Knowledge and practice of radiation safety among health professionals in Trinidad

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Abstract
Objective: To determine the practices and knowledge of radiation safety measures among health care providers in tertiary institutions in Trinidad.
Design & Method: A cross-sectional survey of health care professionals within two public hospitals was conducted using a questionnaire distributed to individuals working in Cardiology, General Surgery, Internal medicine, Orthopaedics, Radiology and Urology who require the use of ionizing radiation machines. The questionnaire comprised of 30 questions divided into five subcategories including demographic data, usage of the ionizing radiation machines, basic knowledge, and attitude towards personal protective equipment as well as radiation exposure measurement. Questionnaire results were tabulated and analysed using Microsoft Excel and Stata v11 with comparative statistical analysis being done using the one-way analysis of variance test.
Results: A total of 118 health care professionals participated in this study. The majority (85/118 (72%)) of individuals revealed that they had no formal training regarding safe practices when working with ionizing radiation despite the daily use of the fluoroscopy machines by at least 25% of participants. Individuals who had formal training in the use of ionizing radiation were found to score significantly higher than those without training (p<0.0001). Participants’ knowledge regarding the proper positioning of the C-arm image intensifier to reduce radiation exposure was low with 46% of individuals providing a correct response.
Conclusions: The level of knowledge among the individuals who participate in the operation of ionizing radiation equipment throughout the country is low. The benefit of training in the use of the C-arm image intensifier is highlighted by the revelation that the individuals who had formal training in the use of these machines performed better than those individuals without training. Annual recertification courses should be implemented such that individuals are kept abreast with current changes and reminded of commonly neglected safety practices.

Keywords
Radiation, safety, health care

Date received: 26 June 2018; accepted: 9 April 2019

Introduction
Recently, there has been a heightened awareness regarding the lack of knowledge of referring doctors about radiation doses incurred during diagnostic radiological procedures.¹ The use of imaging equipment is a vital part of any hospital and surgical specialty. In recent years, the use of X-ray and computed tomography (CT) scans has continually increased as a means of accurately diagnosing patients’ condition to render the most appropriate treatment available.²⁻⁴ As a result, patients and hospital staff are repeatedly exposed to increasing doses of ionizing radiation in comparison to previous years. In 2006, Americans were exposed to more than seven times as much ionizing radiation from medical procedures as was the case in the early 1980s.⁵

Over the past 20 years, the medical fraternity in Trinidad has experienced a vast improvement in the radiological...
facilities available for diagnosis, monitoring, and treatment of patients. The availability of X-rays, CT and magnetic resonance imaging (MRI) scans in our public and private hospitals has increased considerably. Modern orthopaedic and urology have become increasingly characterized by operative procedures that routinely rely on intraoperative fluoroscopy. The availability and usage of fluoroscopic services have also been increased in keeping with worldwide trends towards fluoroscopic-assisted procedures. The operation of these machines should be done by qualified technicians who in our setting are radiographers. However, due to the lack of sufficient radiography staff within the hospitals, these machines are not always operated by specifically trained individuals. As a result, staff operating such equipment may not be appropriately skilled or knowledgeable regarding patient safety.

This survey was designed to determine the practices and knowledge of radiation safety measures among health care providers in a tertiary institution to ascertain the areas of shortcomings in their knowledge as well as their available personal protective equipment, to reinforce the need for proper education for medical professionals intimately associated with these forms of radiation, and to promote the safe and proper usage of these machines in an effort to reduce both patients’ and operators’ radiation exposure.

Methodology

A cross-sectional survey of health care professionals working within Trinidad's government hospitals (San Fernando General Hospital and Port of Spain General Hospital) whose respective fields require the use of machines that produce ionizing radiation was conducted.

Study population

All health care workers who were occupationally exposed to radiation were included in the study. This study included a spectrum of individuals who are exposed to ionizing radiation including cardiologists, orthopaedic and general surgeons, radiologists, radiographers, and urologists. Based on hospital staffing records, this included 540 individuals. However, only individuals who signed the consent for participation were included and asked to complete the questionnaire. Individuals who were unwilling to give written consent and those who were temporarily assigned to the departments were excluded from the survey. A sample size of 118 participants was adequate for this study based on a 95% confidence level. The calculated margin of error based on the calculated sample size and assuming a 95% confidence level was 8%.

Questionnaire

The questionnaire was reviewed and validated by a committee of four experts with different educational backgrounds in the field of medicine. The structured questionnaire was developed based on the experience of the authors as well as information gathered from a literature search. The validity of the questionnaire was assessed based on the content validity index and face validity. The content validity index was determined based on the experts’ review of each question regarding its relevance, simplicity, and clarity. To determine the face validity, the questionnaire was reviewed by 20 medical students and four experts who rated each question in terms of its clarity, understandability, and length of each question. The face validity was ensured by the revision of five questions to improve their understandability. A pilot study was conducted in which the finalized questionnaire was administered to 20 individuals. The internal consistency reliability was calculated using Cronbach’s alpha ($\alpha = 0.83$).

The anonymous 30-item questionnaire (Supplemental material) was distributed to all participants after their respective departmental meetings. The questionnaire comprised five subcategories including demographic data (6), usage of the ionizing radiation machines (3), basic knowledge (9), and attitude towards personal protective equipment (5) as well as radiation exposure measurement (7). Individuals were given a 30-min period within which to complete and return the questionnaires to ensure that participants did not search for the correct answers to the questions related to their knowledge of radiation safety practices. The questionnaires were returned to a designated folder, which was then collected by a member of the research team after all participants completed and submitted their questionnaire to further ensure anonymity of the questionnaires completed by the respective participants. The Caribbean Association of Orthopaedic Surgeons Conference had a short presentation on some intraoperative radiation safety tips, and therefore, participants who attended were expected to perform better than non-attendees.

Analysis and statistical methods

All completed questionnaires were anonymous and data were stored using Microsoft Excel 2010 and analysed using Stata version 11 with a p value of <0.05 was afforded significance. We compared the results of the questionnaire with individuals’ work experience duration, training in the use of ionizing radiation machines, and occupation using the one-way analysis of variance (ANOVA) test. The overall performance of the participants was calculated by assigning a score of 1 to correct responses and 0 to incorrect responses to the questions numbered 10–18, 20, 21, 26–28, and 30 with a maximum achievable score of 15. The other questions pertaining to the individual’s work experience, job position, and place of employment as well as their usage of the machines and personal protective equipment.

Results

A total of 118 individuals participated in the survey with the Orthopaedic and Radiology departments accounting for 25%
**Table 1.** Distribution of participating health care professionals and their mean performance scores based on specialty (N=118).

| Specialty         | No. of participants | Mean score (%) |
|-------------------|---------------------|----------------|
| Orthopaedics      | 29                  | 51.0           |
| Radiology         | 29                  | 58.1           |
| General surgery   | 22                  | 42.3           |
| Urology           | 12                  | 45.2           |
| Internal medicine | 10                  | 35.2           |
| Cardiology        | 9                   | 47.4           |
| Other             | 7                   | 39.8           |

**Table 2.** Summary of participating health care professionals overall score based on their job title (N=118).

| Job title            | No. of participants | Mean score (%) |
|----------------------|---------------------|----------------|
| Consultant           | 6                   | 46.5           |
| Registrar            | 10                  | 50.0           |
| House officer        | 66                  | 44.6           |
| Radiographer         | 27                  | 58.7           |
| Registered nurse     | 8                   | 47.4           |
| Nursing assistant    | 1                   | 36.8           |

of responses, respectively (Table 1). Table 2 summarizes the distribution of overall performance of individuals based on their job title with radiographers performing the highest. Only 25 (21%) of 118 participants reported having over 10 years of experience in their respective fields. One-way ANOVA testing showed that the duration of work experience did not influence the overall performance of individuals (p=0.13). The majority (85/118 (72%)) of individuals revealed that they had no formal training regarding safe practices when working with ionizing radiation despite the daily use of the fluoroscopy machines by at least 25% of participants (27/118). Regarding individuals who underwent training, we found that 75% (25/33) of these individuals were radiographers.

Only 54% (64/118) of individuals reported that the ionizing radiation machines in their department were only operated by a qualified technician. The performance of the individuals who underwent formal training in the operation of ionizing radiation was found to be statistically significant in comparison to individuals without training (p<0.0001). The overall performance of individuals, however, was significantly influenced by their occupation (p=0.0045). We found that radiographers scored significantly better in all categories when compared to the other professionals (p=0.001). The three individuals who reported attending the Caribbean Association of Orthopaedic Surgeons Conference were found to perform similarly to the rest of the population.

Assessment of individuals’ knowledge regarding the safe use of ionizing radiation machines revealed that 36% (43/118) were aware that at 6 ft, the radiation emitted from the image intensifier approaches the natural background radiation level. Only 23% (27/118) of users were aware of the position of the image intensifier to allow for the best image quality. Only 46% (54/118) of participants correctly identified the best position of the image intensifier to reduce radiation exposure. Table 3 illustrates a summary of participants’ knowledge regarding radiation exposure.

The results of participants’ basic knowledge on radiation exposure showed that only 13 (11%) of 118 individuals knew the normal level of annual background radiation exposure. The relative risk of developing cancer from a CT abdomen with contrast was appreciated by only 30% (35/118). Approximately 60% (71/118) of individuals knew that an MRI abdomen does not expose a patient to any radiation with only 34% (39/118) appreciating the dose of radiation exposure imparted by a single chest radiograph. Of our 118 participants, 85 (72%) were aware that a foetus is most susceptible to the effects of radiation exposure in the first 6 weeks of gestation. A comparison of responses to this section between individuals who had formal training and those without training is illustrated in Table 4.

Regarding the availability of personal protective equipment for individuals who work closely with ionizing radiation machines, approximately 80% (94/118) of participants agree that there is a lack of availability of equipment across the institutions. Table 5 summarizes the responses regarding the availability of such equipment within our hospitals. Despite the lack of availability, 80% (94/118) believed that utilizing a lead apron provides sufficient protection from ionizing radiation with 95% (112/118) of participants knowing how to properly store these aprons. Only 60% (72/118) of participants reported always making use of the available lead aprons with six participants attributing its lack of use of a lead apron to its unavailability within their department. A thyroid shield was never used by 34% (40/118) of participants due to their unavailability.

Dosimeter badges were owned by 42% (49/118), of which only 60% (30/49) used them regularly. The frequency of using a radiation dosimeter badge was found to be dependent on the department under which the participant was employed (p<0.001). However, only 13 (27%) of 49 individuals who owned a dosimetry badge knew how to position the badge correctly during its usage with 70% (35/49) knowing how to appropriately store their badge. Only 32% (38/118) knew that sunlight affects the readings from the dosimetry badge with the majority (110/118 (93%)) being able to appreciate the function of the dosimetry badge.

**Discussion**

The lack of knowledge and awareness of medical professionals regarding their understanding of ionizing radiation or the use of equipment involved in the process has been previously highlighted by numerous studies. The primary aim of this study was to evaluate the availability,
practices, and knowledge of radiation safety measures of health care workers who were occupationally exposed to radiation. On evaluation, the overall score of participants demonstrated a poor level of awareness regarding the common safety practices to reduce exposure to machine operator, nearby staff, and patient.

In our operating rooms, these machines are frequently operated by staff who lack training in radiation equipment usage and safety. This is subsequent to the lack of radiographers employed to meet the daily demands of all services that rely on radiological expertise within the hospitals. It was alarming that the basic knowledge regarding radiation

| Questions                                                                 | Cardiology (N = 9) No. (%) | General surgery (N = 22) No. (%) | Internal medicine (N = 10) No. (%) | Orthopaedics (N = 29) No. (%) | Radiology (N = 29) No. (%) | Urology (N = 12) No. (%) | Other (N = 7) No. (%) |
|---------------------------------------------------------------------------|-----------------------------|----------------------------------|------------------------------------|-----------------------------|--------------------------|------------------------|---------------------|
| What is the normal background radiation exposure per year?                | 2 (22.2)                    | 3 (13.6)                         | 0 (0)                              | 2 (7)                       | 6 (20.7)                 | 0 (0)                  | 0 (0)               |
| How much radiation does one chest x-ray impart?                          | 4 (44.4)                    | 7 (31.8)                         | 2 (20)                             | 4 (13.8)                    | 17 (58.6)                | 3 (25)                 | 2 (28.6)            |
| What is the relative risk of causing a cancer from doing a CT scan of the abdomen with contrast? | 3 (33.3)                    | 7 (31.8)                         | 1 (10)                             | 10 (34.5)                   | 10 (34.5)                | 2 (16.7)               | 2 (28.6)            |
| How much more radiation is an MRI abdomen versus CT scan abdomen with contrast? | 2 (22.2)                    | 12 (54.5)                        | 4 (40)                             | 18 (62.1)                   | 24 (82.8)                | 9 (75)                 | 2 (28.6)            |
| At what period of gestation is the threat of radiation to the foetus greatest? | 4 (44.4)                    | 20 (90.9)                        | 7 (70)                             | 20 (69)                     | 22 (75.9)                | 10 (83.3)              | 6 (85.7)            |
| Is radiation exposure decreased significantly by wooden objects, for example, doors? | 3 (33.3)                    | 17 (77.3)                        | 7 (70)                             | 20 (69)                     | 22 (75.9)                | 11 (91.7)              | 6 (85.7)            |

CT: computed tomography; MRI: magnetic resonance imaging.

| Questions                                                                 | With formal training (N = 33) No. (%) | Without formal training (N = 85) No. (%) |
|---------------------------------------------------------------------------|----------------------------------------|----------------------------------------|
| At what distance does radiation exposure from image intensifier approach natural background radiation? | 20 (60.6)                             | 23 (27.1)                             |
| Which position of the image intensifier gives the best image quality?     | 16 (48.5)                              | 38 (44.7)                             |
| Which position of the tube reduces exposure to surgeon when doing fluoroscopy x-rays? | 11 (33.3)                              | 16 (18.8)                             |

| Question                                                                 | No. of positive responses (%) |
|--------------------------------------------------------------------------|------------------------------|
| Is there sufficient protective equipment for use with such machinery?    | 25 (21.2)                    |
| Do you think a lead apron provides sufficient protection during surgical or interventional cardiology procedures? | 92 (78)                     |
| What do you think is required further?                                   |                              |
| Thyroid shields                                                          | 91 (77)                      |
| Lead garments                                                            | 42 (35.6)                    |
| Lead gloves                                                              | 48 (40.7)                    |
| Lead drapes                                                              | 47 (39.8)                    |
exposure and safe machine usage was insufficient among participants with most individuals not being able to appreciate facts regarding the proper positioning of the image intensifier and safe distances to stand from the ionizing radiation machines. Research evaluating radiation safety education among vascular surgery residents has demonstrated that residents who have been trained in the use of these machines knew more basic radiation safety information than those who lacked training. Similarly, we found that those who have had formal training regarding the use of ionizing radiation machines had a greater awareness compared with those who have had no training.

There have been different recommendations in the literature to cut down radiation exposure. X-ray scatter can be reduced by minimizing the number of magnified views, using digital-only cine acquisition, keeping the image intensifier as close to the patient as possible, using lower framing rates and pulsed fluoroscopy, and minimizing both fluoroscopic and cine time. Individuals within our institution who commonly operate these machines were surprisingly unaware of these simple measures.

The average radiation exposure imparted by a single CT scan of the abdomen and pelvis is approximately 1000 times more than that imparted from a single chest x-ray. The authors were disheartened that the departments that most frequently request this investigation modality in preference to alternative modalities were also the same departments whose personnel were unaware of this fact. Our internal medicine staff was one of the lowest scoring subsets with a surprising lack of appreciation for the radiation imparted by investigations that are routinely used in their practice such as chest radiographs and abdominal CT scans. The assessment of Norway’s general practitioners’ knowledge concerning radiation doses for patients undergoing common radiological investigations and the associated risks of these doses found a similar outcome. The majority of general practitioners were not aware of the radiation hazards associated with diagnostic imaging procedures that they commonly use in their practice. Individuals need to pay closer attention to the radiation exposure imparted by their preferred investigation modality and consider the risk versus benefit ratio to the patient since sometimes the same pathology can be revealed by another modality that imparts less or even no radiation to the patient.

Zhou et al. evaluated the awareness of medical students and interns regarding the radiation exposure associated with common diagnostic investigations and found that 31.6% of participants correctly reported the dose received by patients during a standard chest x-ray and 25.5% did not know that ionizing radiation is not used during MRI. An assessment of the knowledge regarding radiological examination radiation doses among Italian radiographers found that 5% of their studied population believed that MRI scans of the pelvis expose the patient to radiation. Our results have demonstrated that our healthcare professionals are equally unaware of basic radiation facts when compared with our international counterparts. Regarding individuals who have undergone formal training in the use of ionizing radiation machines, our population showed a significant difference regarding the level of knowledge possessed by these individuals compared to those who have not had any training. According to international data, it was found that training regarding radiation protection did not affect individuals’ knowledge level.

In accordance with the Centres for Disease Control and Prevention’s guiding principles of radiation safety, the three most productive strategies for lowering radiation exposure to operators are time, distance, and shielding. The use of fluoroscopy only when necessary has a linear effect on decreasing radiation exposure. Individuals who operate these machines should be aware that doubling the distance from the patient will reduce their exposure by a factor of four. Our research showed that approximately two-thirds of our participants were unaware of the appropriate safe distance from these machines that are required to significantly reduce an individual’s amount of radiation exposure.

The level of knowledge regarding the use of personal protective equipment was satisfactory with approximately 80% appreciating the need for such equipment. The French Association for Urology Residents in their prospective study found that 90% of their participants reported a lack of collective protective equipment in their operating rooms. Our study yielded a similar result with the majority of our participants (80%) reporting a lack of availability of protective equipment such as lead aprons and thyroid shields. This may be attributed to an increased usage of fluoroscopy that has not been matched by procurement of sufficient safety and protective equipment.

The evaluation of Urology theatre personnel’s awareness about ionizing radiation in Turkey showed that despite the Turkish Radiation Safety Regulations recommending that an individual cannot exceed their radiation dose limit, only 46.5% of participants used dosimeter badges for monitoring their exposure. Our population, however, not governed by such regulations, was able to appreciate the necessity for radiation dose badges although their availability and knowledge of their proper use were low.

Continuous medical education with regards to radiation protection practices is necessary to create awareness among the individuals who are occupationally exposed to ionizing radiation since it is believed that awareness is the first step before adoption, compliance, and adherence to a national regularity framework. At present, programmes regarding safe radiation practices for health care professionals are unavailable in Trinidad and have to be independently sourced by individuals from international institutions. The authors strongly recommend that continuous medical education programmes be designed and developed for health care professionals who work in fields that require the use of such machines. In 2015, Szarmach
et al. suggested that medical personnel should undergo periodic training regarding radiological protection regardless of their position and length of service. According to the results of the study, individuals who had previous training scored significantly better than those without any training (p < 0.0001). The need for recertification and the increased accessibility to updates regarding safe practices for individuals who have been previously trained is also imperative.

The study does have a few limitations. The sample did not include individuals who are training in the usage of these machines as well as medical students who will be exposed to ionizing radiation during their training. The questionnaire used multiple choice options, which lends itself to the risk of ‘lucky guesses’ and therefore an erroneous skewing of results. The lack of knowledge demonstrated among individuals in each category was only evaluated against an individual’s training in the use of these machines. However, further evaluation is required to determine whether other factors can be attributed to the poor performance of individuals.

Conclusion

Based on the overall poor performance of our population, we have concluded that formal training in the use of ionizing radiation equipment is important to the safety of both staff and the patient. Personal protective equipment should also be made more readily available to our health professionals who use these machines. It is imperative that operators remember the principles of ‘As Low As Reasonably Achievable’ when using these machines in order to reduce the radiation exposure to both the patient and the staff within the room. Annual recertification courses are imperative so that individuals would be kept abreast with current changes and reminded of commonly neglected safety practices.

Declaration of conflicting interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Ethical approval

Ethical approval for this study was obtained from North West Regional Health Authority Ethics Committee and the South West Regional Health Authority Ethics Committee. However, an approval number was not assigned by the committees.

Funding

The author(s) received no financial support for the research, authorship, and/or publication of this article.

Informed consent

Written informed consent was obtained from all subjects before the study.

Supplemental material

Supplemental material for this article is available online.

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