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Review Article

Challenges in Radiation Protection in Healthcare: A Case of Zambia

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Abstract: ***Background:*** The use of radiation in healthcare plays an important role in the diagnosis and treatment of injuries and diseases. However, there are associated health risks from exposure to radiation. For this reason, good practices have been developed following the recommendations from the International Commission on Radiation Protection (ICRP) to safeguard patients, personnel, and members of the public from unnecessary exposure to radiation.
Objective: The purpose of this review is, therefore, to identify and offer solutions to challenges in radiation protection in Zambian healthcare.
Methods: A literature search was undertaken in four databases: ScienceDirect, CINAHL, Google Scholar and PubMed/MEDLINE, and manual searches of radiography/radiation protection journals to have an in-depth understanding of the challenges of radiation protection in Zambia. This was supplemented with searches of radiation protection and Ministry of Health of Zambia websites.
Results: The main challenges identified include the use of old and obsolete X-ray machines, a shortage of medical physicists and radiologists, limited personal radiation protective equipment, non-availability of a radiation protection course, limited data on patient radiation doses, non-availability of diagnostic reference levels (DRLs), unjustified radiological examinations, non-availability of imaging referral guidelines, and a lack of clinical audits and research on radiation protection.
Conclusion: It is vital to increase the number of medical physicists, and train radiographers and radiography technologists in radiation protection to help medical physicists in conducting quality assurance (QA) and other specialised radiation protection related tasks.

Keywords: Radiation protection, Optimisation, Justification, Dose limitation, Quality assurance (QA), Medical Physicists, Radiation protection officer (RPO).

INTRODUCTION

Zambia is a landlocked country located in South-Central Africa. It has a population of approximately 17 million people (WHO, 2019). The Ministry of Health (MOH) is in-charge for the coordination and management of the healthcare sector in the country. In 2005 (amended in 2011), the Government of the Republic of Zambia enacted the Ionising Radiation Protection Act to provide protection to healthcare professionals, patients and members of the public from ionising radiation. In order to spearhead the implementation of the regulation, the Radiation Protection Authority (RPA), was established. In the Zambian context, radiography technologists and radiographers are imaging professionals with diploma and degree in radiography respectively.

In Zambia, there are currently 141 public hospitals offering diagnostic imaging services and one radiotherapy centre (Ministry of Health, 2017). The demand for diagnostic imaging services has increased in the country following the introduction of modern modalities such as ultrasound (US), computed tomography (CT) and magnetic resonance imaging (MRI), and increase in diseases, such as tuberculosis (TB) and cancer (Ministry of Health, 2017). This increase in demand and medical exposure of patients is becoming a public health concern because of the risks of the effects ionising radiation has on the human body (WHO, 2008). Now is the time to strengthen up radiation protection measures in Zambian healthcare. This could be achieved by strengthening policies that are based on the three principles of radiation protection: justification, optimisation and dose limitation (ICRP, 2007; WHO, 2008).

In view of the above, several measures have been implemented in Zambia in order to adhere to the radiation protection principles. However, like any other developing country, challenges are being faced in effectively implementing radiation protection measures in diagnostic imaging and radiotherapy. This review,

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therefore, discusses the main challenges and possible solutions to help policy makers.

Challenges in Radiation Protection and Suggested Solutions

The twelve challenges identified in the protection of patients, members of staff and public in Zambia from ionising radiation are discussed with possible solutions.

Old and Obsolete Diagnostic Imaging Equipment

Currently, conventional film and screen imaging is the principal method used for image capture, display and storage in Zambia. The use of old and outdated X-ray equipment results in frequent breakdowns, malfunctions and consequently, radiation leakage, as revealed in the research study conducted by Moonga (2016) at the University Teaching Hospital (UTH) and Cancer Disease Hospital (CDH) of Lusaka. This research study finding is consistent with the National Health Strategic Plan of 2017-2021 report which states that approximately 60% of the X-ray machines in Zambia are old and obsolete (Ministry of Health, 2017).

Given the above, it is essential that analogy imaging equipment in all hospitals including remote areas should be replaced with modern digital X-ray machines. According to the International Atomic Energy Agency (2015), digital radiography (DR) has an increased latitude and dynamic range which reduces repeats and patients' radiation doses. In addition, digital image receptors are much more sensitive to low levels of radiation compared to the film-screen system, therefore requiring lower quantity of radiation to produce an image. The Ministry of Health has started upgrading the imaging system and few hospitals such as UTH, Levy Mwanawasa University Teaching Hospital, Ndola Teaching Hospital and other hospitals have had some DR equipment installed. However, the World Health Organisation (2008) warns that the DR could significantly increase the patient dose if inappropriately used. The shift from a narrow latitude of screen-film system to a wide latitude of DR could easily result in overexposure of patients without the knowledge of a radiography technologist or radiographer. As digital radiography is introduced into the healthcare system in the country, radiographers and radiography technologists should be imparted with adequate knowledge and skills of the DR system through work-based learning in order to minimise the possibility of overexposing patients.

Shortage of Medical Physicists

A medical physicist is a healthcare professional who applies both physics and medicine to assist clinical staff in diagnosing diseases and treating patients. Thus, medical physicists have an important role in radiation protection through the implementation of the principle of optimisation. Optimisation of medical exposures means keeping all radiation doses as low as reasonably achievable, considering economic and societal factors (ICRP, 2007). Medical physicists achieve this through the selection of appropriate equipment during the procurement process, designing appropriate diagnostic imaging or treatment room; capable of containing the ionising radiation, acceptance and commissioning of the equipment, putting in place QA programmes, educating and training staff on radiation protection, and to providing support to staff in complying with regulations on radiation protection.

Currently, there are only 5 medical physicists working in Zambia, responsible for QA for equipment in all 141 public healthcare institutions across the country. This works out at one medical physicist for every twenty-eight facilities. Due to the inadequate numbers of medical physicists in the country, their focus is mainly on radiotherapy, and less on diagnostic imaging, despite it being the largest area of radiation protection in healthcare (Kawesha, 2017). This critical shortage is due to a lack of medical physics training programmes within Zambia. However, there are plans to introduce a bachelor's degree in medical physics at the University of Zambia.

Shortage of Radiologists

Radiologists are medical doctors specialised in diagnosing and treating diseases and injuries using imaging techniques. In Zambia, there are currently 5 radiologists working in public hospitals servicing a population of approximately 17 million. The obligation of the radiologist for the radiation protection of patients includes a review of the appropriateness of the diagnostic imaging examinations and optimisation of the protocols (Etard, 2010). Radiologists are not only responsible for image reporting, but perform radiological examinations such as fluoroscopy studies, interventional radiology procedures and consultation services too. The International Atomic Energy Agency (2013) advises that in the absence of radiology referral guidelines, referring medical practitioners should consult a radiologist when unsure of which imaging examination to request in each clinical situation or problem. Furthermore, radiologists provide radiation protection training to staff involved in imaging examinations, such as medical practitioners. To increase the number of radiologists, the Ministry of Health in Zambia has recently introduced a specialised radiology training programme for medical doctors.

Inadequate Personal Radiation Protective Equipment (PRPE)

Imaging professionals, such as radiographers, radiography technologists and radiologists, may be exposed to ionising radiation either from the primary X-ray beam or the scatter. This may create the same risks as for patients. Thus, imaging professionals should be knowledgeable and apply the three principal methods for protecting radiation workers from external exposure: time, distance and shielding. The focus of this review is on shielding using personal radiation protective equipment (PRPE). In Zambia, there is limited PRPE available for use in clinical settings (Monga, 2016) and it is unevenly distributed between urban and rural parts of the country. This is a challenge in protecting imaging professionals from external exposure when performing examinations which require them to remain in the radiation field, such as fluoroscopy, mobile and theatre radiography.

The PRPE includes all clothing and accessories which protect individuals from external exposure, such as lead aprons, thyroid shields, mobile protective screens, lead gloves, lead glasses and gonad shields.

- **Lead apron**- worn by healthcare professionals and patients to shield the track of the body from ionising radiation exposure while in the radiation field.
- **Thyroid shield**- worn by healthcare professionals to minimise the exposure of the thyroid gland to radiation which is very sensitive to ionising radiation (ICRP, 2007).
- **Mobile protective screen**- a mobile barrier designed to protect the individual's whole body from radiation exposure while in the radiation field.
- **Lead gloves**- designed to protect the hands and wrists of imaging professionals who must get close to the primary X-ray beam or perhaps even be within the beam, for example to palpate an area under fluoroscopic exposure (Hart *et al.,* 2002).
- **Lead glasses**- designed to minimise radiation exposure to the eyes in a situation where healthcare professionals must remain close to the radiation source. This is because the eyes are very sensitive to radiation (ICRP, 2007).
- **Gonad shield**- designed specifically to protect patients undergoing X-ray examinations around the pelvis that would otherwise irradiate the gonads (Hart *et al.,* 2002).

It is, therefore, necessary to increase the availability of radiation protection clothing and accessories in all health facilities with X-ray machines. Muhongora and Rehani (2017) state that in most African countries, there is a lack of radiation protection measures despite some, including shielding being simple and inexpensive.

Non-Availability of a Radiation Protection Training Programme

Radiographers and radiography technologists play a key role in the implementation of the principles of radiation protection since they are available in all healthcare institutions offering diagnostic imaging and radiotherapy services. All radiographers and radiography technologists should be knowledgeable in radiation protection at an undergraduate level and those with the responsibility of performing specialised tasks should undertake radiation protection education and training at a postgraduate level (ICRP, 2009; Vano *et al.,* 2018). For this reason, radiation protection has been integrated into the curriculums of all three undergraduate radiography programmes in Zambia: the diploma in radiography at Evelyn Hone College, and bachelors' degree in radiography at the Lusaka Apex Medical University and University of Zambia. Unfortunately, there is no specialised radiation protection course to equip imaging professionals with advanced knowledge and skills, including research.

The Ionising Radiation Protection Act of the Laws of Zambia (2011) requires the appointment of a competent person as a radiation protection officer (RPO) in each medical facility using radiation. The Radiation Protection Authority hosts workshops to facilitate the training of RPOs' across the country (Kawesha, 2017). However, an accredited programme offered by higher education institution is required to formally train radiographers and radiography technologists with special responsibilities in radiation protection. Therefore, a specialised radiation protection course should be developed at a master's level. There are plans to develop a postgraduate diploma in radiation protection at Evelyn Hone College, to be spearheaded by the RPA and IAEA. A needs assessment has already been conducted. The RPO in each facility could assist medical physicists in conducting QA tasks, such as testing the performance of imaging equipment, monitoring personal and patient radiation doses, keeping documents, conducting clinical audits and training.

Lack of Maintenance and Testing of Diagnostic Imaging Equipment

There is a lack of maintenance and servicing of diagnostic imaging and radiotherapy equipment in Zambia. A research study conducted by Moonga (2016) at the UTH and CDH found inconsistencies in equipment maintenance which leads to the use of malfunctioning equipment. This challenge has been acknowledged in the Ministry of Health strategic plan of 2017 to 2021 as a hindrance in the provision of quality radiology services (Ministry of Health, 2017). Routine preventative maintenance and servicing helps to keep X-ray machines performing well by identifying small issues before problems arise (Gawugah, 2016). This includes identifying problems which could cause a radiation risk to clinical staff, patients and members of the public. This challenge may be attributed to a lack of bio-medical engineers to effectively service all diagnostic imaging and radiotherapy equipment and non-inclusion of service contracts. To overcome this problem, Evelyn Hone College has introduced a Diploma in Biomedical Engineering programme. The procurement of equipment also should be including a renewable agreement with the suppliers covering the servicing and maintenance over a specific period.

Medical Physicists based at the CDH are responsible for the acceptance and routine QA testing of all imaging and radiotherapy equipment. The objective of QA testing is to maintain the quality of diagnostic images, whilst radiation doses to patients and staff are controlled to be as low as is reasonably practicable (Messer, 2009). This is achieved with routine monitoring of photographic and equipment parameters to detect deviations of equipment performance and take prompt correctional action (Gawugah, 2016). Unfortunately, there is a lack of national routine testing of medical imaging (Ministry of Health, 2017). This could be attributed to the shortage of Medical Physicists as mentioned earlier. Not only is there a lack of routine testing of equipment, but there are also inadequate number of equipment and accessories to use for QA. It is therefore critical that a QA national framework is put in place to guarantee systematic implementation across the country (Ministry of Health, 2017).

Limited Data on Radiation Doses and Non-Availability of Diagnostic Reference Levels (DRLs)

All imaging professionals utilising radiation are monitored for external whole-body irradiation by the Radiation Protection Authority, the regulator of radiation in Zambia. Thermoluminescence dosimeters (TLDs) are used for personal monitoring of radiation. A research study by Moonga (2016) found that the occupation radiation exposures of radiologists, radiographers and radiography technologists were within the monitoring limits as recommended by ICRP (Table 1).

Table 1: Recommended occupational dose limits (ICRP, 2007)

Type of limit	Dose limit
Effective dose	20 mSv per year, averaged over 5 years
Annual equivalent dose in:	
Lens of the eye	150 mSv
Skin	500 mSv
Hands and feet	500 mSv

Although imaging professionals are monitored for occupational exposures, there is not enough monitoring of radiation doses received by patients. This may be attributed to the inadequate number of imaging professionals specialised in radiation protection. With the introduction of high radiation dose examinations and procedures, such as fluoroscopically guided interventional, CT and radiotherapy in Zambian hospitals, there is a need to monitor the radiation doses to patients through the development and implementation of diagnostic reference levels (DRLs) at local and national levels. The ICRP (2017) recommends the establishment of DRLs as a tool for optimising the radiation dose delivered to patients in the course of diagnostic and/or therapeutic procedures. The Council of the European Union (2007) defines DRLs as:

> *"Dose levels in medical radiodiagnostic practice or, in the case of radiopharmaceuticals, levels of activity, for typical examinations for group of standard-sized patients or standard phantoms for broadly defined types of equipment. These levels are expected not to be exceeded for standard procedures when good and normal practice regarding diagnostic and technical performance is applied."*

The objective of DRLs is to help avoid excessive radiation dose to the patient that does not contribute additional clinical informational value to the imaging task (ICRP, 2017). It should be mentioned that excessive doses for DR and CT are not as readily identified through image darkness, as in film-screen imaging system. Therefore, the awareness of typical dose levels allows imaging professionals to quickly identify and address any X-ray machine, radiographic technique or protocol which does not meet the principle of keeping radiation doses as low as is reasonability achievable.

Typically, DRLs are used as a quality assurance tool for investigative purposes and are not dose limits. The application of DRLs is for the local imaging facility to establish a reference dose for the common imaging protocols that can be compared with the national and regional DRLs (ICRP, 2017). The DRLs can be used to improve the local distribution of observed doses for a general imaging task, provide a common dose metric, assess the dose impact of the introduction of new protocols and provide compliance with state and international requirements (EU, 2007; ICRP, 2017). An example of the DRLs for general radiography is shown in Table 2.

Table 2: Recommended diagnostic reference doses for general radiography for individual radiographs on adult patients (ARPNSA, 2013).

Radiograph	ESD per radiograph (mGy)	DAP per radiograph (Gy cm^2)
Skull AP/PA	3	-
Skull LAT	1.5	-
Chest PA	0.2	0.12
Chest LAT	1	-
Thoracic spine AP	3.5	-
Thoracic spine LAT	10	-
Lumbar spine AP	6	1.6
Lumbar spine LAT	14	3
Lumbar spine LSJ	26	3
Abdomen AP	6	3
Pelvis AP	4	3

In view of the above, DRLs should be developed and implemented at the Southern African Development Community (SADC), national and local levels as per ICRP (2017) recommendations and need to monitor the radiation dose to patients. This also includes monitoring radiation doses of patients undergoing radiotherapy through the development and implementation of an in-vivo dosimetry programme.

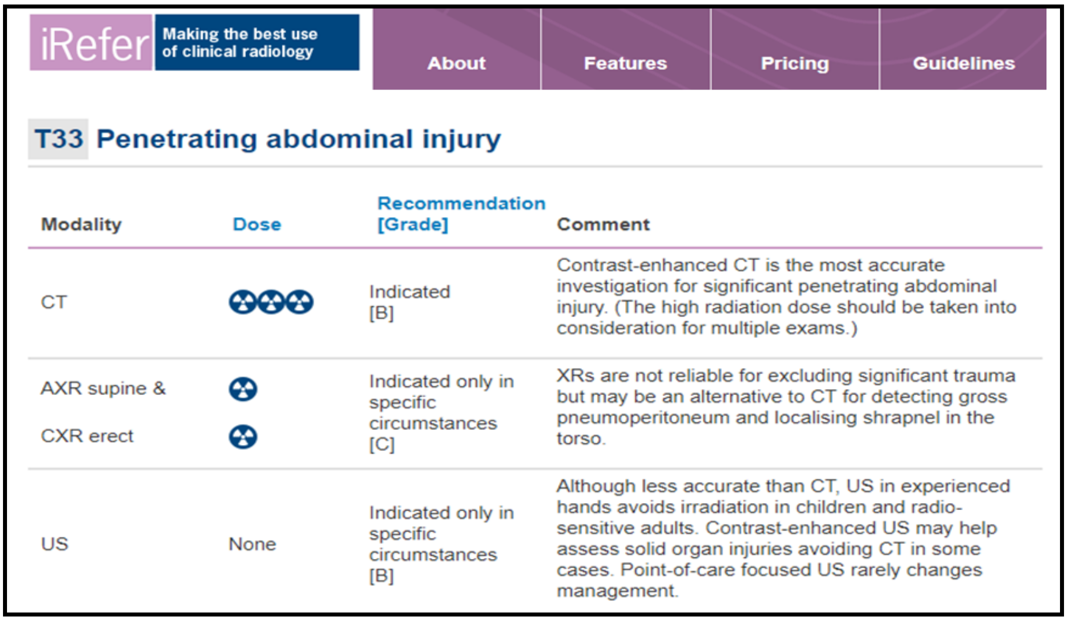
Lack of Knowledge about Radiation Protection amongst Medical Practitioners

There are three groups of referring medical practitioners in Zambia: medical doctors, clinical licentiate officers and clinical officers. Referring medical practitioners are key players in reducing radiation doses to patients through the justification of medical exposures. As the initiators of referrals, they usually have a complete picture of the patient's condition to guide them in undergoing only necessary examinations. A medical exposure is justified if the benefits to the individual patient will do more good than harm (ICRP, 2007). However, a research study conducted by Siwila (2015) found no evidence of any component of radiation protection in the medical curriculum for medical students at the University of Zambia. The ICRP (2009) recommends that all healthcare professionals utilising ionising radiation should include a radiation protection component into their curriculum. In terms of referring medical practitioners, this is vital in acquiring the necessary knowledge and skills relating to the justification of medical exposures.

There is a paucity of research on the knowledge of referring medical practitioners regarding radiation protection in Zambia. However, a survey conducted by Bwanga (2019) revealed a lack of knowledge amongst medical doctors and clinical officers regarding justification of radiological examination. Another research conducted by Siwila (2015) found insufficient knowledge about radiation protection amongst final year medical students with at least 32.8% believing that ultrasound uses ionising radiation. This lack of ability to compare the ionising and non-ionising imaging examinations is one of the causes of unnecessary medical exposures. It should be mentioned that US and MRI are non-ionising radiation imaging modalities and could be used where appropriate to minimise medical exposures. It is clear that radiation protection should be integrated in medical and clinical science curriculums. Furthermore, RPO in each medical facility should conduct radiation protection awareness programmes for non-radiology staff as part of the QA programme.

Unjustified Medical Exposures and Non-Availability of Referral Guidelines

It is essential that all radiological examinations be well-justified to avoid unnecessary exposure of patients to radiation. Under the Ionising Radiation Protection Act of Zambia (2011), medical practitioners have a legal responsibility as referrers to justify each medical exposure. However, limited research studies (Siwila, 2015; Bwanga, 2019) conducted in Zambia revealed referring medical practitioners had inadequate knowledge regarding justification of medical exposures which results in the request of unjustified examinations. This problem may be attributed to a failure of referring medical practitioners to consult with radiologists, radiographers or radiography technologists on best imaging examination to request on a given patient's clinical condition as well as to the non-availability of imaging referral guidelines. The Royal College of Radiologists (2012) defines referral imaging guidelines as evidence-based tools that assist referring medical practitioners in making the most appropriate imaging or treatment decision for a specific clinical condition. It provides referring medical practitioners with clinical and diagnostic problems, a list of some possible imaging modalities with the band of radiation exposure involved, levels of radiation doses for each type of procedure, recommendations on whether or not the investigation is appropriate, and explanatory notes on each modality. Figure 1 show an example on penetrating abdominal injury.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T33 Penetrating abdominal injury

Modality	Dose	Recommendation [Grade]	Comment
CT		Indicated [B]	Contrast-enhanced CT is the most accurate investigation for significant penetrating abdominal injury. (The high radiation dose should be taken into consideration for multiple exams.)
AXR supine & CXR erect		Indicated only in specific circumstances [C]	XRs are not reliable for excluding significant trauma but may be an alternative to CT for detecting gross pneumoperitoneum and localising shrapnel in the torso.
US	None	Indicated only in specific circumstances [B]	Although less accurate than CT, US in experienced hands avoids irradiation in children and radio-sensitive adults. Contrast-enhanced US may help assess solid organ injuries avoiding CT in some cases. Point-of-care focused US rarely changes management.

Figure 1: Royal College of Radiologists referral guideline (RCR, 2012)

There is evidence that a reduction in the number of imaging examinations requested and performed could be achieved using referral guidelines. For example, Glaves (2006) conducted a research study to determine if the use of referral guidelines could achieve a sustained reduction in the number of radiological examinations amongst general practitioners (GP) in the UK. The research study revealed a reduction of 68% and 79% in the first and second years respectively. Some experts have also estimated that a general reduction of up to 50% of unnecessary radiological examinations could be achieved by applying these justification tools (WHO, 2008). This has the potential to reduce the radiation doses to patients, patients' waiting lists, cost of healthcare, and imaging professionals' workload.

There is a need to produce a local diagnostic imaging referral guideline based on local diseases and resources in Zambia. This should be produced in collaboration with the Radiological Society of Zambia (RSZ) and the Zambia Medical Association (ZMA). In the research study conducted by Siwila (2015), the majority (86.2%) of final year medical students did not know about imaging referral guidelines as a tool in reducing unnecessary medical exposures. Thus, after the development of imaging referral guidelines, an awareness programme should be set up with the use of this justification tool amongst referring medical practitioners.

Lack of Clinical Audits in Radiological and Radiotherapy Practices

There is a lack of clinical audits in radiological and radiotherapy practices in Zambia. The EU guidelines (2009) define a clinical audit as:

"A systematic examination or review of medical radiological procedures which seeks to improve the quality and the outcome of patient care, through structured review whereby radiological practices, procedures, and results are examined against agreed standards for good medical radiological procedures, with modifications of the practices where indicated and the application of new standards if necessary."

This means that clinical audits are essential for improving the quality of diagnostic imaging services. Therefore, imaging professionals have a responsibility to develop and implement clinical audits, whilst the professional bodies such as the Radiological Society of Zambia (RSZ) have a role in developing guidelines. According to IAEA (2010), clinical audits should focus on four areas: quality management procedures and infrastructure, patient related procedures, technical procedures, and education. To overcome this challenge, there is a need to establish a national clinical audit programme of the radiological and radiotherapy practices in Zambia as part of quality assurance. The Radiological Society of Zambia and Medical Association of Zambia should develop guidelines for its members regarding clinical audits.

Scarcity of Research on Radiation Protection in Healthcare

There is a lack of research in radiography in Zambia (Fuller, 2015). This includes radiation protection. Medical physicists, radiologists, radiographers and radiography technologists are all responsible for research related to radiation protection. Firstly, medical physicists are responsible for researching new physical concepts which might be used for diagnosis and treatment, developing and testing of new imaging equipment, and conducting clinical trials for new imaging and treatment techniques (Meghzifene *et al.*, 2010). Secondly, radiologists play a key role in research looking at the diagnosis, treatment or clinical management of patients. The most common research activities for radiologists include being involved in clinical trials. As mentioned earlier, due to a shortage of medical physicists and radiologists in Zambia, the area of research in radiation protection has received less attention. Thirdly, radiographers and radiography technologists should be involved in research in order to inform evidence-based practices to improve patient care. Unfortunately, due to the non-availability of a radiation protection training programme, radiographers and radiography technologists may lack the knowledge and advanced skills to conduct research in this area. There is need to encourage imaging professionals to be active in conducting and publishing research for evidence-based practice and sharing knowledge.

CONCLUSION

There is a shortage of medical physicists in Zambia to develop and implement QA programmes to overcome the challenges identified in this review. Therefore, a local medical physics educational programme should be developed in order to increase the number of medical physicists in the country. There is also a necessity to expand the roles of radiographers and radiography technologists to fill the gap created due to the shortage of medical physics and radiologists. With the availability of three undergraduate radiography programmes in Zambia, there are enough radiographers and radiography technologists to take up the specialised radiation protection tasks. Lastly, countries in Southern Africa could work together through groupings such as SADC to develop regional regulations and guidelines on radiation protection.

CONFLICT OF INTEREST- None

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