REVIEW ARTICLE

A Review of Orthopaedic Theatre Radiography Services in Zambia

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ABSTRACT

Orthopaedic theatre radiography plays a critical role in the treatment of bone injuries and joint diseases. Fluoroscopic imaging using a mobile image intensifier (C-arm) is required to aid in trauma orthopaedic surgery. Plain X-rays using a mobile X-ray machine are also required for non-trauma corrective orthopaedic surgery. In Zambia, there are an increase in the use of motor vehicles and associated road traffic accident (RTA) injuries. Assaults and falls are other common mechanisms of trauma injuries reported in Zambia. The growing number of trauma patients puts a strain on trauma and orthopaedic services, particularly theatre radiography. Most trauma patients require surgical treatment of their bone injuries. However, in terms of establishing a well-organised trauma and orthopaedic healthcare system in the country, less emphasis has been paid to this problem. As a result, theatre radiography is similarly underdeveloped. This review aimed to assess orthopaedic theatre radiography services and raise awareness among stakeholders on this important topic in Zambia. As the country's planned improved orthopaedic services evolve, the radiography profession must begin bolstering training and advocating for more theatre radiography equipment.

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INTRODUCTION

Medical imaging plays an important role in the delivery of orthopaedic theatre services. It is used for many orthopaedic surgical procedures to provide guidance to the surgeon while reducing fractures, inserting various orthopaedic devices, or inserting stabilising rods in long bones.[1] Important to this service are radiographers who provide surgeons with "eyes" or vision during theatre procedures.[2] Radiographers are the main imaging professionals mandated to operate medical imaging equipment under the Ionising Radiation Protection Act of 2011 of the Republic of Zambia.[3] For this reason, theatre radiography is integrated into undergraduate radiography programmes.

Keywords: Medical Imaging, Orthopaedics, Radiographer, Theatre Radiography, Zambia

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Radiography students are taught about this topic in radiographic technique and apply theory into practice under the supervision of experienced theatre radiographers. Newly qualified radiographers also learn through on-the-job training.

The Ministry of Health (MoH) is responsible for the country's coordination, organisation, and management of the health sector. It is also a major provider of health services. Faith-based (church) and the private sector (private investors, Civil Society Organisations, and mining companies) are other health providers that contribute 30% and 15%, respectively of the overall healthcare services.[4] The healthcare delivery system is administered under ten provincial offices: Lusaka, Copperbelt, Central, Southern, Eastern, Western, North-Western, Luapula, Muchinga, and Northern. However, most of the specialised medical services such as orthopaedic surgeries and theatre radiography are exclusively provided in the two urban provinces of Lusaka and Copperbelt. As of 2017, there were 141 government hospitals with no orthopaedic specialised hospital.[5] This hinders the MoH's aim of providing effective healthcare services close to the community.

Orthopaedic theatre radiography is underdeveloped in Zambia. This may be attributed due to a lack of an organised trauma healthcare system.[6,7]The most reported mechanisms of trauma injuries are Road Traffic Accidents (RTAs), falls and assault cases.[7,8]There is an increase in the use of motor vehicles and associated RTA injuries are increasing annually.[9]For example, 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.[8,10] It is estimated that 10% of trauma cases require surgical treatment in the Zambian healthcare system.[9]The increase in trauma cases puts pressure on healthcare delivery, including orthopaedic theatre radiography services.

In the last decade, the government and private sectors have started establishing specialised hospitals such as the Cancer Diseases Hospital (CDH) and National Heart Hospital (NHH). There are discussions going on about the establishment of an organised trauma system and a national trauma registry.[6,7, 9,11]This includes orthopaedic specialised public hospitals. As planned developed orthopaedic services progress, it is necessary for the radiography profession to start strengthening the training and advocating for more theatre radiography equipment. Therefore, the aim of this article was to review orthopaedic theatre radiography services and bring awareness to stakeholders on this important topic in Zambia.

IMAGING EQUIPMENT FOR THEATRE RADIOGRAPHY

Fluoroscopic imaging during orthopaedic procedures is most required to aid in trauma surgery.[1] However, some non-trauma cases require plain film X-rays. There are two (2) types of theatre radiography equipment: mobile X-ray and image intensifier (II)machines. At the time of writing this article, the public health sector information obtained from the Provincial Radiography Coordinators indicated that there were 37 mobile X-rays and 10 image intensifier machines across the country. There was no register specifically for mobile X-ray and image intensifier (II) machines at the Radiation Protection Authority (RPA). The Ministry of Health (MoH) also had no records of all mobile X-ray and image intensifier (II) machines in public medical facilities.

The choice of equipment depends on the type of procedure being performed in the operating theatre. A mobile X-ray machine (Figure 1) is mostly used for postoperative examinations in post-anaesthesia care units (theatre recovery rooms). For example, a check X-ray of the hip following a total hip replacement (THR). It is also used to perform limited examinations such as the portable chest X-ray when a patient's condition makes it impossible for them to be transported to the radiology department.[1,12] Such patients are commonly found in

intensive care units (ICU), coronary care units (CCU), cardiac surgery units (CSU), special care baby units (SCBU), and resuscitation units of the accident and emergency departments. On the other hand, a mobile image intensifier(Figure 2) is often employed for screening theatre procedures such as intramedullary (IM) nailing of a fractured femur. The mobile image intensifier is commonly called the C-arm because of the description of its design which is in the form of a C-shape with the X-ray tube located at one end and the image intensifier tower at the other end.[2]

Figure 1: Mobile X-ray machine

Figure 2: Mobile image intensifier (C-arm)

MEDICAL FACILITIES OFFERING ORTHOPAEDIC THEATRE RADIOGRAPHY

Only a few medical facilities in Zambia provide orthopaedic theatre radiography services, most of which are in Lusaka and a few elsewhere in the provincial centres of the country (Table 1). The country has only one specialised orthopaedic hospital, St John Paul II Orthopaedic Mission Hospital (Former Italian Orthopaedic Hospital) which is under the faith-based health sector. Other orthopaedic theatre radiography services are offered in public and private medical facilities offering general medical services.

Table 1: Medical facilities offering orthopaedic theatre radiography services in Zambia

No	Medical Facility	Province	Category
1	St. John Paul II Orthopaedic Mission Hospital, Lusaka	Lusaka	Private/Faith
2	University Teaching Hospitals, Lusaka	Lusaka	Public
3	Levy Mwanawasa University Teaching Hospital, Lusaka	Lusaka	Public
4	CFB medical centre, Lusaka	Lusaka	Private
5	Medland Hospital, Lusaka	Lusaka	Private
6	Ndola Teaching Hospital, Ndola	Copperbelt	Public
7	Kitwe Teaching Hospital, Kitwe	Copperbelt	Public
8	Maina Soko Medical Centre, Lusaka	Lusaka	Public/Military
9	Livingstone University Teaching Hospital, Livingstone	Southern	Public
10	Kabwe Central Hospital, Kabwe	Central	Public

Note: There is no register for medical facilities offering orthopaedic theatre radiography services in Zambia. For this reason, some medical facilities may have been missed at the time of writing.

St. John Paul II Orthopaedic Mission Hospital- is an independent charitable medical facility located in

Lusaka. The hospital was founded in 1995 to offer orthopaedic services in Zambia.[13] St. John Paul II Orthopaedic Mission Hospital has a bed capacity of 42 and has carried out 17,918 surgeries since its establishment. The hospital offers a number of orthopaedic procedures both trauma and non-trauma. Other imaging services which support orthopaedic theatre radiography at the facility include but not limited to general (plain film) radiography, ultrasonography (US), and Magnetic Resonance Imaging (MRI).

University Teaching Hospitals (UTHs)- This is the biggest public hospital in Zambia. It has a bed capacity of 1655 and 250 baby cots. It offers a full range of primary, secondary, and tertiary health and medical services. UTH is the primary trauma centre for a catchment of nearly 3 million people in Lusaka, and its surrounding areas and referrals from all hospitals across the country. A study carried out by Rae[11] to determine the prevalence of trauma cases at UTH found that nearly half of the patients who presented with trauma injuries were admitted. The most prevalent reason for admission was fracture cases with a mortality rate of 4.1%. The radiology department offers a range of imaging services: general (plain film) radiography, theatre radiography, US, computed tomography (CT), dual-energy X-ray absorptiometry (DEXA), radionuclide imaging (RNI), and catheterisation laboratory (Cath Lab). UTH offers limited orthopaedic theatre radiography services twice a week.

Levy Mwanawasa University Teaching Hospital (LMUTH)-is a new 850-bed capacity medical facility located in Lusaka. LMUTH is a primary trauma centre but offers limited orthopaedic theatre radiography. The hospital also hosts the Levy Mwanawasa Medical University(LMMU) which offers undergraduate and postgraduate programmes in various medical, nursing, and allied health professions. The radiology department at LMUTH offers imaging services in general (plain film) radiography, US, CT, and MRI.

Ndola Teaching Hospital (NTH)- is the second largest referral centre in Zambia,[4] serving a population of 925,726 in the Ndola District of the Copperbelt province. NTH also serves as a referral hospital for the northern part of the country. It has a capacity of 851 beds and 97 baby cots. NTH hosts the Copperbelt University School of Medicine as well as the Tropical Diseases Research Centre (TDRC) which is the main medical research institute in the country. The radiology department offers medical imaging services which include general (plain film) radiography, theatre radiography, US, CT, and mammography.

Kitwe Teaching Hospital (KTH)-is the third largest hospital in Zambia located in the city of Kitwe. The hospital was opened in 1958 and has a bed capacity of 630.[4] KTH is a primary trauma centre for the Northern part of the country and offers limited orthopaedic theatre radiography procedures every Monday. Other imaging services which support orthopaedic theatre radiography include general (plain film) radiography, US, and CT.

Livingstone Teaching Hospital (LTH)-is a public hospital located in the southern province with a bed capacity of 325.[4]It provides a wide range of medical services including orthopaedic surgery. The hospital has an orthopaedic clinic on Wednesdays and orthopaedic theatre radiography on Tuesdays and Thursdays. The radiology department is equipped with a range of imaging equipment for general (plain film) radiography, US, and CT.

Kabwe General Hospital (KGH)-is one of Zambia's oldest hospitals commissioned in 1953. The hospital has a bed capacity of 430 and offers orthopaedic surgeries among its services. Every first Tuesday of the month, limited orthopaedic theatre radiography procedures are conducted. Other medical imaging services the radiology department provides include general (plain film) radiography, US, and mammography.

Maina Soko Medical Centre-is a general military medical facility located in Lusaka with a bed capacity of 250. The medical facility has an accident and emergency department with a complete trauma

unit.[14]The imaging centre is equipped with a range of imaging equipment: general (plain film) radiography, fluoroscopy, US, CT, MRI, and mammography. The medical facility offers limited orthopaedic theatre radiography.

Medland Hospital -is a private hospital located in Lusaka with a bed capacity of 78 and offers specialised and comprehensive medical services.[15,16]One of the specialities offered is orthopaedics which requires theatre radiography. Other imaging services offered at the hospital include general (plain film) radiography, orthopaedic theatre radiography, US, mammography, CT, MRI, and DEXA.

CFB Medical Centre- a private medical facility in Lusaka offering comprehensive medical services. The operating theatres deal with both elective and emergency cases, including limited orthopaedic surgeries.[17]The radiology department offers a range of imaging services such as general (plain film) radiography, mammography, US, and CT.

ORTHOPAEDIC THEATRE RADIOGRAPHY PROCEDURES PERFORMED IN THE ZAMBIAN HEALTHCARE SYSTEM

There are two types of orthopaedic theatre radiography: non-trauma and trauma procedures.

Non-trauma orthopaedic procedures

There is an endless list of non-trauma corrective orthopaedic procedures performed throughout the world.[1,18]However, most of the procedures performed in the Zambian healthcare system involve the replacement of joints due to degenerative disease or chronic trauma. In case of severe degenerative disease or chronic trauma, a prosthetic hip or knee may be required to return to the normal function of the joint.[2] Thus, hip and knee replacements are the most performed non-trauma orthopaedic procedures. The main indication for joint replacement is osteoarthritis. In a Zambian study carried out by Mulla and others, [6] to identify the indications for performing joint replacements, primary osteoarthritis accounted for 70.6%, osteoarthritis secondary to traumas 5.9% and 13.7% osteoarthritis due to Avascular Necrosis (AVN) of the head of the femur.

Total hip replacement (THR)-is an orthopaedic procedure that involves the surgical excision of the femoral head and cartilage of the acetabulum and replacement with a metal ball attached to a stem inserted in the proximal femoral shaft.[18] Image 1 shows a radiograph of bilateral total hip replacements.

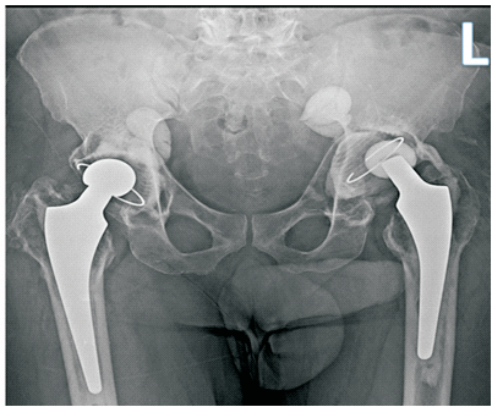
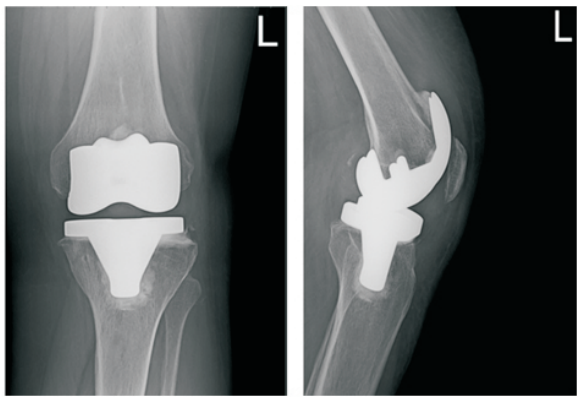


Image 1: Bilateral total hip replacements (THR)

Total knee replacement (TKR)-is an orthopaedic procedure whereby the articular surfaces of the knee joint are replaced by prosthetic components.[18]Image 2 shows postoperative radiographs of the left TKR.



Images 2: Left total knee replacement (TKR)

Trauma orthopaedic procedures

There is also an endless list of trauma orthopaedic procedures carried out globally.[1,18] Trauma injuries represent a global public health threat, and that threat is disproportionally felt, especially in developing countries that experience 90% of global mortality.[19]The main contributing factors include an increase in motorisation, poor road infrastructure, lack of safety awareness, a lack of trauma centres, and specialised health professionals.[7,9] A research study by Seidenberg and others, [7] found three common mechanisms of trauma injuries in Zambia: Falls (26.3%), RTAs (25.6%) and assault cases (20.0%). The most common trauma orthopaedic procedures performed in the Zambian healthcare system include Kirschner wires (k-wiring), tension band wiring (TBW), open reduction and internal fixation (ORIF), dynamic hip screw (DHS), gamma nail(trochanteric), and intramedullary (IM) nailing.

Kirschner wires (K-wires)-are a type of stainless-steel wires used in orthopaedic surgery to stabilise a fracture. [18] K-wires are mostly used to treat simple fractures of extremities using closed surgery.[20]Intermittent fluoroscopic imaging is required throughout the procedure. Image 3 shows radiographs of the right hand with k-wiring fixation of the second metacarpal.

Image 3: K-wring of the second metacarpal

Tension band wiring (TBW)-is a type of wire which is applied as a loop to the outer side of the fracture so that it comes under tension when the joint is flexed.[18] It prevents the re-displacement of the fracture and allows healing to take place. TBW is an open surgical procedure commonly used for fractures of the olecranon and patella. Since these are under open reduction, fluoroscopic imaging is often kept to a minimum and often required at the end of the surgical procedure.[20] Image 4 shows radiographs of the left patella surgically treated with TBW and K-wires.

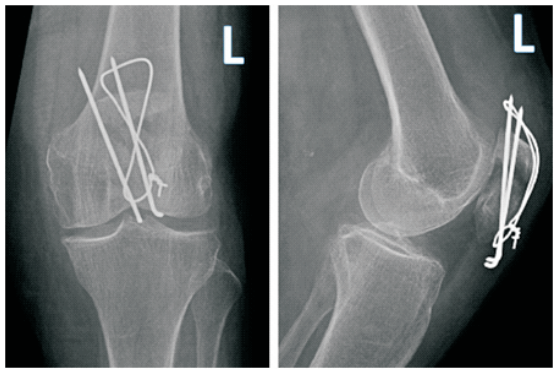


Image 4: Tension band and K-wiring of the left patella

Open reduction and internal fixation (ORIF)- orthopaedic operative management of a fracture where open surgical reduction and internal fixation are applied.[18] ORIF is used to treat severe fractures with significant displacement or fragmentation.[2] The fracture site is exposed, and a variety of plates, screws, or rods are inserted as needed to maintain the alignment of the bony fragments until new bone growth can take place.[2] Fluoroscopic imaging is often required at the end of the procedure as the orthopaedic surgeon can often visualise the fracture site as being an open surgical procedure.[20] Image 5 shows radiographs of the right ankle surgically treated using the ORIF technique.

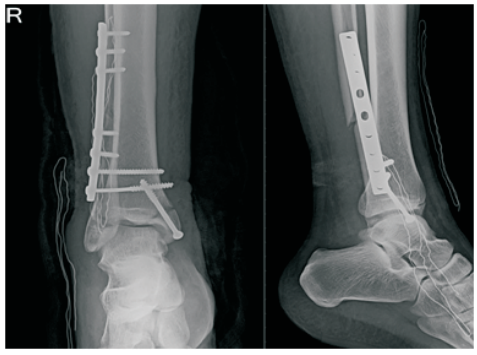


Image 5: ORIF of the rightankle

Dynamic hip screw (DHS)-is an orthopaedic procedure used to treat femoral neck fractures using a pin and plate. [20] Intermittent fluoroscopic imaging is required during the procedure to aid orthopaedic surgeons. Image 6 shows radiographs of the right DHS.

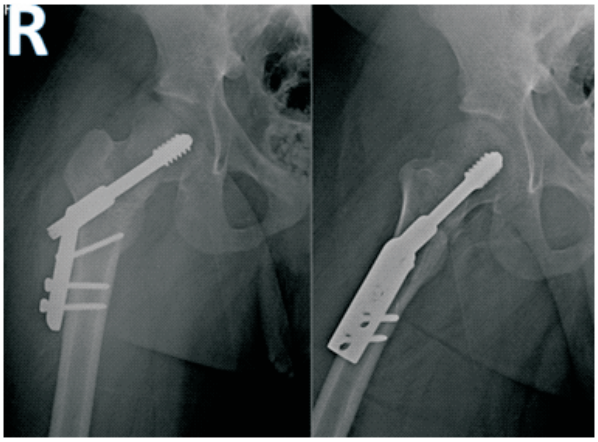


Image 6: Dynamic hip screw (DHS) of the right hip

Gamma nail-is an orthopaedic procedure used to treat proximal femoral fractures in the trochanter area based on intramedullary nailing principles using the closed fixation method. [21] The procedure is similar to a DHS and intermittent fluoroscopic imaging is required during the procedure. Image 7 shows a Gamma nail of the right proximal femur.

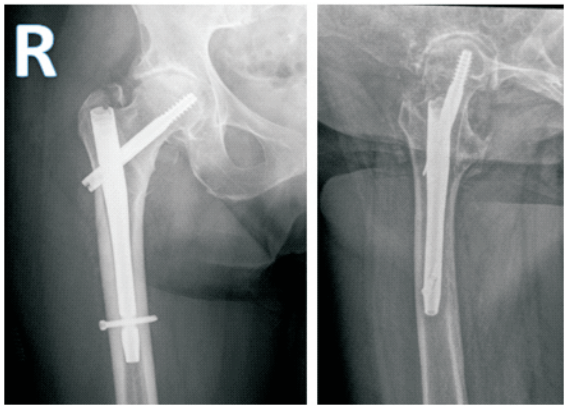


Image 7: Gamma nail of the right proximal femur

Intramedullary (IM) nailing-is an internal fixation method where intramedullary rods and nails are inserted within the shaft of a long bone to stabilise the fracture. [2] IM nailing is commonly used to treat shaft fractures of the femur, tibial and humerus.Intermittent fluoroscopic imaging is required throughout the procedure to visualise the nail as it passes through the medulla and assist in the proximal and distal locking of the nail with cortex screws.[20] Image 8 shows IM nailing of the right femur.

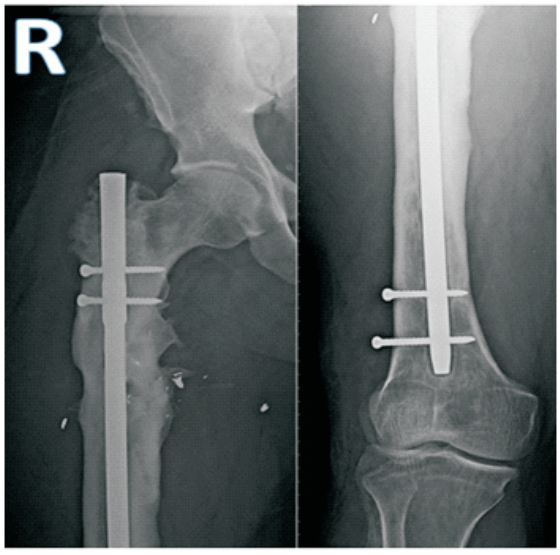


Image 8: IM nailing of the right femur

CHALLENGES FACING ORTHOPAEDIC THEATRE RADIOGRAPHY IN ZAMBIA

Zambia, like many other developing countries, is faced with challenges related to the provision of quality healthcare, including theatre radiography. The main challenges facing orthopaedic theatre radiography can be grouped under five themes (Table 2).

Table 2: Challenges facing orthopaedic theatre radiography in Zambia

No	challenge
1	Less attention has been paid to theatre radiographyat the undergraduate level
2	Newly qualified radiographers learn theatre radiography through on-job-training
3	Limited, non-servicing and frequent breakdown of theatre radiography equipment
4	Non-imaging professionals operating theatre radiography equipment
5	Lack of radiation protection devices and enforcement of standards

The first challenge relates to undergraduate education and training in radiography. Although theatre radiography is included in the radiography curricula for all four (4) undergraduate radiography programmes in Zambia, less attention has been paid to this sub-speciality. This may be attributed to a lack of organised orthopaedic services in the country.[6,7]Radiography students are taught radiographic techniques about theatre radiography, but there is little or no clinical practice because of a limited number of orthopaedic procedures performed in medical facilities. The other reason is the increase in the number of radiography students being enrolled with limited clinical sites which makes it difficult for them to adequately apply theory into clinical practice. [22] This is even worse with theatre radiography where limited procedures are performed. This challenge can be overcome with simulation experiences where radiography students can practice how to operate a C-arm without a real patient under the supervision of clinical educators.

The second challenge relates to post-qualification training in theatre radiography. Due to no or less exposure of radiography students to theatre radiography, most newly qualified radiographers learn through on-job-training (OJT) under the direct supervision of senior theatre radiographers. However, OJT lacks planning and a formal structure for teaching and learning. [23] It is opportunistic in nature where the trainee theatre radiographer is exposed to available cases based on the daily operative list. Therefore, the knowledge and experience gained are highly dependent on the availability of cases during the training period. [23] In addition, the quality of the training varies according to the trainer's capacity. [24] Maintaining a standard of excellence for theatre radiographers requires formal training to gain appropriate knowledge, skills, and competence in theatre radiography.[23] Therefore, the schools of radiography should upscale the training, if possible, establish a postgraduate short course in theatre radiography to meet the needs of current and future demands.

The third challenge relates to theatre radiography equipment. The Zambia National Health Strategic Plan of 2017-2021 reports that 60% of medical imaging machines are old and obsolete.[5]This includes mobile X-ray and image intensifiers (II)machines used for theatre radiography. This results in frequent breakdowns and disruptions of medical imaging services such as orthopaedic theatre radiography.[5,25]The information obtained from the Provincial Radiography Coordinators shows that out of 37 mobile X-ray and 13 image intensifiers machines in the country, 16 and 3 are non-functional respectively. This number of mobile radiography equipment is also inadequate to cover all 141 public hospitals reported in 2017.

The fourth challenge relates to the operation of theatre radiography equipment. There is anecdotal evidence that some medical doctors are undertaking imaging during theatre procedures. This is a violation of the Ionising Radiation Protection Act of 2011 of the Republic of Zambia[3] and RPA license regulation which permits only imaging professionals such as radiographers, radiography technologists and radiologists to operate medical imaging equipment that uses ionising radiation. It

should be mentioned that imaging professionals undertake radiographic techniques and radiation protection training to acquire appropriate knowledge and skills in protecting themselves, patients, staff, and members of the public. This is because ionising radiation has biological effects on the human body.[26,27] This practice by medical doctors is putting patients and themselves at health risk. This practice has contributed to the underdevelopment of theatre radiography in the country. It is the duty of the RPA to reinforce radiation protection standards to protect patients and staff.

The fifth challenge relates to radiation protection. In Zambia, there is inadequate personal radiation protective equipment (PRPE) such as lead aprons, thyroid shields, mobile protective screens, and gonad shields used during mobile and theatre radiography.[27] There is also a lack of monitoring and enforcement of radiation protection standards. Although the Radiation Protection Officer (RPO) position for each facility using ionising radiation has been included in the Ionising Radiation Protection Act of 2011 of the Republic of Zambia, [3] the position is not formalised in radiography under the MoH that carries an appropriate salary of an expert in radiation protection. RPO has a duty of monitoring the radiation standards where ionising radiation is being used, including operating theatres. There is also a lack of training to impart RPOs with appropriate knowledge and skills. However, in 2023, the University of Zambia (UNZA) started offering a one-year postgraduate radiation protection course. It is anticipated that with the qualified RPO, the standards of radiation protection will be enforced to protect patients, staff and members of the public from the biological effects of ionising radiation.

RECOMMENDATIONS

1. Radiographers through the Radiological Society of Zambia (RSZ) should be involved in the discussions regarding the establishment of organised orthopaedic services in the country because they are key stakeholders in the delivery of theatre services.
2. Radiographers who are mandated under the Ionising Radiation Protection Act of 2011 of the Republic of Zambia [3] should fully take up the role of imaging in theatre. In this regard, RSZ, RPA and Health Professions Council (HPCZ) should monitor the implementation of this practice in all medical facilities.
3. Training of radiographers in theatre radiography should be strengthened both academically and in the clinical area. The RSZ should also provide continuing professional development (CPD) events on theatre radiography to keep radiographers updated with knowledge and skills.

CONCLUSION

This review found that orthopaedic theatre radiography services are underdeveloped in Zambia. This can be attributed due to a lack of training in theatre radiography and a well-organised trauma healthcare system having specialised public orthopaedic medical facilities. There is a need to prioritise the strengthening of orthopaedic theatre radiography at all levels of healthcare where orthopaedic theatre services are provided. Further, as planned developed orthopaedic services progress in the country, it is necessary for the radiography profession to start strengthening education and training and advocating for more theatre radiography equipment. A few challenges were discovered during the review which warrants a research to explore the experiences of radiographers regarding orthopaedic theatre radiography.

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radiographic images provided and included in this article.

CONFLICT OF INTEREST

The authors have no conflict of interest to declare.

AUTHORS' CONTRIBUTIONS

Osward Bwanga, the main author conceptualised this review and was responsible for the supervisory role. Ncheebe Sindaza, Malunga Chipulu and Dr Patrick Mwenga Kinda supplied the number of medical facilities offering orthopaedic theatre radiography services and organised the radiographic images used in this article. In addition, Ncheebe Sindaza obtained the number of mobile X-ray and image intensifiers in the county. Joseph Mulenga proofread the article. Lastly, all authors assisted in the drafting of the article.

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