KNOWLEDGE OF RADIATION SAFETY AMONGST PAEDIATRIC DOCTORS IN PIETERSBURG AND MANKWENG HOSPITALS

by

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DEDICATION

To the Creator of Heaven and earth and all that is within it. It is through Your goodness that all this was possible. You are indeed a miracle-working God. All that is, is from Your Word. You are the beginning and the end, Alfa and Omega, Omnipotent, Omniscient and Omnipresent God. TRIPLE POWER, GOD IN TRINITY.

To my husband, Mr T.E. Bendlela. Thank you for loving me the way you do. Thank you for your faith in God and in me. You made it possible for me to go through this process of growth. You made me trust God more.

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Thank you.

DECLARATION

I Takalani Masala Bendlela declare that KNOWLEDGE OF RADIATION SAFETY AMONGST PAEDIATRIC DOCTORS IN PIETERSBURG AND MANKWENG HOSPITALS (mini-dissertation) hereby submitted to the University of Limpopo, for the degree of Master of Science in Diagnostic Radiology, has not previously been submitted by me for a degree at this or any other university, that is my work in design and in execution, and that all material contained herein has been acknowledged.

Bendlela TM (Dr) 25 April 2022

Surname, Initials (title)

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ABSTRACT

BACKGROUND: Ionizing radiation is detrimental to growing cells. The potential risk of any dose of radiation in growing cells can lead to permanent damage of basic cellular structure resulting in a high risk of developing cancer in children. Therefore, paediatric doctors need sufficient knowledge to protect their patients from late effects of radiation resulting from medical use. Most studies report poor knowledge of radiation safety measures among doctors.

PURPOSE: The purpose of this study is to assess the knowledge of radiation safety and radiation doses among paediatric doctors in Pietersburg and Mankweng Hospitals, Limpopo province, South Africa.

OBJECTIVE: To assess the paediatric doctors' knowledge of radiation doses used in radiological diagnostic imaging examinations, as well as their knowledge of radiation safety measures.

METHODOLOGY: This is a survey of paediatric doctors in the paediatrics general ward, paediatric oncology, intensive care and neonatal units, and paediatric surgery department, at Pietersburg and Mankweng Hospitals. A self-administered questionnaire with 23 items on knowledge of radiation safety and radiation doses emitted during normal radiological examinations is used to collect the data in May 2021. Data are analysed using Statistical Package for Social Sciences (SSPS) version 26.0 software. Chi-squared test is used to analyse the relationship between variables. Analysis of variance (ANOVA) is used to analyse the differences between variables. A p value of <0.05 is considered statistically significant. A total score of 50% in each section is used to denote adequate knowledge. The result are presented in charts and tables.

RESULTS: Out of 52 paediatric doctors, 47 completed the questionnaire achieving a 90.4% response rate. Majority of participants were females (n = 31; 66%). Overall, only 10 (21.2%) of the participants scored 50% and above, including three consultants, two registrars, two medical officers and one medical officer intern. Twenty-five (53.1%) participants scored 50% and above on knowledge of radiation safety. Nearly half (44.7%) of the doctors were familiar with the concept of ALARA principle in radiation dose optimisation. Three participants scored more than 50% in the knowledge of radiation doses section. Only five (10.6%) and 17 (36%) participants correctly identified MRI and ultrasound, respectively, as the radiological diagnostic modalities that do not utilize ionizing radiation.

CONCUSION: The level of knowledge of radiation safety and radiation doses among the paediatric doctors are poor. A very small number of the paediatric doctors were able to identify non-ionizing radiation modalities that can be used as an alternative to reduce radiation exposure to paediatrics during radiological investigations. Paediatric doctors will benefit from courses on radiation safety and radiation doses to improve their knowledge and/or eliminate unwarranted exposure of their patients to ionizing radiation.

KEY CONCEPTS: Background radiation; Ionizing radiation; ALARA; Radiation protection; Awareness

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DEFINITION OF CONCEPTS

Background radiation: This is ionizing radiation from natural sources that people are exposed to (Bezuidenhout, 2014). In this study, the background radiation considered will be as found in South Africa, where the stipulated amount is 0.07mSv per year.

Children: Children are human beings under the age of 18, according to South African laws (Strode, Slack and Essack, 2010). In this study, children are all patients under the age of 18 years, who are under the care of paediatric doctors.

Ionizing radiation: Ionizing radiation is the radiation that is traveling as a particle or electromagnetic wave, with enough energy to remove tightly bound electrons from the orbit of an atom during an interaction with the atom, causing the atom to become charged or ionized (International Atomic Energy Agency [IAEA], 2018 ; World Health Organization, 2016). In this study, the radiation used in conventional radiography and computer tomography is regarded as ionizing radiation.

Knowledge: Knowledge is the theoretical or practical understanding of a subject, manifesting as familiarity, awareness, or understanding of someone or something, such as facts, information, description, or skills, which is acquired through experience or education by perceiving, discovering, or learning (Tiblier, 1961). In this study knowledge is the acquired information on the understanding of radiation use in common diagnostic procedures by registered doctors in paediatrics, its effects, and the prevention of adverse effects in children (Singh, McCoubrie, Burney and Miles, 2008).

Paediatric doctor: Paediatric doctor is a doctor who is concerned with the physical, mental, and social health of children from birth to young adulthood (Rimsza, Hotaling, Keown, Marcin, Moskowitz, Sigrest and Simon, 2015). In this study, paediatric doctors will include all doctors assigned to treat children in both Mankweng and Pietersburg Hospitals, including medical officers, registrars, primary care paediatricians, paediatric medical subspecialists, and paediatric surgical specialists.

Radiation dose: Radiation dose is the amount of energy deposited in the form of x-rays, in a given mass of a medium by ionizing radiation, measured in Gray (Gy) in materials, or Sieverts (Sv) in biologic tissue (Dainiak, 2013). In this study, the radiation dose level is measured with reference to the dose required to take a chest radiograph.

Radiation exposure: Radiation exposure is a measure of the ionization of air due to ionizing radiation from high energy photons (x-rays and gamma rays) (IAEA., 2018). In this study, radiation exposure is a measure of ionising radiation reaching different parts of the body.

Radiation safety measures: Radiation safety measures encompass all forms of protection measures, rules, and regulations for all forms of ionizing radiation (IAEA., 2018; World Health Organization, 2016). In this study, radiation safety measures mean any method used to reduce radiation exposure to children being examined and staff who operate the radiation equipment

LIST OF ABBREVIATIONS

ALARA	:	As low as reasonably achievable
BIER	:	Biologic effects of ionizing radiation
CDC	:	Centers of disease control and prevention
CT	:	Computed tomography
DNA	:	Deoxyribonucleic acid
Gy	:	Gray
IAEA	:	International atomic energy agency
ICRP	:	International commission on radiological protection
LAR	:	Lifetime attributable risk
LBR	:	Lifetime baseline risk
MAMMO	:	Mammogram
MO	:	Medical Officer
MRI	:	Magnetic resonance imaging
NHS	:	National health services
Sv	:	Sievert
US	:	Ultrasound
USA	:	United States of America
WHO	:	World health organization

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CHAPTER ONE

1. INTRODUCTION AND BACKGROUND

1.1 INTRODUCTION AND BACKGROUND

Use of ionizing radiation in medical imaging has dramatically increased over the years (Kada, 2017). Partap and colleagues posit that in 2016, Americans were exposed to more than seven times as much ionizing radiation from medical procedures as was the case in the early 1980s (Partap, Raghunanan, White and Seepaul, 2019).

Plain radiography in everyday practice of medicine has become standard in many institutions worldwide. In England, statisticians who investigated the use of radiological imaging in a particular year found that 41.3 million studies were done, of which the most common were plain radiography (53%), followed by ultrasound [US] (22, 5%) and computed tomography [CT] (12%). The less common ones were magnetic resonance imaging [MRI] (8%), fluoroscopy (2.4%) and nuclear medicine studies (0.9%) (National Health Services England, 2017). All these studies use ionizing radiation to generate images except ultrasound and MRI that use sound waves, and magnetic fields and radio waves, respectively.

In a study by Mettler, Thomadsen, Bhargavan, Gilley, Gray, Lipoti, McCrohan, Yoshizumi and Mahesh (2008), CT examinations accounted for 15% of the total procedures done in radiology in almost 25 years contributing to a significant portion of the collective radiation dose due to medical use. A CT scan is one of the radiological diagnostic tools that uses ionizing radiation. In recent years, it has gained favour with the referring doctors due to a more accurate diagnostic capability and short acquisition time. Primary care physicians and paediatric emergency medicine physicians also rely on CT scans for quicker diagnostic evaluation of children in the emergency department. Many hospitals have CT scanners near emergency departments to facilitate quick access (Frush, 2014).

There has been an escalating use of CT for diagnostic investigations as compared to other modalities (Boone, Hendee, McNitt-Gray and Seltzer, 2012; Tamm, Rong, Cody, Ernst, Fitzgerald and Kundra, 2011; Faggioni, Paolicchi, Bastiani, Guido and Caramella, 2017). A marked demand for CT scans in South Africa has also been reported whereby the number of scans performed in a regional hospital in the Western Cape province almost doubled within a 2-year period from 2011 to 2013 (Becker, Jenkins, De Swardt, Sayed and Viljoen, 2014). However, CT scan use was shown to contribute approximately three quarters of all medically acquired radiation dose (Tamm *et al.*, 2011). This has led to an increased radiation dose exposure to patients and staff (Partap *et al.,* 2019).

Low-dose Ionizing radiation, as with CT scans, is carcinogenic. It harbours the potential risk of contributing to developing cancer in future (Smith-Bindman, Lipson, Marcus, Kim, Mahesh, Gould, De González and Miglioretti 2009; Algohani, Aldahhasi and Algarni, 2018). In paediatric patients, the risk is much higher as compared to adults due to their rapid growth and a larger exposed area compared to their body surface area in each examination (Tepper, 2008). Children are particularly more vulnerable to the effects of ionizing radiation (Sidhu, Strauss, Connolly, Yoshizumi, Racadio, Coley, Utley and Goske, 2010). Children's cells have a high mitotic rate and a long "dividing" future, which are mostly of unspecialized cell type, making them more vulnerable to effects of radiation. A small surface area in a child predisposes to a larger exposed area during radiological examinations, when compared to adults.

Medical imaging, with reference to conventional radiography and CT imaging, plays an increasing role in the accurate diagnosis and treatment of many medical conditions in the paediatric population. The speed of acquiring images, accuracy in determining pathology, as well as non-invasiveness of medical imaging have also contributed to the exponential rise in the number of imaging procedures among paediatric patients. Moreover, multidetector computer tomogram (MDCT) has shown increased image quality in short acquisition time, but with increased radiation dose (Heyer, Hansmann, Peters and Lemburg, 2010).

Children with complex health conditions, such as neoplastic and congenital cardiac diseases may be exposed to relatively high cumulative burden of ionizing radiation from medical imaging procedures, like the CT scan for both diagnosis and re-evaluation of their conditions (Hill, Frush, Han, Abbott, Armstrong, DeKemp, Glatz, Greenberg, Herbert, Justino and Mah, 2017). Even though the imaging is necessary and essential to their care, exposing them to a high cumulative radiation dose is associated with potential risks, including an increased lifetime attributable risk of cancer (Hill *et al*., 2017; Sidhu *et al.*, 2010).

Surveys investigating the awareness of radiation exposure and safety amongst health professionals of different disciplines have been conducted in different countries. With the knowledge of the effects of ionizing radiation on human bodies, different researchers worldwide have tried to establish the level of knowledge of ionizing radiation among doctors from different disciplines. The focus of their inquiry has been to assess how different categories of professionals perceive ionizing radiation and how they implement such knowledge to protect themselves and their patients from its adverse effects. Most of the researchers found that there was insufficient knowledge on the consequences of ionizing radiation exposure, radiation doses and radiation safety measures among selected groups of health professionals. The other important finding is that most health professionals had not undergone any training on radiation safety and radiation doses used by commonly diagnostic modalities to produce images (Saeed, Al-shaari, Almarzooq, Alsareii, Aljerdah and Al-ayed, 2018).

Knowledge on the principle of As Low as Reasonably Achievable (ALARA) in medical use of radiation was generally poor among the health professionals (Wildman-Tobriner, Parente and Maxfield, 2017; Wildman-Tobriner, Parente and Maxfield, 2017). For instance, more than half of the participants in some studies underestimated CT effective doses of examinations (Mettler, Thomadsen, Bhargavan, Gilley, Gray, Lipoti, McCrohan, Yoshizumi and Mahesh, 2008; Heyer *et al*., 2010). A significant number of respondents in some studies were not aware that ultrasound and MRI do not use ionizing radiation in acquiring images (Thomas, Parnell-Parmley, Haidar, Moineddin, Charkot, BenDavid and Krajewski, 2006; Heyer *et al*., 2010; Wildman-Tobriner, Parente and Maxfield, 2017; 8).

Evaluation of knowledge of radiation safety among health professionals from different disciplines in South Africa, such as orthopaedic surgeons, interventional radiologists, cardiologists, anaesthetists, theatre nurses, and radiographers have been performed. The results mostly reveal inadequate knowledge of radiation protection skills and inadequate use of radiation safety measures while using ionizing radiation for diagnosis and treatment of clinical conditions (Rose and Rae, 2017; Rose , Ubel and

Rae, 2018; Moolman, Mulla and Mdletshe, 2019; Dauda, Ozoh and Towobola, 2019; van Papendorp, Suleman and Hanekom, 2020; Thambura and Ikiara, 2020).

However, none of these studies were conducted among paediatric doctors, or in Limpopo. The researcher could not find any literature on studies that have specifically assessed the knowledge of radiation safety among paediatric doctors in Limpopo, South Africa, even though they treat patients who are exceptionally vulnerable to the long-term effects of ionizing radiation.

This study endeavours to assess the knowledge of radiation safety and radiation doses among paediatric doctors in Mankweng and Pietersburg Hospitals, situated in Limpopo province. The outcome of this study would be useful in identifying any knowledge gaps that can be remedied, thus ensuring safe use of modalities that require ionizing radiation in the scope of practice of paediatric doctors. Application of such knowledge could result in a reduction of inappropriate exposure of children to ionizing radiation from medical imaging.

1.2 RESEARCH PROBLEM

1.2.1 Source and background of the problem

Use of ionizing radiation in medical imaging has increased through the years (Kada, 2017). Ionizing radiation has considerable adverse effects on dividing cells. This is particularly true in case of paediatric patients, where most of their critical organs are made up of an unspecialized cell type with a high mitotic rate, which make them more vulnerable to radiation effects. However, there is still a growing demand for medical imaging, which uses ionizing radiation in recent years in both adults and children. It is important that the use of ionizing radiation for medical intent be thoroughly scrutinised by the referring doctors to make sure that only necessary imaging is done. Therefore, adequate knowledge about ionizing radiation, its side effects, and radiation safety measures amongst referring paediatric doctors is crucial. Lack of such knowledge may lead to inappropriate use of radiological studies for medical intent, leading to serious consequences, such as development of infertility and cancer in later life of an exposed individual, as well as mutations and foetal abnormalities in the community. This study aims to evaluate the knowledge of proper use of ionizing radiation among the doctors who take care of the paediatric age group with the purpose of introducing and/or re-enforcing necessary remedial actions to help improve knowledge and prevent adverse effects of radiation on the patients.

1.2.2 Statement of the research problem

Globally the use of ionizing radiation has increased. Health care providers using radiology services are obliged to have adequate knowledge on ionizing radiation used to provide optimum service to the patients. There are different modalities in the radiology departments at Pietersburg and Mankweng Hospitals that use ionizing radiation, such as conventional radiography, fluoroscopy, and CT, which are useful in the diagnoses and treatment of children. It is therefore important that the referring paediatric doctors possess adequate knowledge of the requested examinations and how they are performed, to give an explanation to the patients, and determine the appropriateness of such examination. This research seeks to assess the level of knowledge of paediatric doctors on ionizing radiation and its safety to determine if any knowledge gaps exist that can be remedied.

1.3 PURPOSE OF THE STUDY

1.3.1 Research aim

To investigate the knowledge of radiation safety and radiation doses among paediatric doctors in Pietersburg and Mankweng Hospitals, Limpopo province, South Africa.

1.3.2 Objectives

- To assess the knowledge of radiation doses of radiological procedures and its associated risks in relation to diagnostic imaging examinations amongst paediatric doctors.
- To assess the knowledge of radiation safety measures among paediatric doctors.

1.4 RESEARCH QUESTION

What is the knowledge of radiation safety, and radiation doses (used by diagnostic equipment during radiological procedures) amongst paediatric doctors at Pietersburg and Mankweng Hospitals, Limpopo province, South Africa?

1.5 RESEARCH METHODOLOGY

1.5.1 Research design

A survey is used as the study design for this research.

1.5.2. Sampling

A total population convenience purposive sampling method is used.

1.5.3 Data collection

A questionnaire is used as a data collection tool. Data were collected in the month of May 2021.

1.5.4 Data analysis

Data analysis is done using Statistical Package for Social Sciences (SSPS) version 26.0 statistical software. A variety of statistical analyses are applied to the data, including cross-tabulations and analysis of variance (ANOVA) to test the difference between the gender groups, age groups, and level of experience.

A Chi-square test is used to determine whether or not a significant relationship existed between knowledge on radiation safety and radiation doses, and the participants' demographic characteristics. Statistical confidence is reported on a 95% confidence interval. The significance level, with p-value <0.05, is used as a guideline to determine the significant relationships between variables.

1.5.5 Reliability, Validity and Objectivity

A previously validated questionnaire, used in similar studies (Paolicchi F et al, 2015; Partap *et al*., 2019) is adapted and used in the present study. The validity of the original questionnaire, based on its content validity index and face validity, is acceptable.

The reliability of the source questionnaire is also acceptable. In the present study, reliability is enhanced by issuing the questionnaire at the time of data collection in a monitored environment. The responses are collected immediately after completion of the questionnaire.

1.5.6 Bias

Bias is reduced by truthfully reporting the responses of the participants, as they appeared on answer sheets.

1.6 ETHICAL CONSIDERATIONS

Ethical clearance to conduct the present study was obtained from Turfloop Research and Ethics Committee (TREC), with the project number: TREC/31/2021: PG. (Annexure V). Permission from the Limpopo provincial Department of Health was obtained from the research office with reference number: PMREC 21APRIL UL2021/A. (Annexure VI). Permission was also granted by the Clinical Executive Director of Pietersburg Hospital (Annexure VII) for both Pietersburg and Mankweng Hospitals, and the clinical heads of paediatrics department, paediatric surgery departments, and diagnostic radiology (Annexure VII, IX and X, respectively).

1.7 SIGNIFICANCE OF PROPOSED RESEARCH

The results of this study suggest that knowledge on radiation safety and radiation doses among paediatric doctors is poor. It reveals that the knowledge of paediatric doctors on radiation optimisation as well as on modalities that do not utilize ionizing radiation is poor. Most of the participants agreed that there is need for training on radiation safety and radiation doses. This information will assist in drafting policies and guidelines on the basic knowledge on radiation safety and radiation doses required amongst paediatric doctors.

1.8 CONCLUSION

The most significant finding of this study is that paediatric doctors demonstrated poor knowledge on radiation protection and radiation doses, with a mean score of 2.9 out of 16. Only 10 (21.2%) of participants scored overall mark of more than 50%. Among the 10 respondents who demonstrated sufficient knowledge, there were 3(30%) consultants, 3(30%) registrars, 2(20%) medical officers, and 2(20%) medical officer interns.

1.9 OUTLINE OF THE DISSERTATION

This dissertation consists of five chapters. The first chapter outlines the purpose of the study. It gives a background and the motive behind the research topic. It further relays the research problem, the aim, objectives, and the approach to the study. Chapter 2 provides a context for the research by reviewing relevant literature that supports the importance of learning about ionizing radiation safety and radiation doses. It further deliberates on the side effects of ionizing radiation, cumulative dose of radiation one could be exposed to in terms of background radiation and ionizing radiation from medical intent. It further reviews some articles that discussed the relationship of ionizing radiation and paediatric patients. Publications that assessed paediatric doctors' knowledge on radiation safety and radiation doses are also reviewed in this chapter. Chapter 3 discusses the research methodology, which outlines the design, research setting, the participants, method, data collection and analysis, and reliability and validity of the study. Ethical considerations are also discussed in this chapter. Chapter 4 presents results from the study. These are presented based on the objectives of the study. In chapter 5, the findings of the study are discussed relative to the stated objectives. The findings are also interrogated against the existing literature reports. Chapter 6 gives the conclusion of the study and the recommendations thereof.

CHAPTER TWO

2. LITERATURE REVIEW

2.1 INTRODUCTION

In this chapter, a review of the relevant literature is done, with consideration to the research question and objectives of the study.

2.2 USE OF IONIZING RADIATION FOR MEDICAL IMAGING

The use of ionizing radiation for medical imaging has shown a dramatic increase on the entire globe (Brenner and Hall, 2007; Kada, 2017). Ionizing radiation is encountered in conventional radiography, CT, fluoroscopy, interventional radiology and in nuclear medicine. CT has become one of the most utilised diagnostic tools in recent years (Boone *et al*., 2012; Mayo-Smith, Hara, Mahesh, Sahani and Pavlicek, 2014; Tamm *et al*., 2011; Brenner and Hall, 2007).

Approximately one third of CT scans done in USA were reported to be unjustified by the medical needs. In South Africa, a study conducted by Becker *et al.*, (2014) in two Western Cape provincial hospitals found that the use of CT scan almost doubled over a 2-year period from 2011 to 2013. They also observe that overall, 6.4% of the CT scans requested were inappropriate and could have been avoided (Becker *et al*., 2014). Another South African study conducted in Pietermaritzburg, KwaZulu Natal, also observe a larger increase in the use of CT scan, mainly due to traumatic injuries sustained by the patients attending an emergency department (Bashir, Kong, Weale, Bruce, Laing, Bekker and Clarke, 2019).

The exponential growth in CT examinations has also been observed among paediatric patients. Brenner and Hall (2007) deduce that the largest increase in use of CT in USA was in the paediatric population. In approximately 62 million CT scan examinations in a year in USA, 4 million were done in the paediatric population (Brenner and Hall, 2007). Some of the factors attributed to the rapid increase in number of CT scans in paediatrics include the shorter data acquisition time, reduction in motion artefacts, greater coverage, and improved sharpness of images (Heyer *et al*., 2010; Frush, 2014). Additionally, there is no need for sedation of paediatric patients during CT examination as the scans take relatively short time to acquire. Elimination of the need for sedation and its associated risks, such as respiratory depression and drug interaction, without loss of image quality adds to the favour of CT in the emergency room for diagnostic purposes (Heyer *et al*., 2010). The acquired CT datasets can be reconstructed into any desired axis and dimensions (Heyer et al., 2010; Frush, 2014), such as axial, coronal, or sagittal sections for a better appreciation of the pathology. Primary care physicians and paediatric emergency medicine physicians rely on CT for quicker diagnostic evaluation of children in the emergency department. For these reasons, many hospitals have CT scanners near emergency departments to facilitate quick access to CT facilities (Frush, 2014).

The World Health Organization (WHO, 2016) communicated the risk of uncontrolled irradiation of paediatrics for medical intent and developed a method of determining the effective doses for diagnostic imaging examinations. This method compared the effective dose of each diagnostic imaging examination to its equivalent in terms of number of chest x-rays, and the duration of exposure to natural background radiation (Annexure 1). It should be noted that among all the radiological modalities available, MRI and US are the only ones that do not use ionizing radiation. US uses sound waves. Some of its advantages, besides not emitting ionizing radiation are that it is capable of acquiring cross-sectional images, it is less expensive, it is readily available, it can give physiological data (as in doppler studies of vessels), and it can also give real time images. However, its main disadvantages are that it is operator dependent, and the image quality can sometimes be challenging to interpret or understand by inexperienced doctors. Another disadvantage is that it cannot evaluate structures surrounded by bone or air, as they have poor sound conduction. MRI, on the other hand, uses electromagnetic and radio waves and does not emit ionizing radiation (Littlefield and Thorley, 1979). The advantage of MRI is that it gives cross-sectional images with good contrast and resolution. Additionally, functional dynamic imaging can be acquired on MRI. The disadvantages of MRI are that it is expensive; takes a longer time to complete; and paediatric patients require sedation as the study takes long. Ultrasound is the modality of choice in paediatric patients and pregnant women (Brink and Amis, 2012).

2.3 ACUTE AND CHRONIC ADVERSE EFFECTS OF IONIZING RADIATION

2.3.1 Effect of ionizing radiation at cellular level

When Ionizing radiation collides with a biological system, it imparts its energy to the organic macromolecules, sufficient to overcome the binding energy of the electrons in its atoms and molecules to form ionized free radicals capable of interacting with other molecules. Over 80 percent of the body cells are composed of water, so ionizing radiation in humans interacts with water molecules. This interaction creates hydroxyl radicals:

$$H_2O \rightarrow H_2O^+ + e^-$$

The ion radical (H_2O^+), further reacts with another water molecule to form a highly reactive hydroxyl radical (OH·):

$$H_2O^+ + H_20 \rightarrow H_30^+ + OH\cdot$$

The free radical is capable of chemical reactions and interacts with deoxyribonucleic acid (DNA) moiety in the cell to cause DNA strands' breaks or base damage, which eventually lead to the biologic effect (Figure 1).

Incident ionizing radiation

↓

Fast electrons (e-)

↓

Ion radical

↓

Free radical

↓

Chemical changes from the breakage of bonds

↓

Biologic effect

Figure 2.1. Schematic diagram of the effect of ionizing radiation on a biological cell

Ionizing radiation can also ionize DNA directly to cause DNA strand breakage. Most radiation-induced DNA damage is rapidly repaired by various systems within the cells. However, DNA double-strand breaks are not easily repaired, and this factor of poor repair or anomalous repair can lead to induction of point mutations, chromosome translocations, and gene fusions, all of which are linked to the induction of cancer (Brenner and Hall, 2007).

2.3.2 Deterministic and stochastic effect of ionizing radiation

Effects of ionizing radiation on tissues are characterized as deterministic or stochastic. Deterministic effects of ionising radiation (also referred to as tissue reactions) are related directly to the absorbed radiation dose. The severity of the effect increases as the dose increases. According to International Commission on Radiation Protection's (ICRP) publication 103 (ICRP, 2007), the threshold for deterministic effects following pre- and post-natal exposure is proposed to be >100 mGy. Radiation-induced malformations in a developing foetus are considered by ICRP (ICRP, 2007) to have a dose-threshold of >100 mGy. Two examples of deterministic effects are radiation burns and acute radiation syndrome. Lens opacities induced by ionising radiation have traditionally been regarded as a deterministic effect with a threshold exceeding 1 Gy (Scientific Committee on Emerging and Newly Identified Health Risks [SCENIHR] and Scientific Committee on Emerging and Newly Identified Health Risks _SCENIHR, 2012).

Stochastic effects are chance effects, with the probability of the effect increasing as the dose increases. However, the severity of the effect is independent of the dose received. Stochastic effects are assumed to have no threshold level. Examples of stochastic effects are foetal anomalies in pregnant women, development of cancer, and development of genetic mutation (Mynalli *et al.*, 2017; Yunus, Abdullah, Said and Ch'ng, 2014). Primarily, cancer risk and hereditary disorders are examples of stochastic effects (Scientific Committee on Emerging and Newly Identified Health Risks [SCENIHR] and Scientific Committee on Emerging and Newly Identified Health Risks _SCENIHR, 2012). It is believed that there is a linear non-threshold relationship between the dose of ionizing radiation and cancer risk. Based on this relationship, the probability of developing cancer is presumed to increase with the radiation dose even for low dose radiation (Little, Wakeford, Tawny, Bouffler and Berrington de Gonzalez, 2009; Dainiak, 2013; WHO, 2016).

The lifetime risk of developing or dying from cancer refers to the chance a person has, over the course of his or her lifetime (from birth to death), of being diagnosed with or dying from cancer. The lifetime risk depends on the gender, the type of cancer, and the environmental risk factors. The accelerated incidence of cancer risk attributable to radiation exposure is known as lifetime attributable risk (LAR). The estimated lifetime cancer mortality risk attributable to radiation exposure from one CT scan examination in a one-year-old was estimated to be 0.07 – 0.18%. This estimation leads to approximately 500 deaths attributable to cancer caused by CT radiation in a group of 600 000 abdominal and head CT examinations performed annually in USA (Brenner, Elliston, Hall, and Berdon, 2001; Heyer *et al*., 2010). The LAR is an age- and sex-dependent risk quantity calculated by using the risk model derived from epidemiologic studies (WHO, 2016). From this deduction, female infants may show a higher lifetime attributable risk than their male counterparts, and older children (WHO, 2016).

2.4 BACKGROUND RADIATION

The annual background radiation dose differs in different countries; however, the average global exposure to natural radiation is 2.4 mSv per year (Herbst, 2017). In South Africa, the annual background radiation dose is 0.07 mSv per year (Bezuidenhout, 2014). The ICRP recommends that for occupational exposure, 20 mSv per year averaged over 5 years (100mSv in 5 years) is the maximum permissible dose, of which the maximum dose per year is 50 mSv. The International Atomic Energy Agency (IAEA) and the United States of America Center of Disease Control and Prevention (CDC), recommend an acceptable background radiation dose of 0.1 mSv per year, for members of the public (IAEA., 2018). Approximately 88% of background radiation comes from natural sources and only 12% is from artificial sources (World Nuclear Association, 2021; IAEA, 2018).

Different sources of background radiation have been documented on earth. Humans absorb cosmic radiation daily from the sun and other celestial events in the universe.

Terrestrial radiation originates from the composition of the earth's crust, which is a major source of natural radiation. The main contributors are natural deposits of uranium, potassium, and thorium, which, in the process of natural decay, release small amounts of ionizing radiation. Uranium and thorium are found essentially everywhere. These minerals are also found in building materials, which exposes people to natural radiation indoors and outdoors (Pacelli, 1957).

Radioactive gases produced by radioactive minerals found in soil and bedrock result in inhaled natural background radiation. Examples are radon and thoron (Pacelli, 1957). Another source of accumulating background radiation is food planted in soil that is contaminated with radioactive material. When ingested, trace amounts of radioactive minerals are also ingested along with the food (World Health Organization, 2016; Pacelli, 1957).

Low doses of ionizing radiation acquired as natural background radiation are very hard to determine because several factors can mask or distort its effect. Background radiation forms an additional burden to patients due to its nature and the inability to control it. These warrant stringent measures in ionizing radiation exposure from medical intent that can be regulated and monitored.

2.5 AWARENESS OF IONIZING RADIATION EXPOSURE

Several organizations have developed strategies of reducing and controlling radiation exposure. International bodies such as the International Commission of Radiological Protection (IRCP), World Health Organization (WHO) and International Atomic Energy Agency (IAEA) have developed and adopted strategies of radiation protection in view of the side effects that low and high doses can have on patients (Mynalli *et al*., 2017). The ALARA principles have been adopted internationally to keep radiation doses from controlled sources as low as reasonably achievable. Many campaign strategies have been established to increase awareness and decrease radiation exposure. In 2001, the concept of imaging with radiation dose as low as reasonably achievable or practicable (ALARA principle) was established (IAEA., 2018). It is based on three major safety principles of time, distance and shielding, explained below (Kim, 2018a).

- Time: the time of exposure must be kept as short as possible to reduce absorbed radiation dose. Absorbed radiation dose is proportional to the time it is exposed.
- Distance: radiation exposure is inversely proportional to the square of the distance from the source of radiation. That is, if the distance from ionizing radiation source is doubled, the radiation exposure is reduced to ¼.
- Shielding: devices such as lead caps, lead glasses, thyroid protectors, lead aprons, and lead gloves, may be used to reduce exposure during procedures (Kim, 2018a).

Information campaigns such as "Image Gently" and "Image Wisely" were also established to devise ways to reduce medical radiation exposure in paediatric patients and adults respectively (Brink and Amis, 2012).

One of the goals of Image gently is to raise all stakeholders' awareness about the three key principles of radiation protection: Justification, optimisation, and dose limit. Justification requires that the benefits of exposure to radiation should outweigh the risks of each radiological study. The process of optimisation entails the following:

- establishment of quality assurance programme,
- establishment of dose optimization team that is composed of a medical physicist, radiologist and radiation technologist,
- determination of baseline dose levels and image quality,
- modification of protocols by medical physicist and
- evaluation of optimization process and its effect on patient dose and image quality (Tsapaki, 2020).

The dose limit principle is similar to the principle of ALARA, whereby radiation dose is kept as low as reasonably achievable for each individual examination. These principles are based on the International Council on Radiological Protection guidelines (IAEA., 2018; Kim, 2018b). The International Council on Radiological Protection (ICRP) is an independent, international, non-governmental organization, with the mission to protect people, animals, and the environment from the harmful effects of ionising radiation (IAEA, 2018).

The Image Gently campaign developed educational information for each ionizing radiation modality (CT, fluoroscopy, radiography, nuclear medicine, interventional radiology and dental imaging) for children. Each educational module provides information for all stakeholders involved in paediatric diagnostic imaging, which includes the radiologists, medical physicists and technologists, the referring healthcare providers, patients, parents, and caregivers (IAEA., 2018). The Image Gently Alliance is a combination of different health care organizations dedicated to providing safe, high quality paediatric imaging worldwide. The primary objective of the alliance is to raise awareness in the imaging community of the need to adjust the radiation dose when imaging children. The ultimate goal of the alliance is to change practice by raising awareness of the opportunities to lower radiation dose in the imaging of children (IAEA., 2018).

2.6 RADIATION SAFETY IN CHILDREN

2.6.1 Risk of developing radiation effects

Evidence reveals that children are more sensitive to ionizing radiation as compared to adults and the chance of carcinogenesis is high due to anticipated longer time period from the time of exposure to the end of their life (Tamm *et al*., 2011; Mayo-Smith *et al*., 2014). Furthermore, younger children have significant proportion of tissues with an unspecialized cell type which are still undergoing cell division, making them more vulnerable to radiation effects. Ionizing radiation causes damage to the DNA structure, and even though the body may try to repair the DNA damage, failure of precise repair can lead to chromosomal abnormalities resulting in gene mutation, cell death or carcinogenesis (Sidhu *et al*., 2010). Children have a longer life ahead of them compared to adults and thus potentially have a longer time to manifest radiation effects such as increased risk of developing cancers.

2.6.2 Risk of multiple radiologic procedures

Children diagnosed with complex diseases, such as neoplastic disease, are at a high risk of being exposed to a relatively high cumulative burden of ionizing radiation from medical imaging procedures, including multiple computed tomography, nuclear medicine studies, and fluoroscopically guided diagnostic and interventional catheterization procedures. Although these imaging procedures are all essential to the care of these children and contribute to meaningfully improved outcomes, exposure to ionizing radiation is associated with potential risks, including an increased lifetime attributable risk of cancer (Hill *et al*., 2017). Children with certain diseases associated with certain chromosomal deletions, are also more vulnerable to radiation induced carcinogenesis. The conditions include ataxia-telangiectasia, Fanconi's anaemia, hereditary retinoblastoma, basal cell nevus, Bloom's syndrome, Cockayne's syndrome, Down's syndrome, Gardner's syndrome, Nijmegan breakage and Usher's syndrome (Sidhu *et al*., 2010).

2.7 KNOWLEDGE OF RADIATION DOSE LEVELS AND SAFETY

2.7.1 Knowledge of radiation dose levels and safety among paediatricians

Singh, McCourie, Burnley and Miles (2008) conducted a study to obtain a consensus on competency-based topics in radiation protection that a United Kingdom medical student should know by the time of their graduation from medical school. The 69-member panel of experts, including 48 radiologists and 21 clinicians who participated in this study unanimously agree that by the time they graduate, medical students should possess good knowledge of radiation doses and risks, and be competent in the ways to reduce the radiation dose to patients and staff (Singh *et al*., 2008).

Thomas *et al*., (2006), used a questionnaire to assess the awareness of ionizing radiation dose amongst paediatricians. In this study, the effective dose of a postero-anterior (PA) view chest radiograph (CXR) on a 5-year-old child (0.006 mSv) was considered as one unit, and paediatricians were asked to estimate the relative effective dose of selected investigations in terms of CXR-equivalent units. The results of this study found that there is underestimation of radiation doses of CT and fluoroscopic examinations in relation to CXR amongst paediatricians. More than 70% of paediatricians underestimated the radiation dose in the majority of questions in the questionnaire. Only 15% of the respondents were familiar with the ALARA principles regarding radiation doses in medical imaging. Nineteen percent (19%) of the participants responded with “I don't know” option, whereas 59% overestimated the radiation dose. Approximately 12% of respondents underestimated the background radiation dose.

A study that evaluated the knowledge about radiation doses and its effects among paediatricians in Germany reports that 56% participants underestimated most of the CT studies in children. However, what is positive in the German study is that most of the paediatricians (86%) correctly identified MRI as a modality that does not utilise ionizing radiation to generate images (Heyer *et al*., 2010).

In another study by Wildman-Tobriner *et al*., (2017) conducted in North Carolina, USA, almost 100% of paediatricians interviewed correctly identified that ultrasound does not use ionizing radiation, and more than 90% of them knew that MRI is an ionizing radiation-free radiological modality. However, in a study by Heyer *et al*. (2010) in Bochum, Germany, 14% of paediatricians who participated stated that MRI uses ionizing radiation. Another study conducted in Egypt among diverse category of physicians including radiologists, oncologists, surgeons, and orthopaedic surgeons, approximately 35% and 72%, respectively, knew that MRI and ultrasound are non-ionizing radiations modalities. The study also reveals that even though oncologists and radiologists are more exposed to radiation, their knowledge was just as low as for the other physicians (Abdelah et al., 2015).

A study involving interventional paediatric cardiologists and radiologists from South Africa found that the participating cardiologists had less knowledge about radiation safety than the radiologists did, with the former reporting little or no formal training in radiation safety, in addition to not observing radiation safety measures during procedures (Rose and Rae, 2017).

Two studies conducted in Italy and Egypt to compare knowledge of radiation dose and safety before and after a single workshop on radiation doses and radiation safety did not show any improvement of knowledge among the participants (Paolicchi *et al*., 2016; Algohani *et al*., 2018). The findings of these studies suggest that a once-off workshop may not be beneficial to the participants. Continuous training of all referring doctors on radiation exposure, radiation dose levels and radiation safety is of paramount importance for the benefit of patients. This should be encouraged amongst all healthcare workers regularly.

Therefore, it is vital that all healthcare personnel, especially referring paediatric doctors, have adequate knowledge on how to handle ionizing radiation, and how to implement radiation safety measures in order to reduce radiation dose exposure to their patients. Issues related to dose optimization is also necessary so that patients' welfare can be protected (Yunus, Abdullah, Said and Ch'ng, 2014; Yurt, Cavuşoğlu and Gnay 2014). Referring doctors also need to know the radiation doses involved in the radiology examinations they request to inform patients and their families on the benefits and risks of the procedures they or their children will undergo in the radiology department. Additionally, the referring doctors should possess basic knowledge on radiation protection to reassure their clients on the safety measures that will be undertaken to protect them against unnecessary ionizing radiation.

CHAPTER THREE

3. RESEARCH METHODOLOGY

3.1 INTRODUCTION

The previous chapter presented and discussed literature on the effects of ionizing radiation on body cells and the consequences of this effect on children. It also evaluated publications on the knowledge of radiation safety and doses among paediatricians, who are the main healthcare providers for the children. Although variations existed regarding the knowledge of paediatricians, most studies tend to point out that the knowledge of the majority of paediatricians was poor. The current study investigates the knowledge of paediatricians at Pietersburg and Mankweng Hospitals to assess how conversant they are with this topic.

In this chapter, how this study was conducted is described. The research design, study setting, and the study population are described. How the study participants were recruited is presented. Data collection and analysis processes, as well as the rigors in the study are also presented. Lastly, how bioethical principles were applied in the research is described.

3.2 RESEARCH DESIGN

The research design chosen for this study is a survey. A survey is a non-experimental research design that involves gathering information about prevalence, distribution, and interrelations of a phenomenon within a population, usually through direct questioning of the participants (Polit and Beck, 2017: 242). In this study, the researcher conducts a survey using a self-administered questionnaire, among paediatric doctors at Pietersburg and Mankweng Hospitals about their knowledge of radiation safety and radiation doses in children. The survey allowed the researcher to gather information about the activities of the paediatric doctors, their beliefs, preferences, and attitudes regarding radiation safety and radiation doses of radiological examinations in children.

3.3 STUDY SETTING

The current study was conducted in the two academic tertiary institutions in Limpopo Province, namely, Pietersburg Hospital and Mankweng Hospital. The two hospitals are the only tertiary institutions in Limpopo Province. Pietersburg Hospital is situated in the city of Polokwane, whereas Mankweng Hospital is situated 30 Km east of Polokwane (Figure 3.1). Limpopo Province comprises of five districts, namely Waterberg, Capricorn, Vhembe, Sekhukhune, and Mopani. Both Mankweng and Pietersburg Hospitals are located in Capricorn district. Pietersburg Hospital is pointed by the red arrow and Mankweng Hospital by the blue arrow in the map (Figure 3.1).

Limpopo Province has a population of approximately 5 85 553 people, making up 9.9% of total population of South Africa. About 2 374 000 of them are children (Hall and Sambu, 2018). The two tertiary hospitals render medical services for the whole province with 43 district hospitals dependent on them.

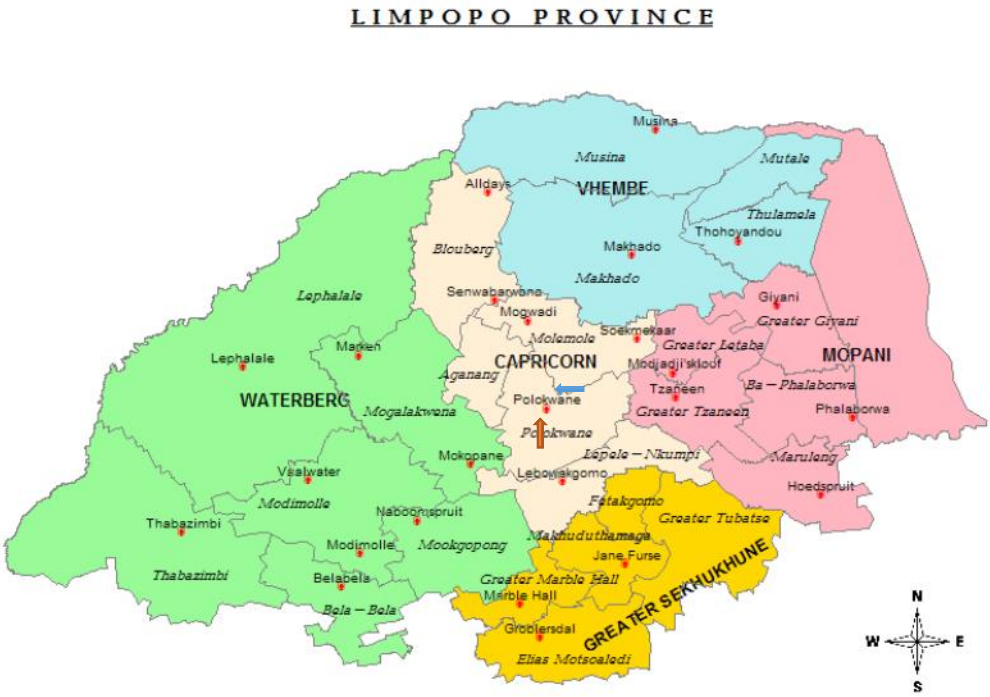

Figure 3.1 Map of Limpopo showing the study sites. Red arrow (Pietersburg Hospital). Blue arrow (Mankweng Hospital).

Pietersburg Hospital has four paediatric wards (medical, surgical, paediatric ICU, and paediatric oncology ward) with 108 beds. Mankweng Hospital has two paediatric wards, one general ward that has medical and surgical wings and paediatric ICU with specialized neonatology unit. The general ward has 49 beds. There is also a special neonatal unit with 66 beds.

3.4 SAMPLING

3.4.1 Study population

A population is the entire aggregation of cases in which a researcher is interested (Polit and Beck, 2017:249). In this study, the population comprised of 52 paediatric doctors including consultants, registrars, medical officers, and medical officer interns, between the two hospitals.

3.4.2 Sampling method

Sampling is the process of selecting cases to represent an entire population, to permit inferences about the population (Polit and Beck, 2017:250). A sample is a sub-set of population elements, which are the most basic units about which data are collected (Polit and Beck, 2017:250). This study used a consecutive sampling method. Consecutive sampling involves recruiting all of the people from an accessible population who meet the eligibility criteria over a specific period of interval, or for a specified sample size (Polit and Beck, 2017:250). All the paediatric doctors, including paediatric surgery doctors were eligible for inclusion in the study.

3.4.3 Inclusion criteria

All paediatric doctors employed by the Limpopo Department of Health in the 2 hospitals, who gave consent, and were present on the date of the interview were included in the study.

3.4.4 Exclusion criteria

Any paediatric doctor who did not give consent to participate in the study, or was not on duty on the day the questionnaires were distributed, was excluded.

Paediatric doctors or paediatric surgeons not employed by the state were also excluded.

3.4.5 Sample size

All the doctors who satisfied the inclusion criteria and gave consent were included in the study and formed the sample. The sample size was made up of the 47 paediatric doctors and paediatric surgery doctors.

3.5 DATA COLLECTION

3.5.1 The data collection tool

A self-administered questionnaire was used for data collection (Annexure IV). The questionnaire was adapted from a previous study which investigated knowledge and awareness of radiation doses and radiation safety among radiographers (Paolicchi, Miniati, Bastiani, Faggioni, Ciaramella, Creonti, Sottocornola, Dionisi and Caramella, 2016). The questionnaire was adapted to suit the paediatric doctors as the population of choice. Some questions from the original questionnaire were deleted as part of the modification, and other questions were added from a questionnaire used in another study with similar objectives (Partap *et al.*, 2019).

3.5.2 Characteristics of the data collection instrument

The questionnaire consisted of 23 multiple-choice questions that were divided into 3 categories. The first category comprised of seven questions on demographic information. The questions were on (1) gender; (2) age; (3) year of qualification as a doctor; (4) the professional level, which distinguished a consultant, registrar, medical officer, and medical officer intern; (5) years of experience at the current level, i.e., as consultant, registrar, medical officer, or medical officer intern. The sixth question required the participants to rate their knowledge on ionizing radiation and related risks.

The last question in this category asked participants if they had ever attended any training or refresher courses on radiation protection.

The second category comprised of nine questions pertaining to knowledge of radiation safety. The questions were on: (1) radiation standards; (2), susceptibility to radiation damage; (3) regulations; (4) knowledge about professionals with the higher radiation exposure risk; (5) tissues more susceptible to radiation; (6) diseases caused by radiation damage; (7) knowledge about dose optimization; (8) knowledge on radiation personal protective equipment; and (9) stakeholders who should be involved in training programmes on radiation dose and radiation safety.

The third category had seven questions about radiation doses of common imaging procedures in radiology. The first question was on the estimation of the average radiation dose of a single postero-anterior (PA) chest X-ray of an infant. The other six questions were radiation dose levels of different radiology examinations done on an infant, based on overage dose of PA chest X-ray that was considered as a common reference unit (1 Unit). Participants were required to estimate the following radiation doses in terms of a single PA chest X-ray dose: (2) natural background radiation accumulated by general public per year in South Africa; (3) abdominal X-ray examination of an infant; (4) non-contrast chest CT examination; (5) non-contrast brain CT examination; (6) MRI pelvic examination; (7) abdominal ultrasound examination. Question 6 and 7 were for modalities that do not use ionizing radiation.

3.5.3 Data collection process

The researcher distributed the questionnaires to each participant on a morning they were holding their academic meeting to achieve a high participation rate. Data collection took place in the month of May 2021. Due to COVID-19 lockdown regulations, data collection was challenging, as only a limited number of doctors would meet in a meeting room at the same time due to room capacity restrictions. Data were therefore collected over a period of several weeks to obtain the participation of as many paediatric doctors as possible. Smaller groups of participants according to subspecialties in paediatrics (Paediatric oncology, Pulmonology, General Paediatrics, Paediatric Surgery, and Neonatology) were created and data collected separately in different venues with smaller number of doctors participating on each occasion. All the participants who consented completed the questionnaires.

A correct response was assigned one mark and an incorrect or missing response was assigned no mark. Fifty percent and above (≥ 50%) was depicted as adequate knowledge, and less than 50% was deemed poor knowledge.

3.6 DATA ANALYSIS

Data analysis was done using Statistical Package for Social Sciences (SPSS) version 26.0 statistical software. A variety of statistical analyses were applied to the data, including cross-tabulations and analysis of variance (ANOVA) to test the differences between the gender groups, age groups, and levels of experience.

The knowledge in radiation safety and radiation doses was correlated with socio-demographic variables. A Chi-square test was used to determine whether a significant relationship existed between knowledge on radiation safety and radiation doses, and participants' demographic characteristics.

Statistical confidence was reported on a 95% confidence interval. The significance level, with p-value <0.05, was used as a guideline to determine the significant relationships between variables.

Frequency and percentages were provided for the demographic characteristics (age, and gender). Descriptive summaries were provided for the radiation protection and radiation doses knowledge score. Comparisons of radiation knowledge scores between gender (male versus female), age groups, and ranks were done.

3.7 INTERNAL AND EXTERNAL VALIDITY OF THE STUDY

The validity of a data collection tool (questionnaire) refers to the ability of the data collection tool to measure what it is supposed to measure (Heale and Twycross, 2015). In this study, a previously used data collection tool (questionnaire) was used (Paolicchi *et al.*, 2015; Partap *et al*., 2019). Some of the questions were modified to suit the study population. Example of a modification is the question:

Which of the following patients are the most sensitive to ionizing radiation?

- 1-year-old male
- 1-year-old female
- 12-year-old male
- 12-year-old female
- Ionizing radiation damage risk is unrelated to patient's age and sex.

A question on mammography was replaced with radiological personal protective equipment question i.e.

The following are personal protective equipment to minimize staff exposure to ionizing radiation, except:

- Lead goggles
- Lead aprons
- Thyroid shield
- Theatre protective gown

The validity of the source questionnaire was assessed based on the content validity index and face validity. The content validity index was determined by reviewing each question for its relevance, simplicity, and clarity (Partap *et al*., 2019). The face validity of the questionnaire was determined by administering the questionnaire to 20 medical students and 4 experts in a pilot study to evaluate the clarity, understandability, and length of each question (Partap *et al*., 2019). The internal consistency validity calculated using Cronbach's α was 0.83.(Partap *et al.*, 2019, Paloicchi *et al.*, 2015).

In the present study, further content validity was done by giving the questionnaire to five experts who evaluated for clarity and understandability of questions. From the process of validation, question 6 (below) of radiation knowledge answer was changed to "All answers are correct" instead of "leukaemia" because all the diseases mentioned can result from ionizing radiation exposure and may occur in the paediatric population.

Which of the following diseases may be a result of ionizing radiation damage?

- Dermatitis
- Leukaemia
- Alopecia
- Cataract
- All answers are correct

Data were collected on same day the questionnaire was handed to each participant. This was done on separate departmental, or subspecialty meeting days to facilitate social distancing as already explained.

Reliability in a quantitative study refers to the degree to which the measuring tool can be relied upon to produce consistent results if used repeatedly over time on the same person, or if used by different researchers (Brink, Van der Walt and Van Rensburg, 2006). In this study, the reliability was enhanced by ensuring that the questions were clear, and every step of conducting this research has been explained clearly. Secondly, reliability was maintained by issuing the questionnaire at the time of data collection in a monitored environment. The questionnaires were collected immediately after completion.

A slot in their categorical academic meetings, in the venue of the participants' choice, was utilised as a conducive environment for the paediatric doctors to complete the questionnaire without external factor considerations. The heads of respective departments on the date and time of data collection alerted the doctors.

Another challenge to the reliability could arise from the familiarity of participants with the questionnaire that might lead to group response instead of individual responses. The participants were requested to complete the questionnaire individually without discussing it with their colleagues. This was to avoid bias in the outcomes. The researcher was present in each meeting to oversee that the questionnaires were completed individually without consultation among the participants.

3.8 BIAS

Bias is defined as strong feeling in favour of or against one group of people, or one side in an argument, often not based on fair judgement (Brink *et al*., 2006). In this study, bias was reduced by truthfully reporting the response of the participants, as they appear on the response sheets. Bias could not be eliminated, as there was 9.6% of the total population that did not take part in the study.

Additionally, questionnaire bias could have resulted from an unanticipated communication barrier between the researcher and the participants (Choi, and Pak, 2005). Such miscommunication could cause inaccuracy in results. In this study, the questionnaire bias was reduced by explaining the requirements of the questionnaire and giving a brief explanation of the three different categories in the questionnaire. Any misunderstanding was clarified before a data collection session.

3.9 ETHICAL CONSIDERATIONS AND ETHICAL CLEARANCE

Ethics clearance to conduct this research was granted by Turfloop Research and Ethics Committee (TREC), with the project number: TREC/31/2021: PG. (Annexure V). Permission from the Limpopo provincial Department of Health was obtained from the research office with reference number: PMREC 21APRIL UL2021/A (Annexure VI). Permission was also granted by the Clinical Executive Director of Pietersburg Hospital (Annexure VII) for both Pietersburg and Mankweng Hospitals, and from the heads of paediatric department, paediatric surgery , and radiology (Annexure VIII, IX and X, respectively).

3.9.1 Informed consent

Before the administration of the questionnaire, the participants were informed verbally and in writing that they had the right to voluntary consent or to decline to participate and to withdraw participation at any time without any penalty. This was done to ensure self-determination and autonomy. Autonomy is related to freedom of choice and corresponds to the ability of an individual to decide for themselves based on the alternatives presented to them, with no fear of internal and external pressures (Brink *et al*., 2006). It is deliberated self-rule and the tendency to make decisions and act on them in freedom (MacPherson, 1989). The purpose of the study was explained to every potential participant before participation. Participation was from understanding of the purpose of the study and full willingness from the potential participants.

Participation in the study was free and voluntary. The participants were given an information leaflet with contact details of the researcher to explain the purpose of the study (Annexure II). Participants who were unwilling to participate in the study were free to do so without fear of victimisation of any kind. Those who agreed to participate were given the written consent form to complete (Annexure III). The consent form and the questionnaire were separated immediately after completion to ensure confidentiality.

3.9.2 Protecting rights of participants and the institution including autonomy

Data collection was scheduled in such a way that it did not interfere with service delivery in both institutions.

3.9.3 Confidentiality

It is the duty of the researcher to keep participants’ responses confidential in all stages of research, from recruitment, through data collection, data analysis, dissemination of the findings, storage and retention of information, to the disposal of records or devices on which information is stored (Thompson, Clary, Costanzo, Knazook, Rochlin, Tayler, Fry, Ripp, Szigeti, Zhang and Reka, 2020). In this study, all steps of the research were well communicated with the participants from the time of the acceptance letter to participate in the research was received. Confidentiality was enhanced by protecting the electronic information obtained by password and storing on a hard copy of information in a locked cabinet accessible only to the researcher, the supervisor and any authorized persons only.

CHAPTER FOUR

4. RESULTS

4.1 INTRODUCTION

In this chapter, the findings of the study are presented with the following under consideration:

- Characteristics of the participants
- Participants' knowledge on radiation safety
- Participants' knowledge on radiation doses
- Conclusion

4.2 DATA MANAGEMENT AND ANALYSIS

The aim of this study is to evaluate the knowledge of radiation safety and radiation doses among paediatric doctors in Pietersburg and Mankweng Hospitals, in Limpopo Province. Forty-seven participants out of the expected 52 paediatric doctors completed the questionnaire, corresponding to 90.4% response rate. The sample size and the response rate were adequate for the population to allow for valid statistical analysis. All questionnaires were completed correctly and were included in the data analysis. The researcher monitored data collection and made sure that all questionnaires were completed. The process of data collection took place in May 2021.

The names and racial groups of the participants were not included in the demographic data to enhance confidentiality and anonymity.

4.3 RESEARCH RESULTS

4.3.1 Characteristics of the participants

The characteristics of the participants are presented as follows.

4.3.1.1 Distribution of participants by gender

Out of the 47 participants, 31 (66%) were females and 16 (34%) were males (Figure 4.1).

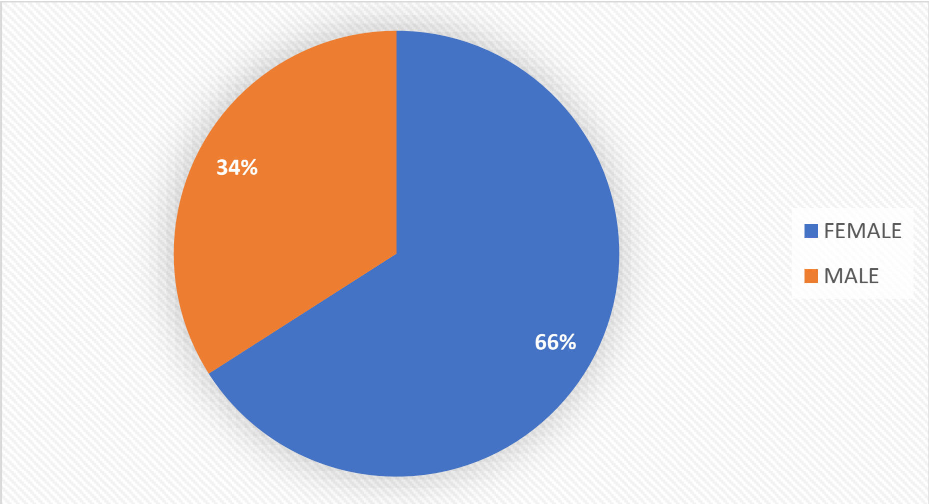

Figure 4.1 Distribution of participants by gender (n = 47)

4.3.1.2 Distribution of participants by age

The distribution of the participants by their age is shown in Figure 4.2. The number of participants per age group varied. The largest age group was 31 to40 years, with 24 (51%) participants. The smallest age group comprised of those older than 50 years, with only three (6%) participants.

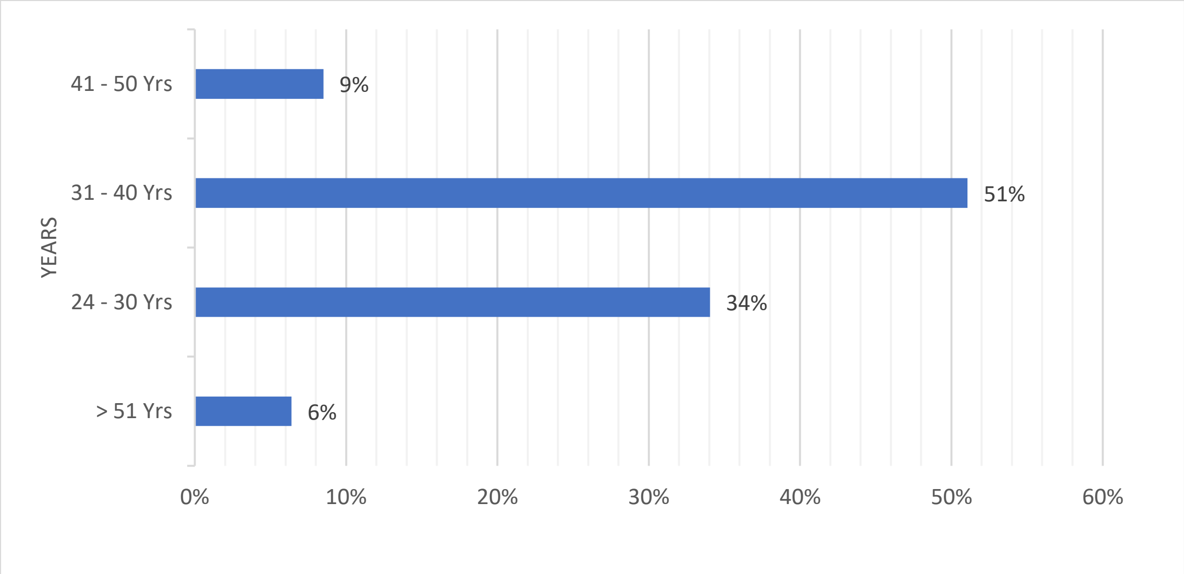

Figure 4. 2 Distribution of participants by age

4.3.1.3. Distribution according to professional category

Regarding the professional category, the majority were the consultants, making up 30% (14), followed by registrars, who were 13(28%). The least two groups were of the medical officers who were eight (17%), and medical officer interns, 12 (26%), as seen in (Figure 4.3).

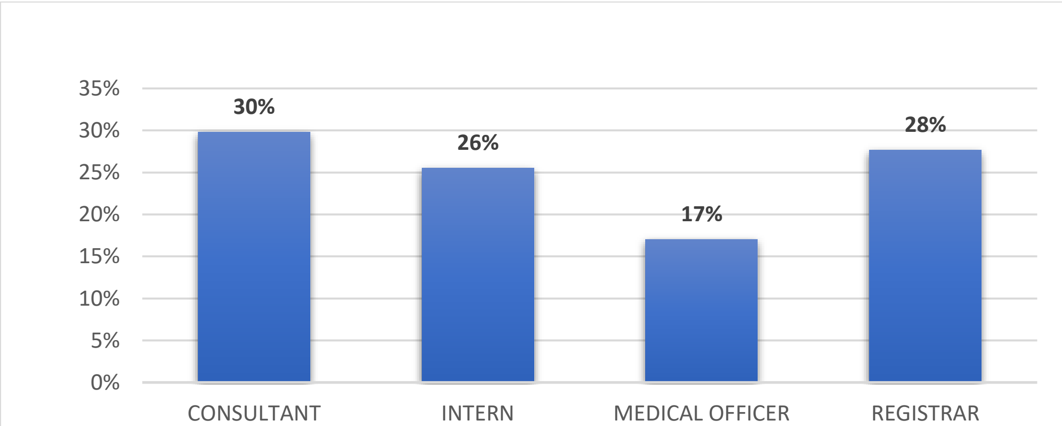

Figure 4.3 Distribution of respondents by professional category (n = 47)

4.3.1.4. Distribution by work experience

Regarding the duration of work experience, the majority had less than 3 years of experience, making up 57% (n=14) participants. The last two categories (11 – 20 years, and >20 years of experience) had three participants each, making 6% each of total participants. Seven (30%) participants were in the category of “11 - 20 years” of experience (**Figure 4.4).**

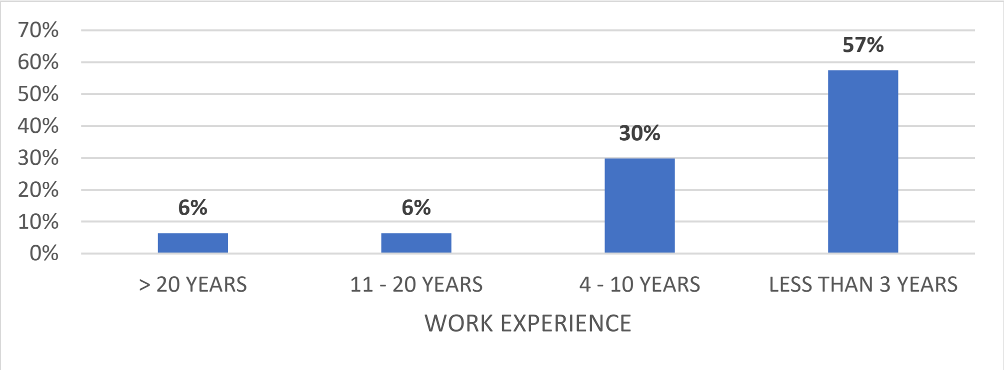

Figure 4.4 Distribution of respondents according to work experience**.**

4.3.1.5 Self-assessment of knowledge

Regarding self-assessment of knowledge on ionizing radiation safety and radiation doses, majority of respondents 66% (n=31) answered that they had insufficient knowledge on radiation whereas only 34% (n=16) responded that they had sufficient knowledge **(Figure 4.5).**

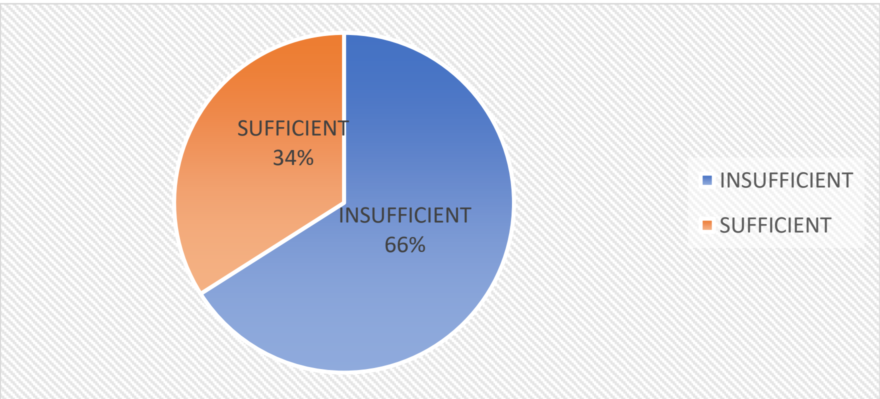

Figure 4.5. Distribution of respondents’ assessment of their knowledge on radiation safety and doses.

4.3.1.6 Prior training or courses

The final question under demographic information asked about participants' prior training or attendance of any training events and/or refresher courses on radiation protection. The majority (98%; n=46) of the participants reported that they have never attended any training event and/or refresher courses on radiation protection.

4.3.2 Knowledge of radiation protection

There were nine questions evaluating the knowledge of radiation protection of the participants (**Table 4.1**). The participants answered all questions, with 25 (53.2%) of them scoring more than 50%. Out of the nine questions, five were the most correctly answered by the participants. The first question asked how often the participants advised their patients on ionizing radiation examinations or procedures. Forty-three (91.5%) participants answered this question correctly. Only four participants said they only advise patients undergoing CT examinations. The second question asked about the medical professional category who are considered legally responsible for unnecessary exposure to ionizing radiation and/or improperly performed radiological examinations. Thirty-six (76.6%) participants provided the correct response to this question. Nine (19.2%) participants selected only radiologists as the professionals responsible for unnecessary radiation exposure to patients. Nine (9) respondents selected nuclear medicine physicists as the professionals responsible for unnecessary exposure of ionizing radiation and/or improperly performed radiological examinations.

Regarding which tissue has a high susceptibility to radiation in children, 26 (55.3%) of the respondents selected “bone marrow” as the correct option. However, 19% (n=9) of the respondents selected brain as the tissue with higher susceptibility to ionizing radiation.

Majority of participants, 63.8% (n= 30), correctly identified a protective theatre gown as the only attire that is not suitable for radiological personal protective equipment, whereas 11 participants selected lead aprons as the correct answer, 4 participants selected thyroid shields and 2 selected lead goggles.

The last question in this section inquired about the stakeholders who should be involved in training programmes on radiation dose and radiation safety, of which 37 (78.7%) correctly identified that all the identified professionals should be involved.

However, eight participants selected only radiologists as the stakeholders to be trained on radiation safety and radiation doses.

The most incorrectly answered questions were: "Which of the following patients are the most sensitive to ionizing radiation?" and "Which of the following professionals are likely to be exposed to more ionizing radiation because of their job?" Only 10.6% and 12.8% respectively, provided correct answers to the two questions.

Almost half of the participants selected only "leukaemia" in the question about which diseases may result from ionizing radiation damage. The rest selected "all answers are correct".

Each correct response was given a score of one mark. Any wrong or missing answers were given a score of zero marks. The average mean score out of 16 was 2.9 (16.1%). The knowledge on radiation protection had a mean average score of 2.4 out of 9. **Table 4.1** shows the responses to questions on the knowledge of radiation protection.

Table 4.1: Response according to Radiation Protection Knowledge

Questions	Answers	Frequency	Percentage
According to your knowledge on radiation safety, is it necessary to advise patients about the risks related to the use of ionizing radiation for medical purposes?	Yes, always	43	91.5
	Yes, but only for patients younger than 18 years' old	0	0
	Yes, but only for patients who are going to a CT scan	4	8.5
	Yes, but only for patients younger than 65 years' old	0	0
	No, never	0	0
Which of the following patients are the most sensitive to ionizing radiation?	1-year-old male	9	19.1
	1-year-old female	5	10.6
	12-year-old female	3	6.4
	12-year-old male	0	0
	Ionizing radiation damage risk is unrelated to patient's age and sex	30	63.8
Which of the following professionals is considered legally responsible for unnecessary exposure to ionizing radiation and/or improperly performed radiological examinations?	Only the referring physician	1	2.1
	Only the radiologist	9	19.2
	Only the medical specialist	0	0
	Only the radiographer	1	2.1
	All answers are correct	36	76.6
Which of the following professionals are likely to be exposed to MORE	Nuclear medicine physicians	9	19.1
	Radiographers	32	68.1
	Interventional radiologists	6	12.8

ionizing radiation because of their job?	Non-interventional radiologists	0	0
	Surgeons	0	0
Which of the following tissues are more susceptible to ionizing radiation damage in a child (1 – 12y)?	Brain	9	19.1
	Bladder	3	6.4
	Bone marrow	26	55.3
	Skin	8	17.0
	Liver	0	0
Which of the following diseases may be a result of ionizing radiation damage?	Dermatitis	1	2.1
	Leukaemia	22	46.58
	Alopecia	2	4.3
	Cataract	0	0
	All answers are correct	22	46.8
7. Which of the following statements are true?	Ionizing radiation-based examination should be prescribed and performed only when indispensable.	1	2.1
	The dose delivered by ionizing radiation-based examinations must be kept as low as reasonably achievable, consistent with obtaining the required diagnostic information.	21	44.7
	The scan volume for ionizing radiation-based examinations should be as large as possible, to maximize diagnostic information from a single acquisition.	2	4.3
	An ionizing radiation-based examination is optimized when resolution is maximized to assess even the finest image details.	4	8.5
	All answers are correct.	17	36.2
The following are personal protective equipment to minimize staff exposure to ionizing radiation, except	Lead goggles	2	4.3
	Lead aprons	11	23.4
	Thyroid shield	4	8.5
	Theatre protective gown	29	61.7
Who are the stakeholders to involve in training programmes on radiation dose and radiation safety?	Referring physicians	1	2.1
	Radiologists	8	17.0
	Radiographers	1	2.1
	Nursing staff	0	0
	All of the above	37	78.7

When comparing responses of males and females on the knowledge of radiation protection (Table 4.2), the average correct response was 52.4% and 53.7% respectively. The average difference was 1.3%. This was not statistically significant.

Out of 25 participants who scored >50% on the radiation protection questions, there were 6 (42.8%) consultants, 9 (69.2%) registrars, 2 (25%) medical officers, and 7 (58.3%) medical officer interns. Medical officer interns performed best in this question with 58.3% of them giving the expected response.

		Gender		
Questions	**Answers**	**Female**	**Male**	**P-value**
According to your knowledge on radiation safety, is it necessary to advise patients about the risks related to the use of ionizing radiation for medical purposes?	Yes, always	28 (90.3%)	15 (93.7%)	0.700
	Yes, but only for patients younger than 18 years' old	0 (0.0%)	0 (0.0%)	
	Yes, but only for patients who are going to a CT scan	3 (9.7%)	1 (6.3%)	
	Yes, but only for patients younger than 65 years' old	0 (0.0%)	0 (0.0%)	
	No, never	0 (0.0%)	0 (0.0%)	
Which of the following patients are the most sensitive to ionizing radiation?	1-year-old male	7 (22.6%)	1 (6.3%)	0.473
	1-year-old female	4 (12.9%)	2 (12.5%)	
	12-year-old female	1 (3.2%)	2 (12.5%)	
	12-year-old male	0 (0.0%)	0 (0.0%)	
	Ionizing radiation damage risk is unrelated to patient's age and sex	19 (61.3%)	11 (68.8%)	
Which of the following professionals is considered legally responsible for unnecessary exposure to ionizing radiation and/or improperly performed radiological examinations?	Only the referring physician	0(0%)	1(6.3%)	0.349
	Only the radiologist	7(22.6%)	2(12.6%)	
	Only the medical specialist	0(0%)	0(0%)	
	radiology procedures			
	Only the radiographer	0(0%)	1(6.3%)	
	All answers are correct	24(77.4%)	12 (75.0%)	
Which of the following professionals are likely to be exposed to MORE ionizing radiation because of their job?	Nuclear medicine physicians	5(16.1%)	4(25.0%)	0.802
	Radiographers	22(70.9%)	10(62.5%)	
	Interventional radiologists	4(12.9%)	2(12,5%)	
	Non-interventional radiologists	0(0%)	0(0%)	
	Surgeons	0(0%)	0(0%)	
Which of the following tissues are more susceptible to ionizing radiation damage in a child (1 – 12y)?	Brain	5(16.1%)	4(25.0%)	0.402
	Bladder	2(6.5%)	1(6.3%)	
	Bone marrow	17(54.8%)	9(56.3%)	
	Skin	7(22.6%)	1(6.3%)	
	Liver	0(0.0%)	(0.0%)	
Which of the following diseases may be a result of ionizing radiation damage?	Dermatitis	1(3.2%)	0(0.0%)	0.647
	Leukaemia	16(51.6%)	6(37.5%)	
	Alopecia	1(3.2%)	1(6.3%)	
	Cataract	0(0.0%)	0(0.0%)	

	All answers are correct	13(41.9%)	9(56.3%)	
7. Which of the following statements are true?	Ionizing radiation-based examination should be prescribed and performed only when indispensable.	1(3.2%)	0(0.0%)	0.493
	The dose delivered by ionizing radiation-based examinations must be kept as low as reasonably achievable, consistent with obtaining the required diagnostic information.	15(48.4%)	6(37.5%)	
	The scan volume for ionizing radiation-based examinations should be as large as possible, to maximize diagnostic information from a single acquisition.	1(3.2%)	1(6.3%)	
	An ionizing radiation-based examination is optimized when resolution is maximized to assess even the finest image details.	1(3.2%)	3(18.8%)	
	All answers are correct.	12(38.7%)	5(31.3%)	
The following are personal protective equipment to minimize staff exposure to ionizing radiation, except	Lead goggles	1(3.2%)	1(6.3%)	0.044
	Lead aprons	4(12.9%)	7(43.8%)	
	Thyroid shield	4(!2.9%)	0(0.0%)	
	Theatre protective gown	22(71.0%)	7(43.8%)	
Who are the stakeholders to involve in training programmes on radiation dose and radiation safety?	Referring physicians	1(3.2%)	0(0.0%)	0.668
	Radiologists	6(19.4%)	2(12.5%)	
	Radiographers	1(3.2%)	0(0.0%)	
	Nursing staff	0(0.0%)	0(0.0%)	
	All of the above	23(74%)	14(87.5%)	

Table 4.2. Response according to Radiation Protection Knowledge by gender

Majority of participants in this study were in the age group of 31 – 40 years. Of the 25 participants who scored more than 50% in radiation safety questions, 12 (48.0%) were of the 31 – 40 age group and 11 (44.0%) belonged to the 24 – 30 years age group. There was only one participant each from the 41-50 and >50 years age groups.

			Age			
Questions	**Answers**	**24-30 y**	**31-40 y**	**41-50 y**	**>50 y**	**P-value**
According to your knowledge on radiation safety, is it necessary to advise patients about the risks related to the use of ionizing radiation for medical purposes?	Yes, always	16(100%)	22(91.7%)	3(75.0%)	2(66.7%)	0.315
	Yes, but only for patients younger than 18 years' old	0(0.0%)			0(0.0%)	
	Yes, but only for patients who are going to a CT scan	0(0.0%)	2(8.3%)	1(25.0%)	1(33.3%)	
	Yes, but only for patients younger than 65 years' old	0(0.0%)	0(0.0%)	0(0.0%)	0(0.0%)	
	No, never	0(0.0%)	0(0.0%)	0(0.0%)	0(0.0%)	
Which of the following patients are the most sensitive to ionizing radiation?	1-year-old male	4(25.0%)	4(16.7%)	1(25.0%)	0(0.0%)	0.863
	1-year-old female	2(12.5%)	3(12.5%)	0(0.0%)	0(0.0%)	
	12-year-old female	2(12.5%)	1(4.2%)	0(0.0%)	0(0.0%)	
	12-year-old male	0(0.0%)	0(0.0%)	0(0.0%)	0(0.0%)	
	Ionizing radiation damage risk is unrelated to patient's age and sex	8(50.0%)	16(66.7%)	3(75.0%)	3(100%)	
Which of the following professionals is considered legally responsible for unnecessary exposure to ionizing radiation and/or improperly performed radiological examinations?	Only the referring physician	1(6.3%)	0(0.0%)	0(0.0%)	0(0.0%)	0.006
	Only the radiologist	3(18.8%)	3(12.5%)	3(75.0%)	0(0.0%)	
	Only the medical specialist	0(0.0%)	0(0.0%)	0(0.0%)	0(0.0%)	
	radiology procedures	0(0.0%)	0(0.0%)	0(0.0%)	0(0.0%)	
	Only the radiographer	1(6.3%)	0(0.0%)	0(0.0%)	0(0.0%)	
	All answers are correct	11(68.8%)	21(87.5%)	1(25.0%)	3(100%)	
Which of the following professionals are likely to be exposed to MORE ionizing radiation because of their job?	Nuclear medicine physicians	4(25.0%)	5(20.8%)		0(0.0%)	0.752
	Radiographers	11(68.8%)	15(62.5%)	4(100%)	2(66.7%)	
	Interventional radiologists	1(6.3%)	4(16.7%)	0(0.0%)	1(33.3%)	
	Non-interventional radiologists	0(0.0%)	0(0.0%)	0(0.0%)	0(0.0%)	
	Surgeons	0(0.0%)	0(0.0%)	0(0.0%)	0(0.0%)	
Which of the following tissues is more susceptible to ionizing radiation	Brain	6(37.5%)	2(8.3%)	0(0.0%)	1(33.3%)	0.435
	Bladder	0(0.0%)	3(12.5%)	0(0.0%)	0(0.0%)	
	Bone marrow	7(43.8%)	15(62.5%)	3(75.0%)	1(33.3%)	
	Skin	2(12.5%)	4(16.7%)	1(25.0%)	1(33.3%)	

damage in a child (1 – 12y)?	Liver	0(0.0%)	0(0.0%)	0(0.0%)	0(0.0%)	
Which of the following diseases may be a result of ionizing radiation damage?	Dermatitis	1(6.3%)	0(0.0%)	0(0.0%)	0(0.0%)	0.783
	Leukaemia	8(50.0%)	10(41.7%)	3(75.0%)	1(33.3%)	
	Alopecia	0(0.0%)	2(8.3%)	0(0.0%)	0(0.0%)	
	Cataract	0(0.0%)	0(0.0%)	0(0.0%)	0(0.0%)	
	All answers are correct	7(43.8%)	12(50.0%)	1(25.0%)	2(66.7%)	
7. Which of the following statements are true?	Ionizing radiation-based examination should be prescribed and performed only when indispensable.	0(0.0%)	1(4.2%)	0(0.0%)	0(0.0%)	0.102
	The dose delivered by ionizing radiation-based examinations must be kept as low as reasonably achievable, consistent with obtaining the required diagnostic information.	11(68.8%)	7(29.2%)	3(75.0%)	0(0.0%)	
	The scan volume for ionizing radiation-based examinations should be as large as possible, so as to maximise diagnostic information from a single acquisition.	0(0.0%)	1((4.2%)	0(0.0%)	1(33.3%)	
	An ionizing radiation-based examination is optimised when resolution is maximised to assess even the finest image details.	0(0.0%)	2(8.3%)	1(25.0%)	1(33.3%)	
	All answers are correct.	5(31.5%)	11(45.8%)	0(0.0%)	1(33.3%)	

The following are personal protective equipment to minimise staff exposure to ionizing radiation, except	Lead goggles	1(6.3%)	1(4.2%)	0(0.0%)	0(0.0%)	0.638
	Lead aprons	2(12.5%)	5(20.8%)	2(50.0%)	2(66.7%)	
	Thyroid shield	2(12.5%)	1(4.2%)	1(25.0%)	0(0.0%)	
	Theatre protective gown	11(68.8%)	16(66.7%)	1(25.0%)	1(33.3%)	
Who are the stakeholders to involve in training programs on radiation dose and radiation safety?	Referring physicians	0(0.0%)	1(4.2%)	0(0.0%)	0(0.0%)	0.1390.
	Radiologists	2(12.5%)	5(20.8%)	1(25.0%)	0(0.0%)	
	Radiographers	0(0.0%)	0(0.0%)	1(25%)	0(0.0%)	
	Nursing staff	0(0.0%)	0(0.0%)	0(0.0%)	0(0.0%)	
	All of the above	14(87.5%)	18(75.0%)	2(50.0%)	3(100%)	

Table 4.3. Response of participants according to age groups.

Considering the duration of work experience, of the 25 participants that scored more than 50%, 17(68.0%) were in the category of <3 years of experience in their respective levels, 6 (24.0%) in the 4 – 10 years, 1 (4.0%) in 11 – 20 years, and 3 in the >20 years of experience, respectively. There was a statistical difference between the group with less than 3 years of experience and the other three categories (p = 0.049) **(**Table 4.4).

			Experience			
Questions	**Answers**	**3 y**	**4 – 10 y**	**11 – 20 y**	**>20 y**	**P-value**
According to your knowledge on radiation safety, is it necessary to advise patients about the risks related to the use of ionizing radiation for medical purposes?	Yes, always	25(92.6%)	14(100%)	2(66.7%)	2 (66.7%)	0.336
	Yes, but only for patients younger than 18 years' old		0(0.0%)	0(0.0%)	0(0.0%)	
	Yes, but only for patients who are going to a CT scan	2(7.4%)	0(0.0%)	1(33.3%)	1(33.3%)	
	Yes, but only for patients younger than 65 years' old	0(0.0%)	0(0.0%)	0(0.0%)	0(0.0%)	
	No, never	0(0.0%)	0(0.0%)	0(0.0%)	0(0.0%)	
Which of the following patients are the most sensitive to ionizing radiation?	1-year-old male	6(22.2%)	2(14.3%)	1(33.3%)	0(0.0%)	0.703
	1-year-old female	4(14.8%)	1(7.1%)	0(0.0%)	0(0.0%)	
	12-year-old female	0(0.0%)	0(0.0%)	0(0.0%)	0(0.0%)	

	12-year-old male	0(0.0%)	0(0.0%)	0(0.0%)	0(0.0%)	
	Ionizing radiation damage risk is unrelated to patient's age and sex	3(11.1%)	11(78.6%)	2(66.7%)	3(100%)	
Which of the following professionals is considered legally responsible for unnecessary exposure to ionizing radiation and/or improperly performed radiological examinations?	Only the referring physician	1(3.7%)	0(0.0%)	0(0.0%)	0(0.0%)	0.985
	Only the radiologist	7(22.2%)	2(14.2%)	0(0.0%)	0(0.0%)	
	Only the medical specialist	0(0.0%)	0(0.0%)	0(0.0%)	0(0.0%)	
	radiology procedures	0(0.0%)	0(0.0%)	0(0.0%)	0(0.0%)	
	Only the radiographer	1(3.7%)	0(0.0%)	0(0.0%)	0(0.0%)	
	All answers are correct	18(66.7%)	12(85.7%)	3(100%)	3(100%)	
Which of the following professionals are likely to be exposed to MORE ionizing radiation because of their job?	Nuclear medicine physicians	7(25.9%)	2(!4.3%)	0(0.0%)	0(0.0%)	0.795
	Radiographers	18(66.7%)	10(71.4%)	2(66.7%)	2(66.7%)	
	Interventional radiologists	2(7.4%)	2(14.3%)	0(0.0%)	1(33.3%)	
	Non-interventional radiologists	0(0.0%)	0(0.0%)	0(0.0%)	0(0.0%)	
	Surgeons	0(0.0%)	0(0.0%)	0(0.0%)	0(0.0%)	
Which of the following tissues are more susceptible to ionizing radiation damage in a child (1 – 12y)?	Brain	7(25.9%)	1(7.1%)	0(0.0%)	1(33.3%)	0.660
	Bladder	1(3.7%)	2(14.3%)	0(0.0%)	0(0.0%)	
	Bone marrow	14(51.9%)	8(57.1%)	3(100%)	1(33.3%)	
	Skin	5(18.5%)	2(14.3%)	0(0.0%)	1(33.3%)	
	Liver	0(0.0%)	0(0.0%)	0(0.0%)	0(0.0%)	
Which of the following diseases may be a result of ionizing radiation damage?	Dermatitis	1(3.7%)	0(0.0%)	0(0.0%)	0(0.0%)	0.806
	Leukaemia	11(40.7%)	7(50%)	3(100%)	1(33.3%)	
	Alopecia	1(3.7%)	1(7.1%)	0(0.0%)	0(0.0%)	
	Cataract	0(0.0%)	0(0.0%)	0(0.0%)	0(0.0%)	
	All answers are correct	14(51.9%)	6(42.9%)	0(0.0%)	2(66.7%)	
7. Which of the following statements are true?	Ionizing radiation-based examination should be prescribed and performed only when indispensable.	0(0.0%)	1(7.1%)	0(0.0%)	0(0.0%)	0.049
	The dose delivered by	15(55.6%)	6(42.9%)	0(0.0%)	0(0.0%)	

	ionizing radiation-based examinations must be kept as low as reasonably achievable, consistent with obtaining the required diagnostic information.					
	The scan volume for ionizing radiation-based examinations should be as large as possible, to maximize diagnostic information from a single acquisition.		1(7.1%)		1(33.3%)	
	An ionizing radiation-based examination is optimized when resolution is maximised to assess even the finest image details.	1(3.7%)	1(7.1%)	1(33.3%)	1(33.3%)	
	All answers are correct.	10(37.0%)	5(35.7%)	1(33.3%)	1(33.3%)	
The following are personal protective equipment to minimize staff exposure to ionizing radiation, except	Lead goggles	1(3.7%)	1(7.1%)	0(0.0%)	0(0.0%)	0.316
	Lead aprons	2(7.4%)	5(35.7%)	2(66.7%)	2(66.7%)	
	Thyroid shield	2(7.4%)	2(14.3%)	0(0.0%)	0(0.0%)	
	Theatre protective gown	21(77.8%)	6(42.9%)	1(33.3%)	1(33.3%)	
Who are the stakeholders to involve in training programmes on radiation dose and radiation safety?	Referring physicians	1(3.7%)	0(0.0%)	0(0.0%)	0(0.0%)	0.202
	Radiologists	2(7.4%)	4(28.6%)	2(66.7%)	0(0.0%)	
	Radiographers	0(0.0%)	1(7.1%)	0(0.0%)	0(0.0%)	
	Nursing staff	0(0.0%)	0(0.0%)	0(0.0%)	0(0.0%)	
	All of the above	24(88.9%)	9(64.3%)	1(33.3%)	3(100%)	

Table 4.4 Response of participants according to years of experience.

4.3.3. Participants' knowledge on radiation doses

Table 4.5 shows the response of the participants on the knowledge of radiation doses. There were seven questions in this category related to radiation doses of particular radiological examinations done with different modalities. Radiation dose imparted by a single PA Chest x- ray was regarded as one unit, on which the dose imparted by the other modalities was based.

The first question asked about the average radiation dose of a single chest radiograph. Only eight (17%) answered the question correctly. Thirty-five (74.5%) participants responded with the last option in the multiple choice of "I don't know".

Only nine (19.1%) respondents knew that the value of annual background radiation in South Africa was 0.07 mSv. Another nine (19.1%) overestimated it to an average of 10 - 50 U. Twenty-three (32%) participants selected "I don't know" option.

Only three (6%) participants scored more than 50% in this section. Of the three who scored above 50%, there was one consultant, one registrar and one medical officer. Their individual years of experience were varied, with the registrar having less than 3 years of experience, medical officer with 4 – 10 years of experience, and the consultant with more than 20 years of experience.

Thirteen (27.6%) participants responded with "I don't know in all the seven questions. Majority of questions 1 to 7 respectively, in this section "I don't know" answers returned from most of the participants as follows: 35 (74.5%); 23 (61.7%); 29 (61.7%); 33 (70.2%); 28 (59.6%); and 26 (59.3%) in chronological order.

The last two questions required the respondent to estimated radiation dose in MRI and ultrasound, respectively. Only 5 (10.6%) participants selected "0" as the answer for MRI and 17 (36.2%) answered correctly in the ultrasound modality question.

Underestimation and overestimation of radiation dose were calculated as mild, moderate, and marked, depending on the range of difference from the correct answer. If the correct answer was 1 – 10 U, and the chosen answer was 10- 50 U, it was deemed mild overestimation. If participant chose 50 – 100U, it was deemed a moderate overestimation. If participant chose 100 – 500 U, then that was deemed a marked overestimation. There was mild overestimation of background radiation by nine (19.21%) participants, which was equal to the number of participants as those who answered correctly. There was mild overestimation of CT chest radiation dose by eight (17.0%) of participants. CT of brain estimated radiation dose was mildly and moderately underestimated by four (8.5%). However, six (12.8%) correctly estimated the brain CT radiation dose (Table 4.5).

Table 4.5: Participants' knowledge on radiation doses

Questions	Answers	Frequency	Percentage
Which is the average radiation dose of single chest radiograph?	Less than 0.01 mSv	1	2.1
	0.01– 0.1 mSv	8	17
	1 – 10 mSv	3	6.4
	10 – 100mSv	0	0
	I don't know	35	74.5
If a single chest radiograph counts as 1 unit (U), how much is the average dose due to natural background in South Africa?	0	2	4.3
	1– 10 U	9	19.1
	10-50 U	9	19.1
	50-100 U	2	4.3
	100-500 U	2	4.3
	I don't know	23	32
If a single chest radiograph counts as 1 unit, how much is the average dose due to an abdominal x-ray examination?	0	0	0
	1– 10 U	10	21.3
	10-50 U	2	4.3
	50-100 U	4	8.5
	100-500 U	0	0
	I don't know	29	61.7
If a single chest radiograph counts as 1 unit, how much is the average dose due to non-contrast chest CT examination?	0	0	0
	1– 10 U	0	0
	10-50 U	3	6.4
	50-100 U	3	6.4
	100-500 U	8	17
	I don't know	33	70.2
If a single chest radiograph counts as 1 unit, how much is the average dose due to non-contrast brain CT examination?	0	0	0
	1– 10 U	1	2.1
	10-50 U	4	8.5
	50-100 U	4	8.5
	100-500 U	6	12.8
	I don't know	32	68.1
If a single chest radiograph counts as 1 unit, how much is the average dose due to MRI pelvic examination?	0	5	10.6
	1– 10 U	4	8.5
	10-50 U	2	4.3
	50-100 U	2	4.3
	100-500 U	6	12.8
	I don't know	28	59.6
If a single chest radiograph counts as 1 unit, how much is the average dose due abdominal ultrasound examination?	0	17	36.2
	1– 10 U	4	8.5
	10-50 U	0	0
	50-100 U	0	0

	100-500 U	0	0
	I don't know	26	55.3

Male participants scored better in four questions compared to females who performed well in 3 questions. However, the difference was not significant.

In the estimation of average radiation dose of a single chest radiograph, only eight (25.8%) females answered correctly. Almost all the males (15 out of 16) selected the option "I don't know". Three (9.7%) female doctors correctly estimated the average dose of CT chest examination, and none of the males. There were 3 (9.7%) females and 3 (28.8%) males who correctly identified average dose of non-contrast brain CT. Only 3 (9.3%) females and 2 (12.5%) males, 3 (9.3%) and four (25%) knew that MRI and ultrasound do not use ionizing radiation, respectively (Table 4.6).

		Gender		
Questions	**Answers**	**Female**	**Male**	**P-value**
Which is the average radiation dose of single chest radiograph?	Less than 0.01 mSv	1(3.2%)	0(0.0%)	0.184
	0.01– 0.1 mSv	8(25.8%)	0(0.0%)	
	1 – 10 mSv	2(6.5%)	1(6.3%)	
	10 – 100mSv	0(0.0%)	0(0.0%)	
	I don't know	20(64.5%)	15(93.4%)	
If a single chest radiograph counts as 1 unit (U), how much is the average dose due to natural background in South Africa?	0	1(3.2%)	1(6.3%)	0.143
	1– 10 U	4(12.9%)	5(31.3%)	
	10-50 U	9(29.0%)	0(0.0%)	
	50-100 U	2(6.5%)	0(0.0%)	
	100-500 U	1(3.2%)	1(6.3%)	
	I don't know	14(45.2%)	9(56.3%)	
If a single chest radiograph counts as 1 unit, how much is the average dose due to an abdominal x-ray examination?	0	0(0.0%)	0(0.0%)	0.316
	1– 10 U	6(19.4%)	4(25.0%)	
	10-50 U	5(16.1%)	1(6.3%)	
	50-100 U	2(6.5%)	0(0.0%)	
	100-500 U	0(0.0%)	0(0.0%)	
	I don't know	18(58.1%)	11(68.8%)	
If a single chest radiograph counts as 1 unit, how much is the average dose due to non-contrast chest CT examination?	0	0(0.0%)	0(0.0%)	0.793
	1– 10 U	0(0.0%)	0(0.0%)	
	10-50 U	2(5.4%)	1(6.3%)	
	50-100 U	3(9.7%)	0(0.0%)	
	100-500 U	5(16.1%)	3(18.8%)	
	I don't know	21(67.7%)	12(75.0%)	
If a single chest radiograph counts as 1 unit, how much is	0	0(0.0%)	0(0.0%)	0.446
	1– 10 U	1(3.2%)	0(0.0%)	

the average dose due to non-contrast brain CT examination?	10-50 U	2(6.5%)	2(12.5%)	
	50-100 U	4(12.9%)	0(0.0%)	
	100-500 U	3(9.7%)	3(18.8%)	
	I don't know	21(67.7%)	11(68.8%)	
If a single chest radiograph counts as 1 unit, how much is the average dose due to MRI pelvic examination?	0	3(9.7%)	2(12.5%)	0.756
	1– 10 U	3(9.7%)	1(6.3%)	
	10-50 U	2(6.5%)	0(0.0%)	
	50-100 U	2(6.5%)	0(0.0%)	
	100-500 U	4(12.9%)	2(12.5%)	
	I don't know	17(54.8%)	11(68.8%)	
If a single chest radiograph counts as 1 unit, how much is the average dose due to abdominal ultrasound examination?	0	13(41.9%)	4(25.0%)	0.412
	1– 10 U	3(9.7%)	1(6.3%)	
	10-50 U	0(0.0%)	0(0.0%)	
	50-100 U	0(0.0%)	0(0.0%)	
	100-500 U	0(0.0%)	0(0.0%)	
	I don't know	15(48.4%)	11(68.8%)	

Table 4.6. Responses on Radiation Dose Assessment according to gender.

Estimation of average radiation dose of single chest x-ray was correctly answered by participants in the age of 31 – 40 years (20.9% (n=5)). Three (18.8%) participants from age group 24 -30 years correctly identified the answer. No participants from the 41 – 50 years and >50 years age groups selected the correct answer. Two (8.4%) participants from ages 31 – 40 year and 41-50 years selected the correct answer in question on estimation of non-contrast CT chest. Only one participant from the category (24 – 30 years) selected the correct answer for this question, and no participants from the >50 years selected the correct answer.

Estimation of average radiation dose of the non-contrast CT brain was correctly identified by one participant from > 50 years group, 1 from 41 – 50 years, 2 from 24 – 30 years, and 2 from 31 – 40 years category. Three participants from 31 – 40 years, one from > 50 years, and one from 41 – 50 years correctly identified average dose used by pelvic MRI. Ten out 24 participants from 31 – 40 years, 2 out of 3 from > 50 years, 4 out of 16 participants from the 24 – 30 years, and 1 from out of 4 participants from the category of 41 – 50 years (Table 4.7) correctly identified average dose due to abdominal ultrasound.

		24 – 30 Y	31 – 40 Y	41 – 50 Y	>50Y	
Questions	**Answers**					**P-value**
Which is the average radiation dose of single chest radiograph?	Less than 0.01 mSv	0(0.0%)	0(0.0%)	0(0.0%)	0(0.0%)	0.988
	0.01– 0.1 mSv	3(18.8%)	5(20.9%)	0(0.0%)	0(0.0%)	
	1 – 10 mSv	1(6.3%)	1(4.2%)	0(0.0%)	0(0.0%)	
	10 – 100mSv	0(0.0%)	0(0.0%)	0(0.0%)	0(0.0%)	
	I don't know	12(75%)	16(66.7%)	4(100%)	3(100%)	
If a single chest radiograph counts as 1 unit (U), how much is the average dose due to natural background in South Africa?	0	1(6.3%)	0(0.0%)	0(0.0%)	1(33.3%)	0.233
	1– 10 U	4(25.0%)	4(16.7%)	0(0.0%)	1(33.3%)	
	10-50 U	1(6.3%)	7(29.2%)	1(25.0%)	0(0.0%)	
	50-100 U	2(12.5%)	0(0.0%)	0(0.0%)	0(0.0%)	
	100-500 U	0(0.0%)	2(8.3%)	0(0.0%)	0(0.0%)	
	I don't know	8(50.0%)	11(45.8%)	3(74%)	1(33.3%)	
If a single chest radiograph counts as 1 unit, how much is the average dose due to an abdominal x-ray examination?	0	0(0.0%)	0(0.0%)	0(0.0%)	0(0.0%)	0.923
	1– 10 U	4(25%)	5(20.8%)	0(0.0%)	1(33.3%)	
	10-50 U	1(6.3%)	3(12.5%)	1(25.0% %)	0(0.0%)	
	50-100 U	1(6.3%)	1(4.2%)	0(0.0%)	0(0.0%)	
	100-500 U	0(0.0%)	0(0.0%)	0(0.0%)	0(0.0%)	
	I don't know	10(62.5%)	14(58.3%)	3(75%)	2(66.7%)	
If a single chest radiograph counts as 1 unit, how much is the average dose due to non-contrast chest CT examination?	0	0(0.0%)	0(0.0%)	0(0.0%)	0(0.0%)	0.801
	1– 10 U	0(0.0%)	0(0.0%)	0(0.0%)	0(0.0%)	
	10-50 U	2(12,5%)	0(0.0%)	0(0.0%)	1(33.3%)	
	50-100 U	1(6.3%)	2(8.4%)	2(8.4%)	0(0.0%)	
	100-500 U	2(12.5%)	4(16.7%)	4(16.7%)	1)33.3%)	
	I don't know	11(68.8%)	18(75.0%)	18(75.0%)	1(3.33%)	
If a single chest radiograph counts as 1 unit, how much is the average dose due to non-contrast brain CT examination?	0	0(0.0%)	0(0.0%)	0(0.0%)	0(0.0%)	0.538
	1– 10 U	1(6.3%)	0(0.0%)	0(0.0%)	0(0.0%)	
	10-50 U	1(6.3%)	2(8.3%)	0(0.0%)	1(33.3%)	
	50-100 U	0(0.0%)	4(16.7%)	0(0.0%)	0(0.0%)	
	100-500 U	2(12.5%)	2(8.3%)	1(25%)	1(33.3%)	
	I don't know	12(75.0%)	16(66.7%)	3(75%)	1(33.3%)	
If a single chest radiograph counts as 1 unit, how much is the average dose due to MRI pelvic examination?	0	1(6.3%)	3(12.5%)	0(0.0%)	1(33.3%)	0.775
	1– 10 U	0(0.0%)	3(12.5%)	0(0.0%)	1(33.3%)	
	10-50 U	1(6.3%)	1(4.2%)	0(0.0%)	0(0.0%)	
	50-100 U	1(6.3%)	1(4.2%)	0(0.0%)	0(0.0%)	
	100-500 U	2(12.5%)	4(16.7%)	0(0.0%)	0(0.0%)	

	I don't know	11(68.8%)	12(50.0%)	4(100.0%)	1(33.3%)	
If a single chest radiograph counts as 1 unit, how much is the average dose due to abdominal ultrasound examination?	0	4(25.0%)	10(41.7%)	1(25.5%)	2(66.7%)	0.505
	1– 10 U	3(18.8%)	1(4.2%)	0(0.0%)	0(0.0%)	
	10-50 U	0(0.0%)	0(0.0%)	0(0.0%)	0(0.0%)	
	50-100 U	0(0.0%)	0(0.0%)	0(0.0%)	0(0.0%)	
	100-500 U	0(0.0%)	0(0.0%)	0(0.0%)	0(0.0%)	
	I don't know	9(56.3%)	13(54.2%)	3(75.0%)	1(33.3%)	

Table 4.7. Responses on Radiation Dose Assessment according to age groups.

Of the eight participants who correctly estimated the average radiation dose of a single chest x-ray, five were from those with < 3 years of experience. The other three were from the category of 4-10 years of experience. None from the categories "11 – 20 years and > 20 years" of experience. Only two participants in those with less than 3 years of experience estimated the average dose of non-contrast CT chest correctly. From those with more than 20 years of experience, one selected the correct answer. Two participants from < 3 years of experience, and two from 4 – 10 years of experience correctly estimated the average dose of CT brain non-contrast. Two in 4 – 10 years, one in > 20 years, and two in < 3 years of experience correctly identified knowledge that MRI pelvis does not use radiation. Two out of 3 from > 20 years, 7 out of 14 from 4 – 10 years, 7 out of 27 from < 3 years of experience, correctly identified that ultrasound does not use ionizing radiation (Table 4.8).

		Experience				P-value
		< 3 y	4 – 10 y	11 – 20 y	➢ 20 y	
Questions	**Answers**					
Which is the average radiation dose of single chest radiograph?	Less than 0.01 mSv	0(0.0%)	0(0.0%)	1(33.3%)	0(0.0%)	0.320
	0.01– 0.1 mSv	5(18.5%)	3(21.4%)	0(0.0%)	0(0.0%)	
	1 – 10 mSv	1(3.7%)	1(7.1%)	0(0.0%)	0(0.0%)	
	10 – 50 mSv	0(0.0%)	0(0.0%)	0(0.0%)	0(0.0%)	
	I don't know	20(74.1%)	10(71.4%)	2(66.7%)	3(100%)	
If a single chest radiograph counts as 1 unit (U), how much is the average dose due to natural background in South Africa?	0	1(3.7%)	0(0.0%)	0(0.0%)	1(33.3%)	0.673
	1– 10 U	6(22.6%)	2(14.3%)	0(0.0%)	1(33.3%)	
	10-50 U	4(14.8%)	4(28.6%)	1(33.3%)	0(0.0%)	
	50-100 U	2(7.4%)	0(0.0%)	0(0.0%)	0(0.0%)	
	100-500 U	1(3.7%)	1(7.1%)	0(0.0%)	0(0.0%)	
	I don't know	13(48.1%)	7(50%)	2(66.7%)	1(33.3%)	
If a single chest radiograph counts as 1 unit, how much	0	0(0.0%)	0(0.0%)	0(0.0%)	0(0.0%)	0.988
	1– 10 U	6(22.2%)	3(21.4%)	0(0.0%)	1(33.3%)	

is the average dose due to an abdominal x-ray examination?	10-50 U	4(14.8%)	1(7.1%)	1(33.3%)	0(0.0%)	
	50-100 U	1(3.7%)	1(7.1%)	0(0.0%)	0(0.0%)	
	100-500 U	0(0.0%)	0(0.0%)	0(0.0%)	0(0.0%)	
	I don't know	16(59.3%)	9(64.3%)	2(66.7%)	2(66.7%)	
If a single chest radiograph counts as 1 unit, how much is the average dose due to non-contrast chest CT examination?	0	0(0.0%)	0(0.0%)	0(00%)	0(0.0%)	0.637
	1– 10 U	0(0.0%)	0(0.0%)	0(0.0%)	0(0.0%)	
	10-50 U	2(7.4%)	0(0.0%)	0(0.0%)	1(33.3%)	
	50-100 U	3(11.1%)	0(0.0%)	0(0.0%)	0(0.0%)	
	100-500 U	2(7.4%)	4(28.54%)	1(33.3%).	1(33.3%)	
	I don't know	20(74.1%)	10(71.4%)	2(66.7%)	1(33.3%)	
If a single chest radiograph counts as 1 unit, how much is the average dose due to non-contrast brain CT examination?	0	0(0.0%)	0(0.0%)	0(0.0%)	0(0.0%)	0.811
	1– 10 U	1(3.7%)	0(0.0%)	0(0.0%)	0(0.0%)	
	10-50 U	2(7.4%)	1(7.1%)	0(0.0%)	1(33.3%)	
	50-100 U	2(7.3%)	2(14.3%)	0(0.0%)	0(0.0%)	
	100-500 U	2(7.4%)	2(14.3%)	1(33.3%)	1(33.3%)	
	I don't know	20(74.1)	9(64.3%)	2(66.7%)	1(33.3%)	
If a single chest radiograph counts as 1 unit, how much is the average dose due to MRI pelvic examination?	0	2(7.4%)	2(14.3%)	0(0.0%)	1(33.3%)	0.630
	1– 10 U	1(3.7%)	2(14.3%)	0(0.0%)	1(33.3%)	
	10-50 U	1(3.7%)	1(7.1%)	0(0.0%)	0(0.0%)	
	50-100 U	1(3.7%)	1(7.1%)	0(0.0%)	0(0.0%)	
	100-500 U	6(22.6%)	0(0.0%)	0(0.0%)	0(0.0%)	
	I don't know	16(59.3%)	8(57.1%)	3(100.0%)	1(33.3%)	
If a single chest radiograph counts as 1 unit, how much is the average dose due to abdominal ultrasound examination?	0	7(25.9%)	7(50.0%)	1(33.3%)	2(66.7%)	0.452
	1– 10 U	4(14.8%)	0(0.0%)	0(0.0%)	0(0.0%)	
	10-50 U	0(0.0%)	0(0.0%)	0(0.0%)	0(0.0%)	
	50-100 U	0(0.0%)	0(0.0%)	0(0.0%)	0(0.0%)	
	100-500 U	0(0.0%)	0(0.0%)	0(0.0%)	0(0.0%)	
	I don't know	16(59.3%)	7(50.0%)	2(66.7%)	1(33.3%)	

Table 4.8: Response according to work experience.

4.4 OVERVIEW OF RESEARCH FINDINGS

The significant finding in this study is that paediatric doctors demonstrated poor knowledge of radiation protection and radiation doses, with mean score of 2.9 out of 16. Only eight (17.0%) participants scored overall mark of ≥ 50%. Of the eight respondents, there were 3 (37.5%) consultants, 2 (25%) registrars, 1 (12.5%) medical officers and 2 (20%) medical officer interns. Adequate knowledge on radiation protection was demonstrated by six consultants (21.4%), 23.1% (n = 9) of registrars, 25.0% (n=2) of medical officers, and 16.6% (n=8) of medical officer interns. Five

(62.5%) of the participants were of age 31 – 40 years and with less than 3 years of experience. Only two (25.0%) were from the category with 4 - 10 years of experience. There was only one (12.5%) who had > 20 years of experience, and none from the 11 – 20 years of experience. In the age group of 24 – 30 years, two participants scored more than 50%

Twenty-five (53.2%) participants scored more than 50% in questions assessing the knowledge of radiation protection knowledge. Of that number, 18(58.0%) were females and seven (43.7%) were males. There were 6 (24.0%) consultants, 9 (36.0%) registrars, 2 (8.0%) medical officers, and 8 (28.0%) medical interns. The paediatric doctors that had adequate knowledge for each rank was six of 14 (42.8%) consultants; 9 of 13 (69.2%) registrars; 2 of 8 (25%) medical officers; and 8 of 12 (58.3%) medical interns. Majority of participants were under the age group of 31 – 40 years.

Of the 25 participants who scored more than 50% in radiation safety questions, 12 (48.0%) were of age group 31-40, 11 (44.0%) belonged to the 24 – 30 years age group. Only one participant each came from age groups 41-50 and >50 years.

With regard to attendance of radiation safety course, 46 (97.8%) participants had never attended a course or training on radiation protection. However, 37(87.7%) of the paediatricians agreed that all the referring physicians, radiologists, radiographers, and nursing staff should be trained on radiation safety and radiation risks.

Thirty (63.0%) respondents thought that ionizing radiation risk is not related to patients' age or gender with only five (10.6%) correctly identifying that 1-year-old female infants are at higher risk. Less than half of the doctors (44.7%; n = 24) were familiar with the ALARA principle. Only three (6%) participants scored more than 50% in the section on knowledge of radiation dose, of which one was a consultant, one a registrar and one a medical officer. Years of experience were variable, with the registrar having less than 3 years of experience, medical officer with 4 – 10 years of experience and the consultant with more than 20 years of experience.

The average radiation dose that is used by a chest X–ray was correctly estimated by 17% (n=8) of paediatric doctors. There was only nine (19.1%) who correctly estimated the annual background radiation to the South African population.

There were 3 (6.4%) respondents who correctly estimated average dose due to non-contrast chest CT examination, and 6(12.8%) correctly identified average dose due to non-contrast brain CT examination. There were only five (10.6%) and 17(36.2%) of candidates who correctly identified that MRI and ultrasound do not use ionizing radiation.

4.5 CONCLUSION

The significant finding in this study is that paediatric doctors demonstrated poor knowledge of radiation protection and radiation doses, with mean score of 2.9 out of 16. Only 10 (21.2%) participants scored overall mark above 50%. Of the 10 respondents, there were 3 (30%) consultants, 3 (30%) registrars, 2 (20%) medical officers and 2 (20%) medical officer interns. Adequate knowledge on radiation protection was demonstrated by six consultants (21.4%), 23.1% (n = 9) of registrars, 25.0% (n=2) of medical officers, and 16.6% (n=8) of medical officer interns. Only three (6%) participants scored more than 50% in this section. Of the three who scored above 50%, there was one consultant, one registrar and one medical officer.

CHAPTER FIVE

5. DISCUSSION

5.1 INTRODUCTION

In this chapter, the findings of the research are discussed. Comparison is made with the findings of similar studies appearing in the literature. The chapter is divided into the following subsections:

- Interpretation of the results and discussion of the findings
- Contributions and recommendations
- Limitations of the study

5.2 RESEARCH DESIGN AND METHOD

The research design chosen for this study was a survey. A total population consecutive sampling method was employed. A previously validated self-administered questionnaire was used for data collection. The population comprised of the 52 doctors who provided medical and surgical care to the paediatric patients in the two tertiary hospitals in Limpopo, namely Pietersburg and Mankweng. The sample consisted of 47 doctors who completed the questionnaire, translating to over 90% response rate. Data were collected in the month of May 2021. An overall score of 50% and above, based on the correct response being selected was deemed to signify adequate knowledge of the responder in the survey. A score of less than 50% signified low level of knowledge.

5.3 SUMMARY AND INTERPRETATION OF THE RESEARCH FINDINGS

The aim of this study was to assess the knowledge of paediatric doctors on radiation safety and radiation doses. This is the first study of its kind amongst paediatric doctors in Limpopo province. The most significant finding in this study is that paediatric doctors demonstrated a low level of knowledge in radiation protection and radiation doses, with regard to the doses needed for radiological diagnostic procedures and radiation safety in paediatrics. A mean score demonstrates this for all the 47 participants being

2.9 out of a possible 16. Put in another way, the mean score was only 18.1%, which should be compared with the minimum score of 50% for adequate knowledge. These results concur with the hypothesis that paediatric doctors have inadequate knowledge on radiation safety and radiation doses.

Despite the global increase in the use of ionizing radiation modalities for medical diagnosis in patients and the risk of developing cancer, not many studies have examined the evaluation of knowledge of non-radiologists concerning radiation doses and radiation safety (Hayer *et al.,* 2010). This is worrying because most radiological examinations are requested by non-radiologists (Hayer et al 2010). Furthermore, most of the studies analysing the knowledge of radiation doses among non-radiologists have found this low level of knowledge (Krille, Hammer, Merzenich, and Zeeb, 2010; Eksioglu *et al*., 2012; Jończyk-Potoczna, Pucher, Strzelczuk-Judka, Buraczyńska-Andrzejewska, Więckowska, Krauss, Biliński and Wojtyła-Buciora, 2019; Mammas and Spandidos, 2019)

The findings of the current study are consistent with those of previous studies that report poor knowledge of radiation safety and radiation doses among paediatric doctors and final year medical students (Thomas *et al*., 2006; Kada, 2017). Heyer *et al.* (2010) also found that there is poor awareness of radiation dose and its risks among the paediatricians in Germany. In Saudi Arabia, Al-Rammah (2016) too found that there is generally poor knowledge about radiation doses and risks among paediatricians.

In the current study, registrars and medical officer interns performed better than doctors of other ranks did. Generally, younger doctors performed significantly better than their older counterparts did. This is supported by another study in which the fellows performed better than practising paediatricians (Thomas *et al*., 2006). In a study by Salemo and colleagues (2015), younger practitioners had significantly higher correct response rate compared to the older practitioners (Salerno, Marchese, Magistrelli, Tomà, Matranga, Midiri, Ugazio and Corsello, 2015).

Regarding years of experience, there is a significant relationship between the respondents' years of experience and knowledge on radiation safety. Young doctors with less years of experience had higher scores compared to those with more years of experience in their practice. This may be due to retained knowledge from medical training programmes, and gradual loss of basic knowledge as one advances in years. Thomas *et al*. (2006) found that fellows in paediatrics scored higher than practising paediatricians with more years in paediatric practice.

Singh and Fish (2019) argue that doctors in any field should update themselves professionally to keep abreast with evidence-based medicine, upgrading their knowledge and skills in the practice of medicine. The present study found that almost all paediatric doctors (46 out of 47), despite the years of experience had not attended any form of course on radiation protection. Nevertheless, most paediatric doctors participating in this research also recognize the need for continuous training in radiation doses and safety. In a study by Abdellah *et al*. (2016)), 88.8% of the physicians had not received any training on radiation safety. Al-Rammah (2016) also found that 68% of the paediatricians who participated in a survey never had any specific training on ionizing radiation. Similarly, in South Africa, Dauda *et al*. (2019) report that 80% of doctors in a medical university hospital had no prior training on radiation exposure in diagnostic radiological examinations.

Despite not attending courses to update knowledge on radiation protection, some doctors in the current study (12.8%; n=16) still demonstrated sufficient knowledge on radiation safety. Knowledge of radiation safety is critical in the communication of the benefits and risks of requested diagnostic radiological procedures to the parents and patients. Approximately 63% of this cohort did not relate the patients' age to the risk of radiation related cancer. Since most parents are poorly informed about radiation dose and risks related to diagnostic procedures, especially CT scans, it is the responsibility of the requesting doctor to fully inform them when such tests are requested (Jończyk-Potoczna *et al*., 2019). In a study by Larson *et al*. (2007) 99% of parents learnt that CT scan uses ionizing radiation and 86% of them understood that CT increases lifetime risk of developing cancer only after reading a pamphlet that described the risks and benefits of ionizing radiation. In addition to malignancies such as leukaemia mainly due to low dose radiation, exposure to a high dose that is above the range of normal diagnostic imaging examinations may induce acute effects like skin redness, hair loss, and cataracts.

The ALARA principle states that the dose delivered by an X ray examination must be kept as low as reasonably achievable, compatible with the attainment of required diagnostic information (WHO, 2016). Almost half (44.7%; n=21) of the paediatric doctors in the current study were aware of the ALARA principles. This is better than the proportion of doctors in Germany reported in a study by Heyer *et al.* (2010) where only 15% of paediatricians were aware of ALARA principle, as well as in an Egyptian study by Al-Rammah (2016) in which 15% of the respondents were aware of the ALARA principle.

Only 17% of paediatric doctors correctly identified the radiation effective dose received during a chest X-ray examination of a child, which is one of the common imaging procedures performed. This is of great concern because CXR is one of the most requested study. In a study by Heyer *et al.* (2010), 137 paediatricians participated in a survey to assess the awareness of radiation dose and inherent risks in chest imaging studies among paediatricians, of which 59% and 39% correctly estimated effective doses of an adult (0.01-0.1mSv) and that of a newborn (0.01-0.1mSv), respectively. In Egypt, Abdellah, Attia, Fouad and Abdel-Halim (2015) found that 63.8% of participants knew the estimated dose of chest x ray (Abdellah, Attia, Fouad and Abdel-Halim, 2015). In study by Shiralkar *et al*. (2003), they found that only two (1.5%) in 130 participants, knew the correct dose for abdominal x ray.

Significance of background radiation

Background radiation forms an additional burden to patients due to its nature and the inability to control it. Background radiation should be considered when considering the radiation exposure due to medical intent. In South Africa, the annual background radiation dose is 0.07 mSv per year (Bezuidenhout, 2014). Only nine (19.1%) participants in the current study correctly estimated the South African annual background radiation from natural sources. In a study by Partap *et al*. (2019), only 13 (11%) out of 118 respondents knew the normal level of annual background radiation. By contrast, approximately 33.8% of doctors at a South African university hospital correctly estimated the background radiation (Dauda *et al.,* 2019). Similarly, in a study by Kada (2017), 46% of the medical students correctly identified the annual background radiation in Norway.

CT-scan examinations

Only a small percentage of the paediatric doctors, 6.4% and 12.8%, were able to estimate the average dose CT scan of the chest and brain respectively. This is concerning given that CT scans contribute the most to the radiation dose due to medical intent. A significant increase of CT examinations has been reported in paediatric population. Benner and Hall (2007) deduce that the largest increase in use of CT in USA is in the paediatric population.

CT scan has gained favour among paediatric doctors because of its advantages of faster scanning time and less need for sedation. The advanced technology allows for more sophisticated applications and reconstructions (Thomas *et al.*, 2006). Despite the many advantages, the effects of ionizing radiation are detrimental to the growing tissues.

Non-ionizing radiation modalities

Modalities that do not use ionizing radiation such as MRI and ultrasound are the best alternatives that can be used to reduce cumulative radiation doses in paediatrics (Mammas and Spandidos, 2019). The current study reveal generally low knowledge on non-ionizing modalities that could be used as alternative to reduce exposure to radiation. In a Malaysian study, 28 out of 34 (82%) specialists correctly identified that MRI has no risk as that of ionizing radiation, compared to 62% of medical officers (Kew, Zahiah, Zulkifli, Noraidatulakma and Hatta, 2012). In the study by Heyer *et al.* (2010), 86% of paediatricians correctly identified that MRI has no ionizing radiation risk. Thomas *et al*. (2006) also report that 96% of paediatricians in their study knew that ultrasound uses no ionizing radiation. Similarly, Shiralkar *et al.* (2003) found that 92% and 95% of participants correctly identified that MRI and ultrasound, respectively, do not use ionizing radiation. Contrarily, 70% of paediatricians in a study by Al-Rammah (2016) thought that MRI produced ionizing radiation. In the same study, 34% of the respondents assumed that ultrasound uses ionizing radiation (Al-Rammah, 2016).

5.4 CONCLUSION

Knowledge on radiation protection is vital among paediatric doctors. Paediatric patients are known to be more vulnerable to the effects of radiation than adults are. This study suggests that paediatric doctors from Polokwane and Mankweng hospitals have poor knowledge on radiation protection and radiation doses. The inadequate knowledge was neither dependent on years of experience nor the rank. The results are comparable to those of many previous studies that assessed awareness of radiation protection and knowledge of radiation doses in different groups of paediatric doctors. Lack of adequate knowledge on radiation safety and radiation doses among paediatric doctors is particularly of great concern as they play a fundamental role in communicating radiation risk versus benefit with patients and families.

Paediatric doctors, irrespective of the rank, are the first line of contact with patients and their families. They are the first people that paediatric patients are exposed to when they seek medical assistance. As part of management, radiological examinations are ordered to assist in the diagnosis and treatment of the presenting illness. It is therefore crucial that paediatric doctors have adequate knowledge on ionizing radiation protection and its risks, as well as the radiation doses of common studies. It is important for the referring doctor to know about dose optimization. This will improve the dialogue on radiation risk versus benefit with the parents or guardians who might be anxious to allow their children to undergo a radiological procedure like a CT scan. The referring doctor must explain the benefits versus risks and ensure that the radiological examination is justified for diagnostic purposes. This reassures the caregivers and the paediatric patients.

5.5 RECOMMENDATIONS

The following recommendations are made, based on the findings of this study:

- That paediatric doctors will benefit from training courses on radiation safety and radiation doses in order to build a radiation safety culture in their respective hospitals, wards, and clinics.
- An annual update is recommended to re-enforce and update the information on radiation safety among paediatric population.

5.6 CONTRIBUTIONS OF THE STUDY

This research project brought light to the level of knowledge of a majority of paediatric doctors on radiation doses and radiation safety. The research evaluated the level of knowledge of paediatric doctors and the results seem to suggest that the knowledge is poor. The positive element is that majority of the doctors also realized the need to learn and update their knowledge in this aspect.

The findings of this study are a good motivation for commencing regular in-service training programmes for radiation doses and radiation safety for paediatric doctors at Pietersburg and Mankweng Hospitals.

5.7 LIMITATIONS OF THE STUDY

This was a single site research, in paediatric doctors at a public hospital, which can be limited to opinions of different geographic sections of the province. The knowledge of paediatric doctors in the private sector and paediatricians from other hospitals in Limpopo is unknown and remains to be assessed.

The population of paediatric doctors in this study was small, compared to others found in the literature. However, the sample size was sufficient to reach a valid statistical conclusion. A larger study needs to be done using more participants. Paediatric patients are seen by many other clinical specialties. The knowledge on radiation safety and radiation doses should be evaluated in all the disciplines.

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ANNEXURES

ANNEXURE I: Typical effective doses for diagnostic imaging examinations

Table 1. Typical effective doses for diagnostic imaging examinations and their equivalence in terms of number of chest x-rays and duration of exposure to natural background radiation (WHO, 2016).

Diagnostic procedure	Typical effective dose (mSv)	Equivalent period of exposure to natural radiation	Equivalent number of chest x ray
CXR adult	0.02	3 days	1
5-year-old	0.02	3 days	1
CT head adult	1 – 2	10 months	50 – 100
• Newborn	6	2.5 years	300
• 1-year-old	3.7	1.5 years	185
• 5-year-old	2	10 months	100
• 10-year-old	2.2	11 months	110
• Paediatric head CT angiography	5	2 years	250
CT chest – adult	**7**	**3 years**	**350**
• Newborn	**1.7**	**8,6 months**	**85**
• 1-year-old	1.8	9 months	90
• 5-year-old	3	1.2 years	150
• 10-year-old	3.5	1.4 years	175
CT abdomen – adult	**7**	**3 years**	**350**
• Newborn	5.3	2.2 years	265
• 1-year-old	4.2	1.8 years	210
• 5-year-old	3.7	1.5 years	185
• 10-year-old	3.7	1.5 years	185
Nuclear medicine examinations (5-year-old)			
• FDG PET CT	15.3	6.3 years	765
• Tc – 99mcystogram	0.18	1 month	9
• Tc-99m bone scan	6	2.5 years	300
Dental examinations			
• Intra-oral radiography	.005	<1 day	0.25
• Panoramic (dental)	0.01	1.5 days	0.5
• Cranio-facial cone-beam CT	<1h	<5 months	<50
Fluoroscopy-guided paediatric interventional cardiology	Median 6 (range 1 – 37)	2.5 years (range from 5 months to 15 years)	300 (range from 50 to 1850)
Fluoroscopic cystogram (5-years)	0.33	1.7 months	16

ANNEXURE II: Information form for participants

INFORMATION FORM FOR PARTICIPANTS

Dear prospective participant.

A research study is currently being pursued. The research topic is:

KNOWLEDGE OF RADIATION SAFETY AMONGST PAEDIATRIC DOCTORS IN PIETERSBURG AND MANKWENG HOSPITALS

All paediatrics doctors employed in Pietersburg and Mankweng Hospitals are requested to participate in the study.

A questionnaire will be given for you to fill to your best ability. The questionnaire has three sections: demographics, radiation dose and radiation safety.

The demographic details are for epidemiology of the research. The information will be anonymous and confidential. No information provided will be used against any participant in any way. This study is meant to improve the future curriculum as well provide necessary workshops for the other health care workers on ionizing radiation and its risks as well as radiation protection.

Should you feel, at any point that anonymity or confidentiality was bridged, you can contact the researcher as follows"

Cell phone number: 0832528188

E-mail address: mbendlela338@gmail.com.

Your co-operation will be highly appreciated in this regard.

Thank you for your participation.

Researcher: Dr T.M. Bendlela.

ANNEXURE III: Consent form

CONSENT FORM FOR THE RESEARCH OF "KNOWLEDGE OF RADIATION SAFETY AMONGST PAEDIATRIC DOCTORS IN PIETERSBURG AND MANKWENG HOSPITALS"

I -- participant, have read the information pamphlet on above-mentioned research proposal and agree to participate in the research with full confidence in the researcher that my personal details will be kept confidential.

I understand that the questionnaire that I am completing will be solely for the research purposes and not personal gain.

--- signed at -- on ---- -------------------------------------- (date).

ANNEXURE IV: Questionnaire

"KNOWLEDGE OF RADIATION SAFETY AMONGST PAEDIATRIC DOCTORS IN PIETERSBURG AND MANKWENG HOSPITALS"

QUESTIONNAIRE

Demographics

Please fill the following demographic information. In each number, only one mark should be made.

1. Gender: Male □ Female □ Other □
2. Age: 24 – 30 □ 31 – 40 □ 41-50 □ □ >51 □
3. Year of qualification □
4. Profession level: Intern □ Medical officer □ Registrar □ Consultant □
5. Years of experience in current level:
   □ Less than 3 years
   □ 4 – 10 years
   □ 11 – 20 years
   □ More than 20 years

6. How do you rate your knowledge about ionising radiation (IR) and related risks?
   □ Excellent
   □ Good
   □ Sufficient
   □ Insufficient
7. Have you ever attended training events and/or refresher courses on radiation protection?
   □ Yes, frequently
   □ Yes, seldom
   □ No, never

Radiation Protection Knowledge

Choose one most appropriate answer in the following multiple-choice questions or statement.

1. According to your knowledge on radiation safety, is it necessary to advise patients about the risks related to the use of ionizing radiation for medical purposes?
   □ Yes, always
   □ Yes, but only for patients younger than 18 years' old
   □ Yes, but only for patients who are going to a CT scan
   □ Yes, but only for patients younger than 65 years' old
   □ No, never

2. Which of the following patients are the most sensitive to ionizing radiation?
   □ 1-year-old male
   □ 1-year-old female

- 12-year-old female
- 12-year-old male
- Ionizing radiation damage risk is unrelated to patient’s age and sex

3. Which of the following professionals is considered legally responsible for unnecessary exposure to ionizing radiation and/or improperly performed radiological examinations?
   - Only the referring physician
   - Only the radiologist
   - Only the medical specialist (other than radiologist) performing interventional
   - Radiology procedures.
   - Only the radiographer
   - All answers are correct.

4. Which of the following professionals are likely to be exposed to MORE ionizing radiation because of their job?
   - Nuclear medicine physicians
   - Radiographers
   - Interventional radiologists
   - Non-interventional radiologists
   - Surgeons

5. Which of the following tissues are more susceptible to ionizing radiation damage in a child (1 – 12y)?
   - Brain
   - Bladder
   - Bone marrow
   - Skin
   - Liver

6. Which of the following diseases may be a result of ionizing radiation damage?
   - Dermatitis
   - Leukaemia
   - Alopecia
   - Cataract
   - All answers are correct

7. Which of the following statements are true?
   - Ionizing radiation-based examination should be prescribed and performed only when indispensable.
   - The dose delivered by ionizing radiation-based examinations must be kept as low as reasonably achievable, consistent with obtaining the required diagnostic information.
   - The scan volume for ionizing radiation-based examinations should be as large as possible, so as to maximise diagnostic information from a single acquisition.

□ An ionizing radiation-based examination is optimized when resolution is maximized to assess even the finest image details.

□ All answers are correct.

8. The following are personal protective equipment to minimize staff exposure to ionizing radiation, except
   □ Lead goggles
   □ Lead aprons
   □ Thyroid shield
   □ Theatre protective gown

9. Who are the stakeholders to involve in training programmes on radiation dose and radiation safety?
   □ Referring physicians
   □ Radiologists
   □ Radiographers
   □ Nursing staff
   □ All of the above

Radiation Dose Assessment

(For each question, dose refers to an examination performed with state-of-the-art equipment)

1. Which is the average radiation dose of a single chest radiograph?
   □ Less than 0.01 mSv
   □ 0.01– 0.1 mSv
   □ 1 – 10 mSv
   □ 10 – 100mSv
   □ I don’t know

2. If a single chest radiograph counts as 1 unit (U), how much is the average dose due to natural background in South Africa?
   □ 0
   □ 1– 10 U
   □ 10-50 U
   □ 50-100 U
   □ 100-500 U
   □ I don’t know

3. If a single chest radiograph counts as 1 unit, how much is the average dose due to an abdominal x-ray examination?
   □ 0
   □ 1– 10 U

- ☐ 10-50 U
- ☐ 50-100 U
- ☐ 100-500 U
- ☐ I don't know

4. If a single chest radiograph counts as 1 unit, how much is the average dose due to non-contrast chest CT examination?
   - ☐ 0
   - ☐ 1– 10 U
   - ☐ 10-50 U
   - ☐ 50-100 U
   - ☐ 100-500 U
   - ☐ I don't know

5. If a single chest radiograph counts as 1 unit, how much is the average dose due to non-contrast brain CT examination?
   - ☐ 0
   - ☐ 1– 10 U
   - ☐ 10-50 U
   - ☐ 50-100 U
   - ☐ 100-500 U
   - ☐ I don't know

6. If a single chest radiograph counts as 1 unit, how much is the average dose due to MRI pelvic examination?
   - ☐ 0
   - ☐ 1– 10 U
   - ☐ 10-50 U
   - ☐ 50-100 U
   - ☐ 100-500 U
   - ☐ I don't know

7. If a single chest radiograph counts as 1 unit, how much is the average dose due to abdominal ultrasound examination?
   - ☐ 0
   - ☐ 1– 10 U
   - ☐ 10-50 U
   - ☐ 50-100 U
   - ☐ 100-500 U
   - ☐ I don't know

ANNEXURE V: Ethics clearance certificate

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Department of Research Administration and Development
Private Bag X1106, Sovenga, 0727, South Africa
Tel: (015) 268 3766, Fax: (015) 268 2306, Email:makoetja.ramusi@ul.ac.za

TURFLOOP RESEARCH ETHICS COMMITTEE

ETHICS CLEARANCE CERTIFICATE

MEETING: 17 February 2021

PROJECT NUMBER: TREC/31/2021: PG

PROJECT:

Title:	Knowledge of radiation safety amongst *paediatric* doctors in Pietersburg and Mankweng hospitals
Researcher:	TM Bendlela
Supervisor:	Dr F Ooko
Co-Supervisor/s:	Dr C Nkabinde
School:	Medicine
Degree:	Master of Medicine in Diagnostic Radiology

PROF P MASOKO
CHAIRPERSON: TURFLOOP RESEARCH ETHICS COMMITTEE
The Turfloop Research Ethics Committee (TREC) is registered with the National Health Research Ethics Council, Registration Number: **REC-0310111-031**

Note:

i) This Ethics Clearance Certificate will be valid for one (1) year, as from the abovementioned date. Application for annual renewal (or annual review) need to be received by TREC one month before lapse of this period.

ii) Should any departure be contemplated from the research procedure as approved, the researcher(s) must re-submit the protocol to the committee, together with the Application for Amendment form.

iii) PLEASE QUOTE THE PROTOCOL NUMBER IN ALL ENQUIRIES.

Finding solutions for Africa

ANNEXURE VI: Department of Health permission

LIMPOPO
PROVINCIAL GOVERNMENT
REPUBLIC OF SOUTH AFRICA

DEPARTMENT OF HEALTH

PIETERSBURG/MANKWENG RESEARCH ETHICS COMMITTEE (PMREC)

ENQUIRIES: Mr MA POOPEDI **DATE: 21 April 2021**

MANAGER: CLINICAL RESEARCH

ananiaspoopedi@gmail.com

REFERENCE	:	**PMREC 21APRIL UL2021/A**
Date	:	**20 April 2021**
RESEARCHER	:	**Dr TM Bendlela**
		(PRINCIPAL INVESTIGATOR)
RESEARCH	:	**Post-graduate Research**
DEPARTMENT	:	**Diagnostic Radiology**

Project Title: Knowledge of radiation safety amongst paediatric doctors in Pietersburg and Mankweng hospitals.

Candidate: Dr TM Bendlela

Approval Status: Approved

The candidate is advised to consider the following minor insertions to the proposal:

- The candidate is advised to use problem statement instead of statement of the problem.
- The candidate may consider describing Her/His study as quantitative cross-sectional descriptive study.
- The candidate is advised to add a second research question that speaks to the second objective.
- The candidate is required to state 'under sampling' that a census sample/total population sampling will be used.
- The study is about measuring knowledge; hence these measures should be clearly articulated as part of the methods section. "A slot in an academic meeting will be requested for the filling of the questionnaire, where all doctors will be alerted in advance about the research" and to plead for "individual work" is not enough"

Signed :

PROF TAB MASHEGO

Prof TAB Mashego, PhD
Chairperson: Pietersburg/Mankweng Complex Research Ethics Committee
School of Medicine
University of Limpopo
REC 300408-006

ANNEXURE VII: Permission from Pietersburg Hospital

LIMPOPO
PROVINCIAL GOVERNMENT
REPUBLIC OF SOUTH AFRICA

DEPARTMENT OF HEALTH

PIETERSBURG HOSPITAL

REF : 4/2/2

ENQ : MOLOKOMME N

TO : DR TM BENDLELA
PRINCIPAL INVESTIGATOR

FROM : MR PJ RAMAWA
ACT CEO: PIETERSBURG HOSPITAL

DATE : 17 SEPTEMBER 2021

RE: REQUEST FOR RESEARCH

1. The above matter refers.
2. Your request to conduct research is hereby granted.
3. You will be expected to avail the report to the institution upon completion.

Thanking you in advance

17 - Sept - 2021

MR PJ RAMAWA

ACTING CHIEF EXECUTIVE OFFICER

PIETERSBURG HOSPITAL

DATE

ANNEXURE VIII: Permission from head of Paediatrics department

ANNEXURE VIII

LIMPOPO
PROVINCIAL GOVERNMENT
REPUBLIC OF SOUTH AFRICA

DEPARTMENT OF HEALTH

PIETERSBURG & MANKWENG HOSPITAL

Department of Paediatrics and Child Health, Pietersburg and Mankweng Hospital
Phone: +27-15-2861000, +27-15-2875432

3rd May 2021

Dr TM Bendlela
Department of Diagnostic Radiology
Pietersburg Hospital

Re: Knowledge of Radiation Safety amongst Paediatric Doctors in Pietersburg and Mankweng Hospitals

1. Thank you for your request to conduct this research.
2. Permission is hereby granted to approach the doctors working in the Department of Paediatrics and Child Health for their individual consent to participate in the study.
3. Good luck with your MMed.

Yours Sincerely

Professor Chris Sutton
Paediatric Specialist
Acting Head of Department
Paediatrics and Child Health
Pietersburg and Mankweng Hospitals

EXCELLENCE IS OUR PASSION

CNR DORP AND HOSPITAL STREET, PRIVATE BAG X 9316, POLOKWANE, 0700 TEL: (015) 287 5000, FAX: (015) 297 2604

4 (1) The heartland of Southern Africa – *development is about people*

ANNEXURE IX: Permission from head of Paediatrics surgery department

ANNEXURE IX

LIMPOPO
PROVINCIAL GOVERNMENT
REPUBLIC OF SOUTH AFRICA

DEPARTMENT OF HEALTH

PIETERSBURG & MANKWENG HOSPITAL

Department of Paediatric Surgery, Pietersburg and Mankweng Hospital
Phone: +27-15-2861000, +27-15-2875000

3rd May 2021

Dr TM Bendlela
Department of Diagnostic Radiology
Pietersburg Hospital

Re: Knowledge of Radiation Safety amongst Paediatric Doctors in Pietersburg and Mankweng Hospitals

1. Thank you for your request to conduct this research.
2. Permission is hereby granted to approach the doctors working in the Department of Paediatric surgery for their individual consent to participate in the study.
3. I wish you all the best in your endeavour.

Yours Sincerely

Dr. Motloung
Paediatric Surgeon
Acting Head of Department
Paediatric surgery Department
Pietersburg and Mankweng Hospitals

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ANNEXURE X: CERTIFICATE FROM LANGUAGE EDITOR

N J Nel
PO Box 365,
BENDOR
PARK 0713

Tel: 074184
9600

CERTIFICATE

This serves to certify that I have language edited the Dissertation of

Dr Takalani Masala Bendlela

Student number [redacted]

entitled:

"KNOWLEDGE OF RADIATION SAFETY AMONGST PAEDIATRIC DOCTORS IN PIETERSBURG AND MANKWENG HOSPITALS"

N J Nel

Lecturer of English, Department Applied Languages
Tshwane University of Technology
(Retired)

6 Sept

2021

ANNEXURE XI: permission from head of diagnostic radiology department

LIMPOPO
PROVINCIAL GOVERNMENT
REPUBLIC OF SOUTH AFRICA

DEPARTMENT OF HEALTH
PIETERSBURG & MANKWENG HOSPITAL

Department of Diagnostic Radiology, Pietersburg and Mankweng Hospital Phone: +27-15-287 5121, +27-15-287 5000

3rd May 2021

Dr TM Bendlela
Department of Diagnostic Radiology
Pietersburg Hospital

Re: Study on Knowledge of Radiation Safety amongst and Radiation doses amongst Paediatric Doctors in Pietersburg and Mankweng Hospitals

1. Thank you for your request to conduct this research.
2. Permission is hereby granted to approach the doctors working in the Department of Paediatrics and Child Health for their individual consent to participate in the study.
3. Good luck with your MMed.

Yours Sincerely

Dr Sithole SF
Diagnostic Radiology
Acting Head of Department
Pietersburg and Mankweng Hospital Complex

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