A, Bicknell CJBL. Sharing leadership: current attitudes, barriers and needs of clinical and non-clinical managers in the UK's integrated care system. 2020:leader-2020-000228. https://doi.org/10.1136/leader-2020-000228

90. Abujudeh H, Kaewlai R, Shaqdan K, Bruno MAJAJoR. Key principles in quality and safety in radiology. 2017;208(3):W101-W9. https://doi.org/10.2214/AJR.16.16951 PMid:28075621
91. Govender S, Gerwel Proches CN, Kader AJJomh. Examining leadership as a strategy to enhance health care service delivery in regional hospitals in South Africa. 2018:157-66. https://doi.org/10.2147/JMDH.S151534 PMid: 29535529 PMCid: PMC5836703
92. Reddy R, Thajudeen ASJJoME. Integration in the competency-based undergraduate medical curriculum: A brief review. 2023;16(51):77.
93. Ma X, Thomas HS, Kanmounye USJJPHE. Beyond technology: review of systemic innovation stories in global surgery. 2020;4:19. https://doi.org/10.21037/jphe-2020-gs-06
94. Friebe M, Illanes AJAS. Advancements in Medical Imaging and Image-Guided Procedures: A Potential Rather Likely Paradigm Shift in Diagnosis and Therapy: Understand Disruption and Take Advantage of It! : MDPI; 2023. p. 9218. https://doi.org/10.3390/app13169218
95. HealthCare G. Improving access to medical imaging for more patients. 2022.
96. College of Radiology AoMM. How to improve access to medical imaging in low- and middle-income countries? 2021.
97. Frija G, Blažić I, Frush DP, Hierath M, Kawooya M, Donoso-Bach L, et al. How to improve access to medical imaging in low- and middle-income countries? 2021;38:101034. https://doi.org/10.1016/j.eclinm.2021.101034 PMid:34337368 PMCid: PMC8318869
98. Elezaby M H-PC, MacLaine J. Sustainable Global Outreach Through a Holistic Approach to Virtual Learning. 2023. https://doi.org/10.37549/AR2894 PMid:20122288
99. RAD_AID. Bringing Radiology to the World. 2023.
100. Hierath M. Launch of The Lancet Oncology Commission on Medical Imaging and Nuclear Medicine. 2021.

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