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Fetal Dosimeter Access, Usage, and Training Among Pregnant Radiographers in South Africa

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A B S T R A C T

Background: Pregnant radiographers require more stringent occupational safety monitoring through fetal dosimetry because of the sensitivity of their fetuses' cells to radiation. This study aims to describe fetal dosimetry among pregnant radiographers as regards access, usage, and training.
Methods: Quantitative data were collected using an electronic national survey. The study collected 89 responses from pregnant and previously pregnant radiographers in South Africa between January 2021 and April 2021.
Findings: The responses revealed that 53.9% (n = 48) of participants had never been issued with a fetal dosimeter. This situation was mostly attributed to the employer and financial constraints (n = 29). Of those with access to fetal dosimeters, 46.1% (n = 41), only 56% (n = 28) indicated that they always wore it. An alarming 52% (n = 26) never consistently recorded fetal doses.
Discussion: Most pregnant South African radiographers do not have access to fetal dosimeters. Many of them remain noncompliant, which might be attributed to a lack of training and knowledge about the device.

Introduction

Radiation workers practice in potentially hazardous environments within radiology departments as a result of ionizing radiation used for diagnostic medical imaging (Sherer et al., 2017). Pregnant radiographers are considered high-risk individuals due to the increased sensitivity of the fetus's developing cells (International Atomic Energy Agency, 2022). Exposure to radiation has the potential to cause genetic effects and cancer within the fetus, depending on the amount of radiation dose received. A primary method of ensuring that occupational radiation doses remain within regulatory limits is through occupational radiation dose monitoring (American Association of Physicists in Medicine, 2019). This is achieved through personal dosimeters, also known as fetal dosimeters, which are worn by pregnant radiographers and provide real-time radiation dose measurements. A situational analysis done to investigate compliance of fetal dosimeters revealed that many pregnant radiographers, particularly in South Africa, lack support with regard to the training on the use of the dosimeter as well as consistent record-keeping of the fetal dose measurement. This barrier renders the device as ineffective and hazardous to both mother and the unborn child. Mobile applications offer a wide range of benefits and are often inculcated within an individual's life to ensure effective monitoring of any health needs.

Introduction

Radiation workers practice in radiology departments where they may be exposed to ionizing radiation used for diagnostic medical imaging (Sherer et al., 2017). Due to the increased sensitivity of a fetus's developing cells to radiation, pregnant radiographers are a category of radiation workers whom the International Committee on Radiation Protection (ICRP) (International Committee of Radiation Protection, 2000) and the International

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Atomic Energy Agency (IAEA) (International Atomic Energy Agency, 2022) designate to be prioritized for receiving radiation protection. This includes increased surveillance of the radiation exposure of both the pregnant radiographer and her fetus. The purpose of this paper is to report on fetal dosimetry in terms of access, usage, and training, particularly among pregnant radiographers in an upper-to middle-income country in sub-Saharan Africa.

In 2019, the American Association of Physicists in Medicine (AAPM) released a statement declaring that radiation doses used in diagnostic imaging are not associated with measurable harm to the gonads or fetus (American Association of Physicists in Medicine, 2019). Prashar, (2020) supported this statement and indicated that it is safe for pregnant radiographers to work in radiation environments, provided they practice safe radiation protection principles. The ICRP concurred, yet stated that this recommendation was based on the provision that fetal radiation doses are reasonably and accurately estimated and fall within the recommended limit of one millisieverts (1 mSv) (International Committee on Radiation Protection, 2000). This recommended threshold was established as relatively safe exposure that would not have considerable radiation-induced effects on a fetus.

Harmful Effects of Ionizing Radiation on a Fetus

The effects of radiation doses can be categorized as either deterministic or stochastic (Bushong and Facmp, 2020). Deterministic detrimental effects associated with excessively high radiation doses include pregnancy loss, malformation, developmental delay, and carcinogenesis (Yoon and Slesinger, 2019). Stochastic effects include probable effects resulting from low radiation exposure, since such effects can potentially cause genetic damage (Bushong and Facmp, 2020). According to the American Association of Physicists in Medicine, the radiation doses used in diagnostic radiography are sufficiently low not to pose any significant threat to the fetus of a patient (American Association of Physicists in Medicine, 2019). However, a distinguishing factor between pregnant patients and pregnant radiographers is the accumulated dose that a pregnant radiographer incurs during occupational work exposure. The risk of stochastic effects is heightened during the development of the fetus; therefore, it is important for a pregnant radiographer to monitor her fetal dose to ensure that threshold limits, as recommended by the ICRP (International Committee on Radiation Protection, 2000), are not exceeded. This monitoring is achieved by using fetal dosimeters.

Fetal Dosimetry

Thermoluminescent dosimeters (TLDs) are commonly used by radiography personnel and are considered passive dosimeters, whereby the exposure readout is only available after processing (Izewska and Rajan, 2005). However, pregnant radiographers must monitor radiation doses to their fetuses stringently and are thus required to use personal real-time dosimeters, also known as fetal dosimeters (Mohd Ridzwan et al., 2021; South African Health Products Regulatory Authority, 2022a). Radiation doses from these dosimeters can be viewed immediately through a visual display, rendering it more effective than TLDs at mitigating high exposure to irradiation (Butcher et al., 2015; Müller et al., 2014). A study by Khan et al. supports this view, finding a 36% decrease in radiation dose when using a real-time personal dosimeter (Khan and Yi, 2019). The use of personal real-time dosimeters in high radiation dose environments, such as catheterization laboratories as well as cardiac and orthopedic surgeries, is also growing, allowing personnel to visualize their radiation doses (Vano et al., 2011). These findings point to the added value that personal dosimeters offer to vulnerable groups, such as pregnant radiographers, compared to using routine TLDs independently (Koch et al., 2017).

Dosimeters can only be effective if health-care professionals wear them correctly (Jones and Ramirez, 2022) and receive the appropriate training on using the device (Durán et al., 2013). Karellas (2020) concurred with these findings, stating that if dosimeters are not used consistently, the accuracy of dosimetry and the analytical process might be compromised. Consequently, many studies have investigated noncompliance with dosimeter usage by general radiographers (McCulloch et al., 2018; Modiba, 2014; Mohd Ridzwan et al., 2021; Qureshi et al., 2022). Dosimeter usage and compliance by pregnant radiographers nevertheless remain an unexplored domain. Based on this limitation in the literature, the research investigated fetal dosimeter usage among pregnant radiographers.

Radiographer Compliance With Dosimeters

A study by Qureshi and Ramprasad revealed that an average of 94.4% (n = 221) of physicians admitted to not using a dosimeter (Qureshi et al., 2022). The physicians in that sample included radiation workers operating ionizing radiation equipment. McCulloch et al. (2018) further highlighted that 48% of radiographers attributed their noncompliance with dosimeter usage to “not remembering”. The abovementioned studies were conducted in the United States, where extensive dosimetry support is provided to pregnant radiographers. However, since compliance by radiographers generally appears to be low, it can be assumed that pregnant radiographers may also fall within this category. A limitation of studies exploring dosimetry includes the failure to indicate whether or not any pregnant radiographers had been part of such a research sample.

In contrast to high-income countries, middle-income countries, such as some Asian countries, have reported financial constraints as barriers to compliance with dosimeter usage. A study by Mohd Ridzwan et al. (2021) highlighted that fear of losing and having to replace an expensive dosimeter was a factor in noncompliance. Procurement challenges like delayed dosimeter supply due to late budget approval in the hospitals are also factors contributing to noncompliance. A study by Modiba (2014) further highlighted that only 59% of radiographers wore dosimeters. The scholar further reported that other health professionals, such as dentists, did not have access to dosimeters because employers were unable to provide them to employees (Modiba, 2014). Studies in low-income countries like Nigeria reported that only 50% of radiographers complied with wearing dosimeters (Eze et al., 2013). These statistics indicate that radiographers are complacent about the dangers associated with occupational radiation. Moreover, pregnant radiographers would be assumed to be more conscious of fetal radiation doses owing to the increased sensitivity of a fetus's cells. However, due to a lack of relevant studies, it is unknown how compliant pregnant radiographers are compared to their male and nonpregnant coworkers. The majority of the available literature on fetal dosimetry is related to the occupational guidelines and regulations for pregnant radiographers.

Occupational Radiation Safety Regulations for Pregnant Radiographers

Globally, radiation protection authorities, such as the National Council on Radiation Protection (NCRP) and the International Atomic Energy Agency (IAEA), continue to enforce radiation safety regulations for pregnant radiographers because stochastic effects still exist in the working environment. These regulations include using the necessary occupational health and safety devices, such as pregnancy dosimeters. Pregnancy dosimeters accurately measure the accumulative fetal radiation dose to ensure that the radiographers monitor their radiation doses and that such doses do not

exceed the threshold limit. Pregnancy dosimeters include pocket reading alarm dosimeters, which provide real-time monitoring of fetal radiation dose (Prashar, 2020; South African Health Products Regulatory Authority, 2022b).

Occupational Radiation Support for Pregnant Radiographers

The United States of America, Australia, and Switzerland are considered high-income countries that spend a considerable amount of their gross domestic product on health care (Papanicolas et al., 2018). Such extensive financial resources allow countries like the United States of America to ensure sufficient support for pregnant radiographers working in potentially hazardous ionizing radiation environments. This is evidenced by pregnant radiographers receiving a Pregnant Radiation Worker Declaration Information Packet containing a formal declaration of pregnancy form and stating that a fetal dosimeter has been ordered (Koth and Smith, 2016). The package also contains the NCRP guidelines for pregnant radiographers regarding prenatal radiation exposure, instructions for using a fetal dosimeter, and a film badge dosimeter for the mother (Koth and Smith, 2016). In Nebraska (USA), pregnant radiology workers are enrolled in a fetal monitoring program that provides them with the NCRP guidelines, training on how to place the fetal dosimeter, and a personal dosimeter. Pregnant radiographers are also guided on how to record and report radiation exposure following ICRP and National Council on Radiation Protection and Measurements (NCRP) guidelines (International Commission on Radiation Protection, 2000; University of Nebraska Medical Center, 2022). Pregnant women are considered an underrepresented group in research studies (Blehar et al., 2013). In radiography, early investigations on the effects of radiation included the offspring of radiation workers (Bunch et al., 2009; Draper et al., 1997; Roman et al., 1996); however, a very limited number of studies investigating dosimetry concerning pregnant women exist (Prashar, 2020). For this reason, the researchers in this study investigated compliance with dosimetry by general radiographers as their frame of reference.

Pregnant radiographers are considered the most radiation-sensitive group of individuals as well as the most underrepresented group in research. Thus, it is necessary to understand the context in which such radiographers practice and whether their right to occupational health and safety is supported. Literature across high-, middle-, and low-income countries has suggested low dosimeter usage and, in some cases, a lack of access to dosimeters. However, existing literature on pregnant radiographers is extremely limited; therefore, the reference point regarding dosimeter usage is, of necessity, based on findings acquired from radiographers. This study aimed to investigate fetal dosimeter access, usage, and training among pregnant radiographers in an upper-to middle-income country in sub-Saharan Africa, through which recommendations could be made for ensuring the safety of both the pregnant radiographer and her unborn child. Hence, the study aligns with a key priority area of the World Health Organization, namely the “well-being of both mother and child” (World Health Organization, 2005, 2017), which provides the conceptual framework for the current study. The study can further be related to the United Nations Sustainable Development Goal 3: “Ensure healthy lives and promote well-being for all people at all ages.”

Methods

Study Design and Setting

A quantitative research design was adopted using a survey method. The study population included 6,886 registered female radiographers in diagnostic, radiation therapy, and nuclear medicine in South Africa, which is considered an upper- to middle-income African country (Group WB, 2014). The inclusion criterion for the study's sample population was pregnant radiographers, and thus, the researchers employed a purposive sampling method to include only currently pregnant and previously pregnant radiographers. These radiographers could share their experiences regarding fetal dosimetry in their places of employment. The participants' pregnancy statuses were not limited to a particular timeframe since this risked significantly reducing the sample size. Data were collected from January 2022 to April 2022. Women who reported never having been pregnant were not asked questions about dosimetry in pregnancy and were not included in the sample presented in this paper.

Data Collection Method

A self-formulated electronic survey was developed in consultation with the study's supervisors and a statistician. The survey questions were derived from ICRP guidelines for pregnant radiographers (International Committee on Radiation Protection, 2000). The distribution of the survey included a snowballing method, whereby the survey was sent to the researcher's fellow professionals and shared to social media groups specific to radiography, such as the South African Association of Radiographers, South African radiographers, and locum radiographers, for further dissemination. The survey aimed to ascertain pregnant radiographers' access to, usage of, and training with fetal dosimeters during their pregnancies. The survey also enabled further probing into the factors causing barriers to dosimeter access and usage, with logical links wherever further explanation was required. The questionnaire had three options, categorized by the participants' pregnancy statuses: 1) currently pregnant, 2) previously pregnant, and 3) never been pregnant. The survey incorporated logic links, which redirected the participants to another section of the survey based on their responses. The redirection was particularly applicable to category 3, “never been pregnant”, from which responses informed the second phase of a broader study not within the scope of this paper.

Accordingly, the dataset from categories 1 and 2 were used for the data analysis. The survey posed a series of questions to these participants related to their demographic, access, usage, and training with their pregnancy dosimeters.

Data Analysis

The raw data from the *Google Sheets* responses were downloaded in an *Excel* format (*xlsx*). Data from currently pregnant and previously pregnant radiographers were extracted and provided to the statistician. The IBM *SPSS Statistics* version 28.0.1.0 application was used to produce frequency tables (counts and percentages), and bar charts were generated using Microsoft *Excel* 2019.

Ethical Consideration

The study received ethical clearance from the University's Faculty of Health Sciences Research Ethics Committee (635/2021). Pregnant women have historically been excluded from research studies not directly related to pregnancy and fetal development because they are considered a vulnerable group. However, Van der Graaf et al. (2018) indicate that it is necessary to include pregnant women in research studies, provided ethical principles have been duly addressed. Aspects of nonmaleficence and autonomy were adhered to during the recruitment and data collection processes of this study. The study was not a clinical trial but rather an analysis of

fetal dosimeter access and usage by radiographers. Therefore, the potential for harm to any fetus was eliminated. The survey provided an information section and a consent selection option. Participants could only start answering the survey questions after they had consented to participate in the study; thus, the ethical principle of autonomy was adhered to.

Results

One hundred and forty-three participants responded to the survey. However, only pregnant and previously pregnant radiographers' responses were considered in the dataset, resulting in 89 responses from participants practicing in private or public institutions at the time of their pregnancies. Of the 89 responses received, 9 participants were currently pregnant, and 80 participants had previously been pregnant. Most responses (96.7%) were from diagnostic radiographers. The remaining responses (3.3%) were from radiation therapy and nuclear medicine radiographers. Most participants were radiographers working in public hospitals; 61.8% (n = 55) and 37.2% (n = 34) were from private hospitals.

Access, usage, and institutional support regarding pregnancy dosimeters.

Figure 1 illustrates the disparity in dosimeter access between private (n = 12) and public institutions (n = 29). In this study, 46.1% (n = 41) of radiographers had access to a pregnancy dosimeter during their pregnancies.

Fifty-three (53.9%) (n = 48) of the participants had not been provided with pregnancy dosimeters during their pregnancy. Participants were asked to provide an open-ended response with regard to the reason for not using a dosimeter. The reasons were largely attributed to employers not procuring the meters, as indicated by participants (n = 29) both in private and public hospitals. The extracted narratives described in Table 1 relate to the employers.

Usage

Among the 41 participants who indicated that they had received fetal dosimeters during their pregnancy, 56% (n = 28) reported always using the dosimeter, while 24% (n = 12) reported using it sometimes, and 20% (n = 10) reported never using the dosimeter (Figure 2).

Fetal dosimeters include pocket-reading alarm dosimeters providing real-time measurements that must be recorded by the radiographers according to the time limitation set by the radiographer. In this study, only 24% (n = 12) of participants who had received a fetal dosimeter (56%) indicated that they had recorded their doses daily. However, a concerning 52% (n = 26) of participants indicated that they never consistently recorded their fetuses' radiation doses, even though they had access to a pregnancy dosimeter (Figure 3).

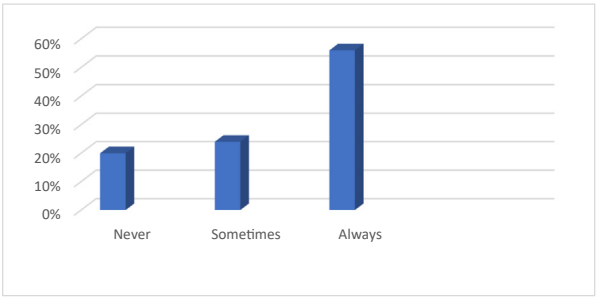

Figure 2. Fetal dosimeter usage by pregnant radiographers with access to fetal dosimeters.

Pregnancy Dosimeter Training

Table 2 presents the responses to whether the radiographers had training on the use of the fetal dosimeter. Seventy-four percent (n = 37) of participants who had access to a fetal dosimeter indicated that they did not receive training on its use.

Record-Keeping

Records of fetal doses must be stored and be accessible in the event of a fetus developing a congenital abnormality, in which case radiation records would be evaluated to identify instances of overexposure. In this study, radiographers had various inconsistent record-keeping methods, as presented in Figure 4. However, a concerning 36% (n = 18) of participants admitted to not keeping their fetal dose records at all, and 34% (n = 17) were unsure of where their fetal dose records were.

Discussion

The results indicate low usage of fetal dosimeters by pregnant radiographers. Factors attributed to this include limited access to fetal dosimeters, negative attitudes, and poor training on the use of dosimeters. The next section elaborates on each of these categories.

Access to Fetal Dosimeters

In this study, more than half of the participants indicated that they did not use fetal dosimeters. Most participants attributed this

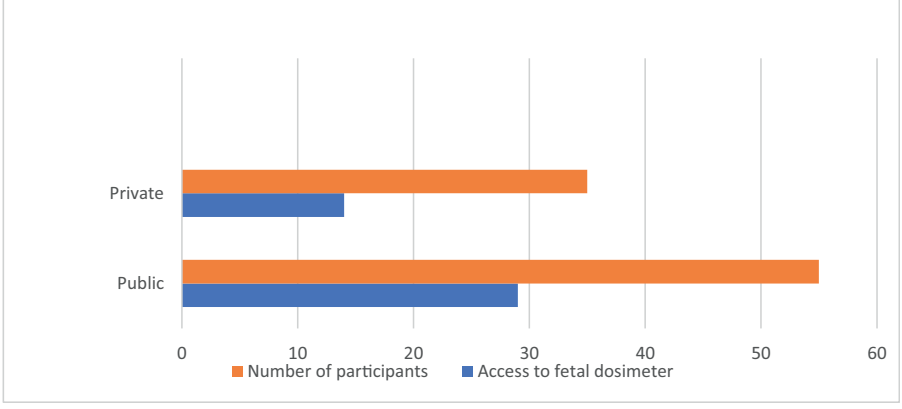

Figure 1. Fetal dosimeter access in private and public institutions.

Table 1
Employer-related factors for noncompliance toward pregnancy dosimeters

Direct quote	Source
Employer never provided	Diagnostic radiographer 9 previously pregnant/private practice
My company never used one before and said the TLD (thermolucent dosimeter) was fine	Diagnostic radiographer 10 previously pregnant/private practice
The department never had one/never procured	Diagnostic radiographer 11 previously pregnant/public institution
They were out of stock and some [were] faulty	Radiation therapy radiographer 30 previously pregnant/public institution
Company didn't want to buy—no money	Diagnostic radiographer 31 previously pregnant/private: medical sales representative
The practice did not have one, the previous radiographers did not wear one	Diagnostic radiographer 38 previously pregnant/private practice
None were available because we were a lot. They could not manage to give [to] all of us	Diagnostic radiographer 43 previously pregnant/public institution
It was not an option in the practice where I worked	Diagnostic radiographer 48 previously pregnant/private practice
The practice felt it wasn't necessary to have a separate dosimeter. We still had to go do mobiles as well while pregnant	Diagnostic radiographer 53 previously pregnant/private practice
I was told everyone uses the same dosimeter in the institution. Ten years later and many other pregnant radiographers, it has not been given to anyone ever in my institution	Diagnostic radiographer 93 previously pregnant/public institution
The hospital does not provide it anymore	Diagnostic radiographer 104 currently pregnant/public institution
There was nothing in place for pregnant radiographers in my department then	Diagnostic radiographer 121 previously pregnant/public institution
I was pregnant in 2004 and 2006 and we didn't have personal dosimeter in our department	Diagnostic radiographer 122 previously pregnant/public institution
Never given by manager. Not available at the time of my pregnancy	Diagnostic radiographer 125 previously pregnant/public institution

to their employers not having the funds to procure fetal dosimeters. Fetal dosimeters are often real-time pocket-reading dosimeters; the most expensive dosimeters cost around $870 for a single device. Radiography departments have evolved into female-dominant departments (Republic of South Africa, Goverment Gazette, 1993), with many women of childbearing age entering the radiography workforce. The use of real-time personal dosimeters has been proven to make its user more aware of radiation doses within their working environment (Butcher et al., 2015). This compels them to take further radiation protection measures toward reducing their exposure to radiation (Butcher et al., 2015). Hence, the aforementioned evidence supports the importance of female pregnant radiographers having access to fetal dosimeters. Dewar states that employers should provide pregnant radiographers with the appropriate protection to enable them to work in radiology settings without experiencing anxiety about harm to their fetuses (Dewar, 2013). The fetal dosimeter does not provide direct radiation protection to a fetus; however, it can alert the radiographer in advance of any radiation exposure that is accumulating beyond her threshold. This might prevent pregnant radiographers from becoming complacent about radiation because of its innate invisibility (Butcher et al., 2015). The ICRP states that pregnant radiographers are free to work in radiation environments, provided that their radiation doses can be reasonably and accurately estimated (Protection ICoR, 2000). The ICRP further mentions that the personal dosimeters worn by all radiographers do not provide accurate

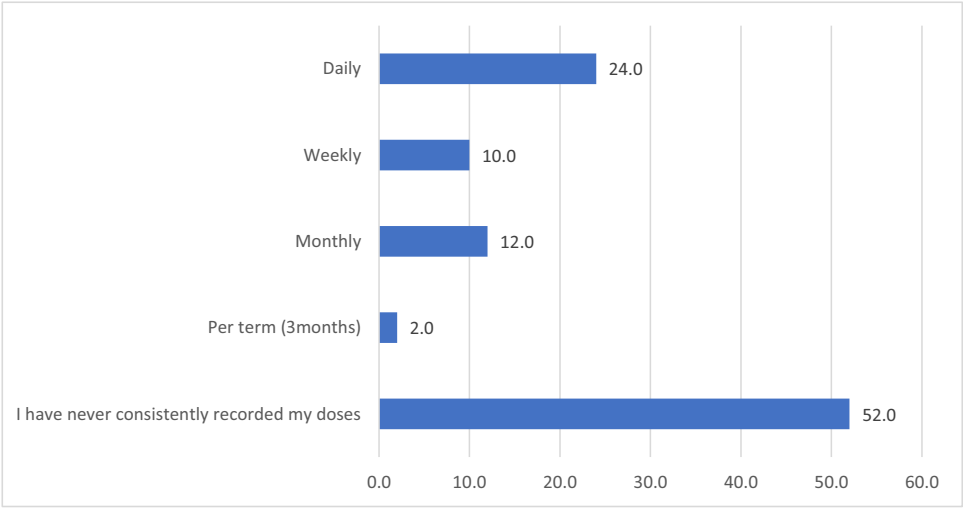

Figure 3. Frequency of fetal dose recording by pregnant radiographers who had access to fetal dosimeters.

fetal dose readings (Protection ICoR, 2000). This highlights that pregnant radiographers need dedicated fetal dosimeters specifically indicated for fetal readings. In South Africa, health regulatory authorities such as the South African Health Products Regulatory Authority further elaborate on the type of dosimeter required and state that "Pregnant radiographers must be issued with a direct-reading audible dosimeter, also known as a direct-reading pocket alarm dosimeter" (South African Health Products Regulatory Authority, 2022a). According to the Occupational Health and Safety Act 85 of 1993, employers are duty-bound toward "taking such steps as may be reasonably practicable to eliminate or mitigate any hazard or potential hazard" (Republic of South Africa, Goverment Gazette, 1993).

Therefore, it is evident that employers who do not provide employees with an effective means to measure fetal radiation doses are noncompliant with the occupational safety regulations pertaining to pregnant radiology workers. In contrast to the lack of access, some pregnant radiographers had indeed received fetal dosimeters from their employers yet were not fully compliant with their utilization.

Fetal Dosimeter Usage

The results revealed that only 46.1% of pregnant radiographers in this study had access to a fetal dosimeter during their pregnancies. Studies ranging from lower- to upper-income countries all report on poor compliance with dosimeter usage by general radiographers, both male and female. This indicates that dosimeter compliance is a global challenge, not only limited to developing countries and issues around access but also the employees' attitudes (McCulloch et al., 2018; Modiba, 2014; Mohd Ridzwan et al., 2021; Qureshi et al., 2022). Mohd Ridzwan et al. (2021) investigated the attitudes and beliefs of radiographers toward dosimeter usage. The scholars found that participants believed using a dosimeter was not as important as employing radiation protection measures; moreover, they believed that not wearing a dosimeter would not be harmful (Mohd Ridzwan et al., 2021).

In this research, the study population was pregnant radiographers; the developing cells and tissues of fetuses are highly sensitive to radiation (Sherer et al., 2017). Women are at peak fertility between their early teens and late 20s (World Health Organization,

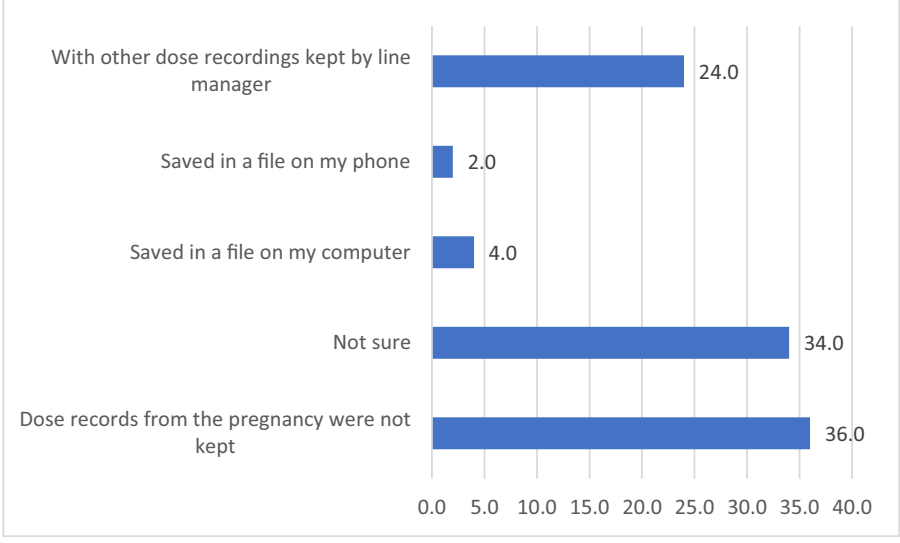

Figure 4. Pregnant radiographers' storage methods of fetal dose records.

Table 2
Frequency and percentage of participants who had received training on the use of the fetal dosimeter

Participant responses	Frequency	Percentage (%)
Valid		
No	37	74%
Yes	13	26%
Total	50	100%

2009). The radiography workforce comprises newly qualified young females of peak reproductive age. Considering this vulnerability, one would assume that the attitudes to dosimeter compliance of such young female members of this workforce would be heightened; however, based on the results of the current study, this appears to be the contrary.

Fetal Dosimeter Training and Dose Record-Keeping

In this study, most radiographers (74%) who were using fetal dosimeters had not been trained on the use of the device or how to keep records of such usage. In the United States, when a woman declares her pregnancy, she is provided with an information package and training by the employer (University of Nebraska Medical Center, 2022). In addition, pregnant women have access to radiation officers who can provide them with support on how to read doses (Vu and Elder, 2013). Nevertheless, in an upper- to middle-income country in sub-Saharan Africa, such as in this study, the findings revealed that many pregnant radiographers are not afforded this support.

Compliance with record-keeping was considerably low in terms of consistent record-keeping, with 52% (n = 26) of participants indicating that they never consistently recorded their fetal dosimeter readings. Subsequently, the overall fetal radiation dose could not be accurately estimated. The ICRP states that the overall fetal dose for the full duration of the pregnancy should be kept below 1 mSv. The results imply that inaccurate record-keeping places the fetus in danger inasmuch as potentially high radiation doses cannot be tracked.

Thus, the study demonstrated the assumption that limited training and, therefore, a lack of the requisite knowledge on how to use a fetal dosimeter might contribute to pregnant radiographers not consistently recording their doses. A study by Adhikari et al. (2009) supports this finding by associating poor personal dosimetry practices with a lack of knowledge regarding ionizing radiation. This study also found pregnant radiographers negligent with storing their recorded doses since 36% (n = 20) of the participants indicated not keeping their dose records (Figure 4). Radiation dose records play an essential role in monitoring and evaluating occupational radiation exposure and thus could contribute to enhancing radiation protection measures for radiation workers (Bhatt et al., 2012). The necessity of pregnant radiographers storing radiation records becomes significant should a child be born with a congenital abnormality.

Conclusion

Dosimetry among pregnant radiographers is an integral aspect of occupational radiation safety. This study found that some current and previously pregnant radiographers did not have access to fetal dosimeters. The most often cited reason was that employers were experiencing financial constraints despite operating in an upper- to middle-income African country. Some pregnant radiographers who indeed had access to fetal dosimeters still neglected to record their fetal doses consistently and accurately. This practice may be associated with a lack of training in the operation of fetal dosimeters. The study also found that many (% and n=) pregnant radiographers did not store their fetal dose measurements. These findings suggest that pregnant radiographers have limited knowledge of the potentially harmful effects of ionizing radiation on a developing fetus. This study recommends both a top-down and bottom-up approach toward improving access to fetal dosimeters, whereby radiation protection authorities enforce more stringent monitoring of employers regarding dosimeter access and training of pregnant employees. Radiographers must also be educated to a level of an understanding of their obligations to their unborn babies as well as their right as radiation workers to be provided with fetal dosimeters. These recommendations would promote the mitigation of the serious occupational risks to the female radiographer and unborn child associated with radiation exposure.

CRediT authorship contribution statement

Hafsa Essop: Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Software, Validation, Visualization, Writing – original draft, Writing – review & editing. **Mable Kekana:** Conceptualization, Funding acquisition, Project administration, Supervision, Validation, Visualization, Writing – review & editing. **Hanlie Smuts:** Conceptualization, Funding acquisition, Project administration, Supervision, Validation, Visualization, Writing – review & editing. **Andries Masenge:** Formal analysis, Methodology, Project administration, Resources, Software, Supervision, Visualization.

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