Nurses' knowledge of radiation protection in medicine: a review of literature

O Bwanga
Midland Regional Hospital at Tullamore, Radiology Department, Co. Offaly, Ireland
Corresponding author, email: o.bwanga@yahoo.com

Nurses are vital in the management of patients for diagnostic imaging examinations. Some nurses work in radiology departments and others assist radiographers during mobile and theatre radiography. In recent years, there has been a role extension in nursing. Some nurses working in the United Kingdom (UK) and Ireland are referring patients for radiological examinations, a role which was traditionally that of medical doctors. This work involves ionising radiation which is harmful to the human body. Therefore, it is essential that nurses understand the measures needed to protect patients, members of the public and themselves from ionising radiation. The primary aim of this article is, therefore, to review nurses' knowledge of radiation protection in medicine. The literature search was conducted in three databases: ScienceDirect, PubMed/MEDLINE and CINAH, as well as hand searching. Ten primary research studies were identified, selected and included in this review. In general, this review found that nurses are not adequately aware of radiation protection. There is a need to integrate this subject into the nursing curriculum and to provide continuing professional development (CPD) to nurses.

Keywords: knowledge, awareness, nurse, radiation, radiation protection

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Introduction

Radiation is used in medicine for diagnosis and treatment of diseases and injuries. It is divided into ionising and non-ionising radiation. Ionising radiation refers to electromagnetic radiation photons which have enough energy to produce ionisation.[1,2] In other words, ionising radiation interferes with cell production and can destroy the cell function.[3,4] Most diagnostic imaging modalities use ionising radiation and include general radiography, fluoroscopy, computed tomography (CT), nuclear medicine (NM), mammography and Positron Emission Tomography/Computed Tomography (PET/CT). On the other hand, non-ionising radiation is any type of electromagnetic radiation that does not have enough energy to cause ionisation.[1] The two diagnostic imaging modalities that use non-ionising radiation are ultrasound (US) and magnetic resonance imaging (MRI). Radiation protection refers to measures taken by health professionals to protect themselves, patients, other clinical staff and members of the public from the harmful effects of ionising radiation.

Nurses are essential in the management of patients. In recent years, their scope of practice has been expanded to allow them to take on some roles traditionally undertaken by medical doctors, for example nurses in the UK and the Republic of Ireland are now entitled to refer patients for radiological examinations.[5,6] There is reason to believe that this change in the nurse's scope of practice will soon be introduced in Africa and the rest of the world. Therefore, nurses with the responsibility of requesting radiological examinations must be knowledgeable and must apply the justification principle of radiation protection. For the radiological examination to be justified, the benefits to the patient being exposed to ionising radiation should outweigh the risk of the medical exposure. This means avoiding unnecessary radiological referrals.

Nurses also work in clinical settings where ionising radiation is used, such as radiology departments, operating theatres, intensive care units (ICU) and hospital wards. In all these areas, nurses offer care to patients before, during and after radiological examinations. During mobile radiography carried out on critically ill patients who are unable to come to the radiology department, radiographers and nurses work together in positioning patients for the radiological examinations. Therefore, all nurses working in these areas should understand the practical control measures for minimising external radiation exposure: time, distance and shielding. Reducing the time of exposure to radiation, maintaining a greater distance from the radiation source, and the use of shielding minimise exposure to external radiation.[7,8] Their understanding of these three principles will help nurses provide quality patient care and protect themselves from the harmful effects of ionising radiation.

Several research studies have been conducted on this subject globally. The aim of this article, therefore, is to review nurses' knowledge of radiation protection in medicine by bringing the findings of these primary research studies together. The review findings have provided information on where to base the development of a radiation protection curriculum and awareness programmes for nurses.

Methods

A literature search was conducted in December 2019 to identify research studies on the knowledge nurses have of radiation protection. This involved a three-stage search strategy: electronic database search, manual search in professional journals and cited references search. Firstly, an electronic search was performed in three databases: PubMed/MEDLINE, Cumulative Index to Nursing and Allied Health Literature (CINAHL) and ScienceDirect, using the keywords "nurses", "radiation protection", "awareness", and "knowledge". These are the main databases for healthcare professional literature. Secondly, hand searches of nursing and radiography journals, and the internet (Google) were carried out to supplement the electronic database searches. The journals searched included Journal of Radiology Nursing, Open Journal of Nursing, Radiography Ireland and Radiography Journal. Thirdly, manual searching of bibliographies of identified primary research studies was also conducted to avoid missing any relevant articles on this subject.

This review included primary research studies that investigated the knowledge or awareness of nurses regarding radiation protection in medicine. These studies were limited to primary research studies written in the English language, with no time limit. There were no location restrictions; all research conducted globally was included in this review. Expert opinions, reviews, case reports and research studies conducted on health professionals other than nurses were excluded for this review.

Results

The initial literature search provided a total of 666 articles (659 from databases and seven from other sources). After removing four duplicates and applying the inclusion criteria to the titles, abstracts and full texts, ten primary research studies remained and were included in this review. The literature search strategy is shown in Figure 1.

The ten research studies included in this review were conducted in Finland (*N* = 1), Australia (*N* = 1), Saudi Arabia (*N* = 1), Iran (*N* = 1), South Africa (*N* = 1), Malawi (*N* = 1), Kuwait (*N* = 1), Ghana (*N* = 1), and Nigeria (*N* = 2). The rest of the characteristics of the included research studies are summarised in Table I.

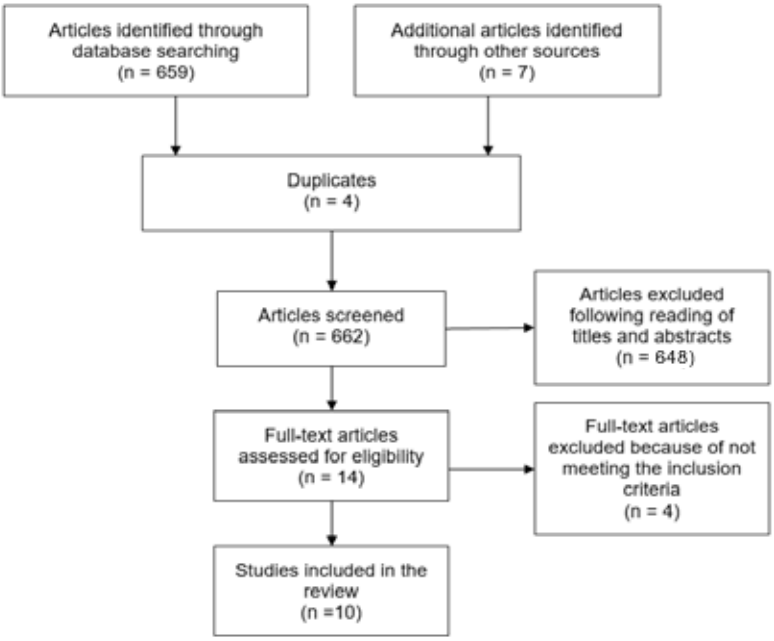

Figure1: Flow chart showing literature search strategy

Discussion

Six areas of radiation protection in medicine were identified in this review: sources of ionising radiation, benefits of ionising radiation in medicine, biological effects of ionising radiation to the human body, principles of radiation protection, control measures for external radiation exposure, populations most vulnerable to ionising radiation, and education and training in radiation protection.

Sources of ionising radiation

Two research studies examined the knowledge of nurses regarding the sources of ionising radiation. In a research study by Maliro,[10] the majority (54%), of nurses were unfamiliar with the sources of ionising radiation. Daily, people are exposed to natural and man-made radiation sources. Natural background radiation comes from many sources, including more than 60 naturally occurring radioactive materials found in the soil, water and air.[2] Radon, a colourless and odourless gas is the main source of natural radiation.[8] Humans have less control over natural radiation. In addition to the natural sources of background radiation, many man-made sources of radiation have been introduced since the discovery of X-radiation and radioactivity at the end of the nineteenth century.[2,8] The use of radiation for medical examinations contributes to over 95% of man-made radiation exposure.[18,19] In radiography, X-radiation is only emitted during the exposure. However, less than half (25.6% and 37.2% respectively) of nurses in a research study by Anim-Sampong et al.,[11] believed that objects in the X-ray room and patients do emit radiation after X-ray exposure. In the same research study, the majority (60.5%), of nurses wrongly believed that MRI modality uses ionising radiation. As discussed earlier in the introduction, MRI and US are the only two imaging modalities which use non-

Table I: Characteristics of included research studies (*N* = 10)

No	Author	Year	Title	Main findings	Country
1	Alotaibi and Saeed[9]	2006	Radiology nurses' awareness of radiation	Most nurses were not aware of radiation risks and the most important aspect of radiation protection.	Kuwait
2	Maliro[10]	2011	Ionising radiation protection awareness among nurses working at Queen Elizabeth Central Hospital of Malawi	There was a general lack of knowledge about the main sources of ionising radiation, possible radiation hazards, ionising radiation protection methods, and the meaning of the ALARA concept.	Malawi
3	Anim-Sampong et al.[11]	2015	Nurses knowledge of ionising radiation and radiation protection during mobile radiodiagnostic examinations	25.6% and 37.2% of nurses were of the view that objects in the X-ray room and patients emit radiation after an X-ray exposure respectively. Most (60.5%) nurses believed that MRI procedures are a source of ionising radiation.	Ghana
4	Badawy et al.[12]	2016	An assessment of nursing staffs' knowledge of radiation protection and practice	The average score on the nurses' knowledge of radiation protection was 40%, and 85% of nurses believed that there is a need for radiation safety training.	Australia
5	Luntsi et al.[13]	2016	Assessment of knowledge and attitudes of nurses towards ionising radiation during theatre and ward radiography	Nurses had good knowledge of ionising radiation and about 60.4% knew the sources, benefits and the potential harm of ionising radiation.	Nigeria
6	Paulinus et al.[14]	2016	Evaluation of nurses' knowledge of radiation protection practice: A case study of two hospitals in Calabar, Nigeria	50% of nurses had adequate knowledge of benefits of radiation in medicine, 35.5% identified the need to use a lead apron for protection, 40.5% knew time, distance and shielding as protective measures and 90% had no knowledge on regulations covering this area, with poor attendance on radiation protection training.	Nigeria
7	Alzubaidi et al.[15]	2017	Assessment of knowledge and attitude of nurses towards ionising radiation during radiography in Jeddah city	Most (65%) nurses had adequate knowledge regarding the ionising radiation risk factors and protective measures.	Saudi Arabia
8	Azimi et al.[16]	2018	Individual protection adopted by ICU nurses against radiation and its related factors	The majority (97.9%) of nurses had not attended any radiation protection training. More than half (62.7%) had poor knowledge of personal protection against radiation.	Iran
9	Hirvonen et al.[17]	2019	Nurses' knowledge of radiation protection: A cross-sectional study	Nurses had high knowledge levels in radiation protection, but low in radiation physics, biology and principles of radiation use. Nurses who had not received radiation education scored lower than those who had received education in radiation safety.	Finland
10	Thambura et al.[18]	2019	Nurses' knowledge of ionising radiation in Northern Gauteng State Hospitals in South Africa	50% of nurses lacked basic knowledge on the principles of radiation safety, and more than half (63%) of nurses did not receive radiation safety training.	South Africa

ionising radiation: using magnetic fields and sound waves respectively. Humans have control over artificial sources of radiation by applying control measures. In general, this review found that nurses are poorly informed on the sources of ionising radiation.

Benefits of ionising radiation in medicine

Two research studies assessed the knowledge of nurses on the benefits of radiation in medicine. In a research study by Paulinus et al.,[14] a quarter (24%) of the nurses knew the use of radiation for diagnosis and treatment. In a similar research study conducted by Maliro,[10] about 60% and 29.9% of nurses respectively knew the diagnostic and therapeutic uses of radiation. Since the discovery of X-radiation in 1895, ionising radiation has been used in many branches of medicine, as both an aid to diagnosis and as a means of therapy.[8] The main therapeutic application of radiation is in the treatment of cancer. Although radiation can induce cancer, in some cases it can be used to treat the disease. This is because cells that are dividing rapidly are particularly sensitive to radiation and, as cancers are groups of cells dividing in an uncontrolled manner, it follows that they are often more sensitive to radiation than normal cells.[8] According to the World Health Organization (WHO),[2] approximately 3 600 million radiological examinations are performed globally, and 7.5 million radiotherapy treatments are given each year. In general, this review found that nurses are more aware of the diagnostic than therapeutic uses of radiation.

Biological effects of ionising radiation

The biological effects of ionising radiation became apparent very soon after the discovery of X-radiation.[8] However, in research studies by Anim-Sampong et al.[11] and Luntsi et al.,[13] about 91% and 16.5% of nurses respectively, indicated that ionising radiation is not harmful to the human body. This unawareness amongst some nurses is a concern

regarding radiation protection. The biological effects of ionising radiation is divided into deterministic and stochastic effects.[3,8,19,20] The International Commission on Radiation Protection (ICRP)[3] describes the deterministic effects as those which occur due to the killing of large parts or the malfunction of cells following high radiation doses. As a result, the cell deaths cannot be compensated by increased natural cellular proliferation. In a research study by Alzubaidi et al.,[15] most of the nurses had adequate awareness of the clinical symptoms of deterministic effects: acute radiation sickness (53%), skin erythema (64.3%), eye cataracts (55.3%), and infertility (59.7%). However, in a research study by Paulinus et al.,[14] only 16.5% of the nurses knew the clinical examples of deterministic effects: skin injuries, hair loss and sterility. On the other hand, the ICRP[3] describes stochastic effects as those which originate due to the mutation of somatic cells or heritable disease in the offspring of exposed individuals owing to the mutation of reproductive cells. In a research study by Alotaibi and Saeed,[9] the majority (83%), of nurses knew cancer to be one clinical example of stochastic effects. However, a limited number (16.5% and 21%) of the nurses knew cancer to be a stochastic effect in the research studies done by Paulinus et al.[14] and Maliro,[10] respectively. Cancer which is caused by radiation is referred to as radiation-induced cancer. In general, this review found that most nurses are aware of the clinical examples of deterministic and stochastic effects of radiation.

Principles of radiation protection in medicine

There are three important principles which form the foundation of radiation protection: justification, optimisation, and dose limitations.[3,4] In this review, three research studies[9,10] investigated nurses' knowledge of the principles of justification and dose optimisation. These two principles apply to patients undergoing radiological examinations, while the dose limitation is applicable to health professionals, such as radiographers, radiologists, and radiology nurses as well as members of the public.

One research study by Paulinus et al.[14] evaluated nurses' knowledge of the justification principle of radiation protection. In this research study, a quarter (26.5%) of nurses were aware that radiation is harmful to the human body and should only be used if it is beneficial to the patient. Nurses with the responsibility of referring patients for radiological examinations should understand and adhere to this principle. Worryingly, it is estimated that up to 50% of radiological examinations may not be justified.[4] According to the College of Radiologists,[21] the common causes of unjustified or unnecessary medical exposures include poor knowledge of radiation doses, wrong investigations and over investigating, repeating investigations which have already been done and investigating too early. Unnecessary medical exposures may also arise due to the non-availability of non-ionising imaging modalities, such as US and MRI. This can lead to patients who require these services being referred for alternative ionising imaging examinations.

Two research studies examined the knowledge of nurses on the optimisation principle of radiation protection. In research studies done by Alotaibi and Saeed[9] and Maliro,[10] only 12% and 11.8% of nurses respectively, were familiar with the principle of optimisation. All medical exposures should be shown to be optimised.[3,8] This means that for radiological examinations, the level of exposure should be as low as reasonably practicable (ALARP). Optimising medical exposure is mostly the responsibility of imaging professionals, such as radiographers and radiologists. Nurses accompanying patients to the radiology department and those involved in mobile radiography should work together with radiographers in positioning, immobilising and giving instruction to patients for quality images to avoids repeats, which can further expose patients to unnecessary radiation.

In this review, there was no research study which evaluated the knowledge of nurses on the third principle of dose limitation. The total radiation dose to any individual from regulated sources in planned exposure situations, other than medical exposure of patients, should not exceed the appropriate limits specified by the ICRP (Table II).

Table II: Recommended occupational dose limits[3]

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

The principle of dose optimisation does not apply to patients undergoing radiological examination. To patients the focus is on justifying and optimising medical exposures.

Control methods for external radiation in medicine

The external ionising radiation exposure arises from sources of radiation outside the body, such as X-ray machines. There are three practical methods of controlling the external ionising radiation exposure: time, distance and shielding.[2,7,8] For nurses working in hospital wards, special care units (SCU), accident and emergency (A&E) departments and operating theatres, these three control measures are important during mobile radiography and fluoroscopic intraoperative imaging. But it is not always possible to apply all three methods at the same time.

In research studies performed by Anim-Sampong et al.[11] and Paulinus et al.,[14] more than half (59.5% and 60.5% respectively) of nurses were unfamiliar with the basic radiation protection measure of time factor. Interestingly, in a research study by Alotaibi and Saeed,[9] only 38% of nurses were unfamiliar with the time factor. The dose from a radiation source is directly proportional to the amount of time an individual is exposed to ionising radiation.[8,22] In theatre radiography, this means that the longer the fluoroscopy time, the more radiation

exposure to the patient and theatre staff. The application of the time factor in theatre radiography is achieved by ensuring the rotation of staff members between cases for everyone to have less exposure time.

In this review, four research studies assessed the knowledge of nurses regarding the radiation-safe distance. In the research study by Azimi et al.[16] and Luntsi et al.,[13] the majority of nurses (85% and 75.5% respectively) were familiar with the principle of reducing exposure by increasing the distance from the radiation source. On the other hand, most of the nurses (60.5% and 81% respectively) were not knowledgeable about this principle in the research studies by Anim-Sampong et al.[11] and Thambura et al.[18] The amount of radiation exposure one receives is inversely related to the distance one is from the source, such as the X-ray machine.[8,22] This is called the inverse square law. In mobile and theatre radiography, staff members can reduce exposure from radiation by keeping as far back from the X-ray machine as is practicable.

Five research studies assessed nurses on the principle of shielding. Protection with shielding is provided by fixed protective barriers or personal protective clothing. In the research studies conducted by Anim-Sampong et al.[11] and Paulinus et al.,[14] most of the nurses (60.5% and 59.5% respectively) were unfamiliar with the third method of controlling external radiation exposure by means of shielding. However, in the research study by Alotaibi and Saeed,[9] the majority (69%) of nurses were familiar with this principle. The amount of exposure decreased by shielding varies according to the energy of the X-radiation and the thickness of the shield.[7] The four main types of personal protective clothing available in radiation protection include lead aprons, thyroid shields, lead gloves and lead glasses. These, when worn, decreases radiation exposure to body organs. In a research study conducted by Luntsi et al.,[13] the majority (84.5%) of nurses were aware of the use of lead aprons to minimise external radiation exposure. However, in another similar research study by Alzubaidi et al.,[15] most nurses were unfamiliar with the use of lead gloves (54%) and thyroid shields (58%) as radiation personal protective clothing. It should be mentioned that specific personal protective clothing should always be worn by an individual when remaining in a radiation field if they cannot stand behind a mobile or fixed protective screen. Lead is used in shielding because its properties and thickness are capable of absorbing ionising radiation.[8] Shielding by wearing a lead apron is necessary during mobile/theatre radiography or when staff need to support a patient during exposure.

Population most vulnerable to ionising radiation

One research study assessed the knowledge of nurses on the most vulnerable population group to ionising radiation. In a research study by Alotaibi and Saeed,[9] the majority (83%) of nurses were unfamiliar with the 10-day pregnancy rule and less than half (35%) identified the foetus as the most sensitive to ionising radiation. Globally, radiation protection regulations prohibit the carrying out of a medical exposure involving the pelvic area of a female of child-bearing age without an enquiry as to whether the patient could be pregnant.[3,23] The 10-day pregnancy rule states that whenever possible, radiological examinations of the pelvis may only be performed in the first 10 days of the menstrual cycle. This is because conception can take place between 12 to 14 days of the menstrual cycle. This measure is in place to protect the foetus from harmful exposure to ionising radiation.

The biological effect of ionising radiation on the human body depends on the age of the individual and the radiosensitivity of the tissue exposed.[4,8] Foetuses, infants and children are more vulnerable to ionising radiation than adults due to a higher sensitivity of the developing organs and tissue.[24] In addition, this population group has a longer lifespan in which to develop and manifest long-term radiation induced health effects, such as cancer.[4] This means that the development of cancers from X-ray exposure in infants and children is significantly higher than in adults. Therefore, more attention should be given to female patients of childbearing age and paediatric patients in the justification of exposure and in keeping the level of exposure as low as reasonably practical.

Education and training in radiation protection

All included research studies in this review recommended the training of nurses in radiation protection. A research study conducted by Hirvonen et al.,[17] revealed that in Finland, nurses working in clinical environments where radiation is used undergo training before taking up the role. The same study further revealed that 65% of nurses had completed radiation protection training and were more knowledgeable than those who did not receive training. The knowledge levels of nurses in this review was below average and most nurses suggested the need for training in radiation safety.[9,12,16,18] The suggestions included the integration of radiation protection into the nursing curriculum and the undertaking of CPD learning activities to keep up to date with any developments in this area.[18] This review reveals that nurses should acquire knowledge of radiation protection during their undergraduate or postgraduate education and kept up to date through CPD learning activities. The ICRP[25] recommends that all health professionals utilising radiation should study radiation protection as part of their curriculum. This includes nurses who are cardinal in providing patient care and who now refer patients for diagnostic imaging.

Conclusion

This review revealed that nurses are essential in the management of patients undergoing radiological examinations. However, there is a general lack of knowledge amongst nurses regarding radiation protection used in radiological examinations. There is a need to integrate radiation protection in the nursing curriculum. Furthermore, imaging professionals, such as radiographers and radiologists should set up radiation awareness programmes

for non-radiology staff. The acquiring of knowledge by nurses through education would lead to a change in attitude and adherence to radiation protection control measures. This is because there is a linear relationship between knowledge, attitudes and practices.[26]

Conflict of interest

The author declares no conflict of interest.

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