

Opportunities and Challenges of Mobile Radiography Services in Zambia

Osward Bwanga ^{1*}, Ncheebe Sindaza ², Ernest Chanda ³, Nkole Bwalya ⁴, Ethel Chilambe Jere ⁵, Joseph Mulenga ⁶

¹ Midlands University Hospital Tullamore, Radiology Department, Ireland

² Cancer Diseases Hospital, Radiotherapy Department, Lusaka, Zambia

³ Lusaka Apex Medical University and Cancer Diseases Hospital, Lusaka, Zambia

⁴ Chipata Central Hospital, Department of Radiology, Chipata Zambia

⁵ Arthur Davison Children's Hospital, Radiology Department, Ndola, Zambia

⁶ Warwick Hospital, Radiology Department, Warwick, UK

* **Corresponding Author:** Osward Bwanga, Midlands University Hospital Tullamore, Radiology Department, Ireland. E-mail: o.bwanga@yahoo.com

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Abstract

Mobile radiography is requested and performed using a mobile X-ray machine when a patient's condition makes the transfer to the radiology department unsafe. In the Zambian healthcare system, these patients are admitted to special care units, such as intensive care units (ICU), resuscitation units of the accident and emergency (A& E) departments, COVID-19 isolation wards, and special care baby units (SCBU). These are critically ill patients who require constant monitoring and nursing care. Moving these patients to radiology departments for medical imaging due to non-availability of or non-functional mobile X-ray machines can negatively affect their condition, treatment, and nursing care. Chest X-rays are the most performed radiological examinations during mobile radiography. However, radiographers face challenges in providing mobile radiography services to critically ill patients due to limited space, life-support equipment attached to patients, infection control measures, limitations of mobile X-ray machines, and radiation protection. The biggest opportunity identified during this review is the increased demand of patients requiring mobile radiography services. However, an insufficient number of mobile X-ray machines, lack of equipment and maintenance, inadequate radiation protection devices, and a critical shortage of radiologists to report on portable X-rays were the main challenges identified affecting mobile radiography services. Recommendations are made to improve the delivery of mobile radiography services in Zambia.

Keywords: Challenges, Mobile Radiography, Opportunities, Radiographer, Zambia

Introduction

Radiography in Zambia was established in the 1930s, offering medical imaging services using stationary and mobile (portable) X-ray machines.¹ Since then, several medical facilities have been built and other specialised medical imaging services have been introduced, such as ultrasonography (US), computed tomography (CT), magnetic resonance imaging (MRI), and mammography. The National Health Strategic Plan 2017-2021 Report produced by the Ministry of Health (MOH)² reported that 141 public hospitals currently offer imaging services in Zambia. These hospitals should offer mobile radiography services for patients whose medical conditions make it unsafe to be moved to the radiology department without seriously affecting their clinical management.³ Moving ICU patients and SCBU neonates to radiology departments for imaging due to

non-availability of or non-functional mobile X-ray machines can negatively affect their condition, treatment, and nursing care. The movement also compromises infection prevention measures for critically ill patients.

Mobile radiography refers to the imaging of patients outside the radiology department using a mobile X-ray machine.³⁻⁵ In medicine, mobile radiography is sometimes referred to as "portable X-rays". The word "portable" comes from early small portable X-ray units which were designed to be dismantled and assembled at the patient's location or bedside.⁴ These are no longer in use due to radiation protection concerns. A mobile X-ray machine is considered mobile equipment as it is equipped with wheels that enable it to be moved to different locations.⁶ In the Zambian healthcare system,

mobile radiography is undertaken in intensive care units (ICU), resuscitation units of the accident and emergency departments, COVID-19 isolation wards, and special care baby units (SCBU). Patients in these areas are on special treatment and nursing care which makes it unsafe to be moved to the radiology department for imaging.³ The most common medical imaging examination performed using a mobile X-ray machine is a chest X-ray.

Mobile radiography training is included in the radiography curriculum in Zambia. In theory, it is taught in the radiographic technique module, and radiography students apply theory to practice during their clinical training under the supervision of clinical educators.^{1,7} Research studies on medical imaging services in Zambia have identified numerous problems with the equipment, including a lack of imaging equipment, frequent breakdowns, old and obsolete equipment, and unequal distribution of it with most machines located in Lusaka and the Copperbelt provinces.⁸⁻¹⁰ However, there is a scarcity of information specific to mobile X-ray machines and the availability of this service in medical facilities. Therefore, the aim of this article is to review the opportunities and challenges of mobile radiography services in Zambia and raise awareness of this important medical imaging service.

Equipment for Mobile Radiography

Mobile X-ray machines vary in their design and size depending on the manufacturer, but all have similar components. In general, an X-ray mobile system consists of a motorised drive, a compact wheelbase that includes the generator, an X-ray tube attached to a positioning column, and an exposure control panel.^{6,11} Most units also have extendible tube support and an adjustable height to provide a good range of movement.¹¹ This makes it possible for the radiographer to adjust the focus-film distance (FFD) and angulations of the X-ray beam in a limited space.⁴ The power source can be a battery or the electrical mains depending on the manufacturer and the intended use. These X-ray machines are powered by an electric motor supplied by a battery that assists in the movement of equipment to different locations.¹¹

There are two types of mobile radiography equipment being used in the Zambian healthcare system: analogue (Figure 1) and digital (Figure 2). The broad distinction



Figure 1. Analogue Mobile X-ray Equipment



Figure 2. Digital Mobile X-ray Equipment

between the two is the difference in how the radiographic image is captured and processed.

The analogue mobile X-ray machines allow the taking of X-ray exposure on a film-screen cassette, which is then processed using chemicals. Although this is an old and outdated method of imaging, most Zambian medical facilities are still using analogue stationary X-ray machines.^{2,10,12} Mobile X-ray machines have been designed to provide a limited number of

radiological examinations and should not replace the stationary, high-powered X-ray machines used in the radiology department. The traditional film and screen imaging system requires the use of chemicals to develop the X-ray film in the darkroom. The processing chemicals require safe, specific storage and usage conditions to produce a quality radiographic image.^{3,13} Processing chemicals also have a negative effect on the environment and the health of radiology staff due to the fumes produced.^{3,11,13} Although the initial costs of digital imaging equipment are higher than traditional film-screen imaging equipment, it has low running costs.¹³ There is no periodic buying of X-ray films and processing chemicals. In addition, it is difficult to find spare parts for analogue mobile X-ray machines because most of the manufacturers have moved to digital imaging. This was identified in a research study conducted by Ng'andwe and Bwanga¹⁰ as a hindrance in the provision of quality imaging services in Zambia.

The second type of mobile X-ray machine uses a digital imaging system. Globally, the move from traditional film-based imaging to digital imaging

systems started in the 1990s.^{13,14} Digital radiography (DR) mobile X-ray machines are modern imaging equipment that use a digital detector to produce an instant radiographic image following the X-ray exposure. Storage to Picture Archiving and Communication System (PACS) and availability to the requesting clinician are also immediate after the radiographer has evaluated the radiographic image.³ This digital imaging has several advantages when compared with traditional film-screen imaging (analogue). These include the ability to post-process radiographic images to aid visualisation of anatomy and pathology, increased latitude and dynamic range, no manual handling of cassettes and processing chemicals, ease in storing and retrieving radiographic images, patient radiation dose reduction, and lastly, lower running costs, as purchases of X-ray films and processing chemicals are no longer required.^{3,13,14} The Zambian health sector is also taking advantage of digital imaging by moving away from old and outdated film-screen imaging to improve the quality of healthcare services. This is evidenced by the availability of more digital mobile X-ray machines than analogue ones (Table 1).

Table 1. University Teaching and Provincial Hospitals with Mobile Radiography Services in Zambia

	Medical Facility	Available	Type	No. of Units	Functional	Non-functional
1	University Teaching Hospital- Adult	Yes	Digital	1	Yes	-
2	University Teaching Hospital- Children	Yes	Dig & ana.	3	Yes (N=1)	N=2
3	Cancer Diseases Hospital	Yes	Digital	1	Yes	-
4	Levy Mwanawasa University Teaching Hospital	Yes	Digital	1	No	6 months
5	National <i>Heart Hospital</i>	Yes	Digital	1	Yes	-
6	Ndola Teaching Hospital	Yes	Digital	1	Yes	-
7	Arthur Davison Children's Hospital	No	-	-	-	-
8	Kitwe Teaching Hospital	Yes	Analogue	1	No	12 months
9	Kabwe Central Hospital	Yes	Digital	1	Yes	-
10	Choma General Hospital	Yes	Analogue	1	Yes	-
11	Livingstone Teaching Hospital	Yes	Digital	1	Yes	-
12	Lewanika Central Hospital	Yes	Analogue	1	No	42 months
13	Solwezi General Hospital	No	-	-	-	-
14	Kasama Central Hospital	Yes	Digital	1	Yes	-
15	Chipata Central Hospital	Yes	Digital	1	Yes	-
16	Mansa General Hospital	Yes	Digital	1	No	13 months

Teaching and Provincial Hospitals Offering Mobile Radiography Services in Zambia

At the time of writing, there was no specific register for mobile X-ray machines at the Radiation Protection Authority (RPA) or the Ministry of Health (MOH). Information obtained from University Teaching and provincial hospitals (N = 17) revealed a total of N = 16 mobile X-ray machines (Table 1). The number of mobile X-ray machines does not correspond with the capacity of University Teaching and provincial hospitals

and the increase in demand for mobile radiography services. These large hospitals should have more than one mobile X-ray machine to meet the demand and have a contingency plan in case of equipment breakdown. It can also meet the best practice of having dedicated mobile X-ray machines kept in infection-controlled areas such as the ICU, SCBU, and isolation wards (e.g., COVID-19).

Procedure for Performing Mobile Radiography

In Zambia, both the traditional film screen and digital radiography are being practiced (Table 1). The procedure for performing mobile radiography can be grouped into three stages: before, during, and after the radiological examination.

Before the Radiological Examination

The first stage of mobile radiography involves requesting a radiological examination. In Zambia, there are three groups of medical practitioners who request imaging examinations: Medical Doctors, Medical Licentiate Practitioners, and Clinical Officers.¹⁵ However, mobile radiography is mostly requested by medical doctors who work in special care units. Under the Radiation Protection Act of 2011 of the Republic of Zambia,¹⁶ the referring medical practitioner should justify the reason for requesting a portable X-ray. The benefits to the patient undergoing a radiological examination should outweigh the risks of radiation.^{15,17} However, in mobile radiography, justification goes beyond the justification principle.⁴ The referring medical practitioner should also consider restricting mobile radiography to patients on life-support machines, or those with medical conditions where nursing care and treatment could be seriously affected if transported to the radiology department.³ To operationalise the justification principle, the referring medical practitioner should state on the radiology request form (RRF) the clinical indication and how a portable X-ray is the best option in the management of the patient.⁴ The completed RRF is sent to the radiology department and should also include other information related to the urgency of the request, such as whether the patient is on life support machines and if any infection control measures need to be undertaken.

During the Radiological Examination

The second stage of mobile radiography involves performing the radiological examination. In the Radiology department, the radiographer assigned to mobile radiography checks the justification of the request and proceeds to undertake the radiological examination. The radiographer transports the mobile X-ray machine to the location where the patient is being managed and carries accessories such as lead rubber aprons, a digital plate for digital radiography, cassettes (for analogue portable X-rays), and anatomical side markers (ASMs). Upon arrival, the

radiographer should liaise with nursing staff and explain the procedure. The radiographer should not move or disturb the patient before first asking the nursing staff about the patient's medical condition.³ This is because the nurse responsible for the patient knows the condition and the patient's needs.^{4,5} Nurses and supporting staff should assist the radiographer in communicating with the patient and in positioning the X-ray cassette or detector by lifting the patient.^{3,4} After positioning the patient, the radiographer selects the exposure factors, puts on a lead apron, and requests all staff and members of the public to stand at a distance. At the end of the examination, the radiographer informs the nurse or referring medical practitioner of when the image (s) will be ready and available in hard copies or on the Picture Archiving and Communication System (PACS) system.

After the Radiological Examination

The last stage of mobile radiography involves sending the radiographic image (s) and a written report to the referring medical practitioner. A definitive radiological report is the final stage in the diagnostic imaging process.¹⁸ However, many hospitals in Zambia are without a radiologist to report on medical imaging examinations. Image interpretation of plain radiographs including portable X-rays is normally performed by referring medical practitioners who may have limited training in image interpretation. Radiologists only report on plain film radiographs upon special request.¹⁹ In Zambia, out of 141 public hospitals, only six (6) have radiologist services: University Teaching Hospitals (UTH), Levy Mwanawasa University Teaching Hospital (LMUTH), National Heart Hospital, Ndola Teaching Hospital (NTH), Kitwe Teaching Hospital (KTH), and Livingstone Teaching Hospital (LTH). Mobile radiography is undertaken on critically ill patients who require urgent and immediate diagnostic written reports. To overcome this challenge, there is a suggestion to establish reporting radiographers in Zambia.^{19,20} The practice of introducing reporting radiographers has worked well in countries such as the United Kingdom (UK) and Uganda.

Radiation Protection during Mobile Radiography

In Zambia, radiation protection in medicine is regulated by the Radiation Protection Act of 2011 of the Republic of Zambia.¹⁶ The act is enforced by the

Radiation Protection Authority (RPA) by certifying the imaging equipment before first use and routinely checking its performance through Medical Physicists and Radiation Protection Officers (RPO) annually or when there are radiation leakage concerns. Under this act, a radiographer operating the mobile X-ray machine is responsible for the protection of patients, staff, and members of the public from radiation by adhering to 3 cardinal rules of radiation protection: time, distance, and shielding.

Time

The first cardinal rule for reducing X-ray exposure to radiation during mobile radiography is time. The amount of radiation dose received by the patient is directly proportional to the exposure time.²¹⁻²³ The same applies to radiographers, nurses, and other ward staff assisting during mobile radiography; the X-ray exposure received is directly proportional to the time spent in scatter radiation.²¹⁻²³ This means that the longer the exposure time, the greater the radiation dose to the patient and radiographer. To reduce the exposure time, the radiographer should use the best radiographic techniques to avoid repeating the examination, such as correct patient identification, good positioning technique, use of optimal exposure factors, and giving clear instructions to the patient and ward staff.

Distance

The second cardinal rule of radiation protection involves using distance. Standing further away from the mobile X-ray machine during exposure reduces the radiation dose received by the radiographer, clinical staff, and members of the public.²¹⁻²³ The recommended minimal safe distance is 2 meters at which radiation is attenuated to levels equivalent to the background doses.^{4,5} For this reason, mobile X-ray machines have long cords on the exposure switches, enabling the radiographer to get as far away from the radiation sources as possible while making an exposure.^{5,22} However, during our review, it was discovered that some mobile X-ray machines had non-functional extension exposure cables. This compromises the radiation safety of radiographers operating the X-ray machine. The area (2 meters radius) around the patient becomes a controlled area and the radiographer has a responsibility to inform all persons in the immediate area that an X-ray exposure is about to occur and ask

them to move to a safer distance.⁵ To alert others, the best practice is for the radiographer to shout “X-ray” before making an X-ray exposure.

Shielding

The third cardinal rule of radiation protection is shielding. During mobile radiography, the radiographer and anyone assisting in an examination and remaining in the radiation field should wear a lead-rubber apron (Figure 3) or stand behind a mobile lead screen (Figure 4). It is good practice to have more than one lead-rubber apron and a mobile lead screen stationed in areas where mobile radiography is undertaken.



Figure 3. Lead Apron



Figure 4. Mobile Protective Screen

However, most Zambian public hospitals lack mobile lead protective screens, lead aprons, and thyroid shields to use during mobile radiography to protect radiographers and other clinical staff from ionising radiation.²⁴ There is a need to bring this to the attention of the Ministry of Health (MOH) along with the importance of radiation protection devices and procure them for use by radiographers and other staff.

Nurses play a vital role in mobile radiography because they provide care to patients before, during, and after the diagnostic imaging examination.⁴ Nurses working in special care units such as ICU, A & E department, SCBU, and other areas where mobile radiography takes place should be knowledgeable about the three practical methods of controlling external radiation exposure: time, distance, and shielding.^{4,25} A recent research study carried out in Zambia by Bwanga and colleagues²⁵ found almost half $N = 34$ (47.0%) of nurses working at the University Teaching Hospital (UTH) were not knowledgeable about time, distance, and shielding as methods of controlling external radiation exposure. This may jeopardise their ability to practice and protect themselves, patients, and members of the public from radiation exposure. The research study suggested the provision of radiation protection awareness programmes by the Radiological Society of Zambia (RSZ) and the Radiation Protection Officers (RPO) in each medical facility to nurses as part of continuous professional development (CPD) learning activities.

Opportunities for Mobile Radiography in Zambia

There are three main opportunities for mobile radiography in Zambia identified during the review. These include an increase in demand for medical imaging services, an increase in neonates being administered to SCBU, and the availability of radiographers.

Increase in Demand for Medical Imaging Services

There is an increase in demand for medical imaging services due to an increase in the population, a high incidence of communicable diseases such as tuberculosis (TB) and HIV/AIDS, and an increase in road traffic accident (RTA) injuries.² The population of Zambia as captured during the 2010 census was approximately 13 million while in 2022 it was 19.6 million.^{26,27} This shows an increase of 6.6 million. In

addition, the Road Transport and Safety Status Reports in Zambia revealed an increase in RTA cases countrywide from 28,484 in 2020 to 32,372 in 2021.^{28,29} This demand is putting pressure on medical imaging services, including mobile radiography. Seriously injured and critical RTA patients should have their imaging done in A & E departments, ICU, and in isolation wards (COVID-19) using a mobile X-ray machine. Therefore, more mobile X-ray machines are needed to meet this demand.

Increase in Neonates Being Administered to SCBU

Neonates admitted to the special care baby units (SCBU) greatly benefit from mobile radiography. Most of these patients are preterm babies. According to the World Health Organisation (WHO),³⁰ an estimated 13.4 million babies were born pre-term in 2020, with nearly 1 million dying from preterm complications. In Zambia, the preterm birth rate is estimated to be 13% with 6,800 deaths due to preterm birth complications.³¹ One of the contributing factors is healthcare-associated infections because of their profound physiologic instability and exposure to invasive devices.³² In the radiography context, this is transmitted during mobile radiography as most of these patients suffer from chest infections and require periodic portable chest X-rays. Therefore, it is recommended that SCBU have dedicated mobile X-ray machines.^{3,22} Furthermore, an increase in the Zambian population means an increase in neonates being administered to SCBU and requiring mobile radiography services.

Availability of Radiographers

Radiographers are readily available in all 141 hospitals offering medical imaging services in Zambia to provide mobile radiography services. The number of radiographers has increased from 400 in 2016² to 1600 in 2022.³³ The increase in the number is due to the establishment of the Bachelor of Radiography courses at three Higher Education Institutions (HEI), namely: Lusaka Apex Medical University (LAMU), University of Zambia (UNZA), and Levy Mwanawasa Medical University (LMMU). Although there is limited exposure of radiography students to clinical practice in mobile radiography, the availability of more mobile X-ray machines may result in improved

training in this area.

Challenges Facing Mobile Radiography in Zambia

In Zambia, mobile radiography, like any other imaging modality, faces many challenges. The main challenges are summarised in Table 2.

Inadequate Number of Mobile X-ray Machines and a Lack of Clinical Training among Radiography Students

The inadequate number of mobile X-ray machines across the country is the major identified challenge facing mobile radiography services in Zambia. Despite an increase in mobile X-ray requests by referring

medical practitioners for ICU, neonates, post-surgery, and critical ward patients (e.g., COVID-19), little attention has been paid to equipping hospitals with mobile X-ray machines. Data obtained from the Provincial Radiography Coordinators in all 10 provinces of Zambia revealed just 37 mobile X-ray machines serving 141 public hospitals.² At the University Teaching and provincial hospital level (N = 17), there were a total of N=16 mobile X-ray machines: N = 6 were non-functional, and N = 2 had had no mobile X-ray machine for a long time (Table 1). The inadequate number of mobile X-ray machines is also negatively affecting the clinical training of radiography students. There is little exposure for radiography students to mobile radiography.

Table 2. Challenges Facing Mobile Radiography Services in Zambia

No	Challenge
1	Inadequate number of mobile X-ray machines and a lack of clinical training among radiography students
2	Inappropriate use of mobile X-ray machines
3	Lack of mobile X-ray machines replacements and service plans
4	Lack of standardised infection control measures

Inappropriate Use of Mobile X-ray Machines

The second challenge facing mobile radiography in Zambia is the inappropriate use of mobile X-ray machines. This type of imaging equipment is designed for mobile radiography with limited capacity.^{11,22} Hence, they cannot replace stationary high-powered X-ray machines located in the radiology departments for general-purpose work. However, it was found during our review that some public hospitals are using mobile X-ray machines for general-purpose radiological examinations due to non-functional fixed X-ray machines. This is negatively affecting the capacity or lifespan of mobile X-ray machines. In addition, critical patients who need mobile radiography services are delayed until the equipment is free from general work.

Lack of Mobile X-ray Machines Replacements and Service Plans

The third challenge relates to the lack of equipment replacement, servicing, and maintenance plans for the mobile radiography machines. The Zambia National Health Strategic Plan of 2017-2021 reports that 60% of medical imaging machines are old and obsolete.² This also includes mobile X-ray machines for mobile radiography. The information obtained from the Ministry of Health medical equipment unit shows that there is currently no replacement plan in effect to replace obsolete medical imaging equipment, including

mobile X-ray machines. This situation has caused some hospitals to experience frequent breakdowns of the equipment and disruptions of medical imaging services.^{2,10,12,24} Furthermore, medical imaging equipment, including mobile X-ray machines, lacks a service and maintenance plan, causing inconsistency in equipment maintenance and long downtime for mobile radiography services.² This is a hindrance to the provision of quality imaging services.

Lack of Standardised Infection Control Measures

The last challenge facing mobile radiography services is infection control. To prevent the spread of infection, mobile X-ray machines used in ICU, SCBU and isolated wards (e.g., COVID-19) should be dedicated units and kept on site.^{3,22} However, due to a limited number of such equipment in Zambia, there are no dedicated mobile X-ray machines for infection-controlled places. As a result, one machine is moved from one ward to another (e.g., from the COVID-19 ward to Neonates SCBU). Anecdotal evidence shows that some radiographers pay little, or no attention to cleaning and disinfection before taking the equipment to infection-controlled wards. There is a need to provide educational awareness programmes about infection control during mobile radiography. The Radiological Society of Zambia (RSZ) and the Head of Radiology departments can organise continuous

professional development (CPD) learning activities on infection control.

Recommendations

The following recommendations are made to improve the delivery of mobile radiography services in Zambia.

1. All hospitals offering medical imaging services with special care units such as intensive care units (ICU), resuscitation units of the accident and emergency departments, special care baby units (SCBU), and isolation wards (e.g., COVID-19) should have a mobile X-ray machine. To meet the increasing demand for mobile radiography services and meet the best practice of having dedicated mobile X-ray machines in infection-controlled areas such as the ICU and SCBU, University Teaching and Provincial Hospitals should have more than one mobile X-ray machine.
2. In Zambia, most medical facilities are still using traditional film-screen (analogue) imaging. It is recommended that analogue X-ray machines be replaced with digital X-ray machines. This includes mobile X-ray machines. It is difficult to find spare parts for analogue equipment and this results in a lack of maintenance and prolonged breakdowns.^{10,13}
3. The Ministry of Health (MOH) should prioritise servicing and maintenance of all medical imaging equipment, including mobile X-ray machines by implementing a medical imaging equipment replacement, servicing, and maintenance plan.
4. The Ministry of Health (MOH) should conduct a national audit for medical imaging equipment, including mobile X-ray machines, and keep an updated register that can easily be accessed by stakeholders. It is challenging to know which medical imaging equipment to replace when there is no up-to-date equipment register.

Conclusion

Mobile radiography services in Zambia present both opportunities and challenges. The increase in demand for patients requiring mobile radiography services is an important opportunity for improving healthcare delivery. However, the inadequate number of mobile X-ray machines, lack of servicing and maintenance, limited radiation protection devices, and a critical shortage of radiologists pose significant challenges.

Addressing these challenges is crucial to ensuring timely and effective diagnosis and treatment for critically ill patients. By addressing these challenges and capitalising on the opportunities, Zambia can improve access to high-quality mobile radiography services, leading to better patient outcomes and overall healthcare delivery. A research study to explore factors affecting radiographers in the delivery of quality mobile radiography may provide more information regarding mobile radiography in Zambia. This information could be essential for improving mobile radiography services in the country.

Conflict of Interest

The authors declare no conflicts of interest.

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