Radiation Protection in an Interventional Laboratory: A Comparative Study of Australian and Saudi Arabian Hospitals

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Abstract

This study aimed to investigate whether the use of protection devices and attitudes of interventional professionals (including radiologists, cardiologists, vascular surgeons, medical imaging technicians and nurses) towards radiation protection will differ between Saudi Arabian and Australian hospitals. Hard copies of an anonymous survey were distributed to 10 and 6 clinical departments in the Eastern province of Saudi Arabia and metropolitan hospitals in Western Australia, respectively. The overall response rate was 43% comprising 110 Australian participants and 63% comprising 147 Saudi participants. Analysis showed that Australian respondents differed significantly from Saudi respondents with respect to their usages of leaded glasses ($p<0.001$), ceiling suspended lead screen ($p<0.001$), and lead drape suspended from the table ($p<.001$). This study indicates that the trained interventional professionals in Australia tend to adhere to benefit from having an array of tools for personal radiation protection than the corresponding group in Saudi Arabia.

Keywords: attitude, interventional laboratory, radiation protection, protective devices, training.

Introduction

The number of minimally invasive, fluoroscopy-guided procedures has significantly increased because of its benefits over traditional invasive approaches [1, 2]. However, both interventional radiologists and cardiologists are exposed to the highest levels of ionizing radiation in the medical field while imaging in multiple series with real-time x-rays [3]. Despite the fact that there is no increased cancer risk among medical radiation workers who are exposed to the current levels of radiation doses by complying with safety regulations, it is important to be aware of the evidence that no level of radiation exposure is free of associated risks [4, 5]. The stochastic effect, or radiation-induced malignancy, is a result of DNA damage that may develop after receiving any dose of ionizing radiation, since there is no identifiable threshold relationship between the dose and effect [6]. Further, neglecting safety guidelines can result in radiation exposure exceeding the recommended threshold levels, causing deterministic ionizing radiation effects. Skin injury, hair loss and cataract formation are examples of deterministic effects [7, 8]. However, some recent studies suggested that the lens of eyes is more sensitive to radiation than what is previously believed and the radiation-induced cataract formation could be stochastic effect without any threshold. These studies confirmed incidences of lens opacities at doses lower than 0.5 Gy among A-bomb survivors, astronauts, and staff in interventional laboratories [9-11].

Recent evidence suggests that healthcare professionals' attitudes and use of protective devices may differ even though they are aware of radiation safety procedures. In 2013, a study surveying the knowledge and the attitude of European urology residents with regard to ionizing radiation showed insufficient use of lead aprons and very poor usage of other radiation protection tools, even though more than half of respondents have attended a radiation protection (RP) program [12]. Another study conducted by Lynskey et al. [13] evaluated the interventional radiologists' use and attitudes towards radiation protective devices. Their data analysis showed that in spite of the clear understanding of the sensitivity of the eyes to radiation being higher than any other body organs, a low response was shown regarding the use of leaded eyeglasses (54%) and a ceiling-suspended leaded shield (44%). The two most common factors affecting the use of the eye protective shield were comfort and ease of use. Although it is unclear why interventional radiology (IR) personnel are compromising protection for comfort, it may be due to a lack of strong regulations requiring their use or an inadequate understanding of the benefits of these devices [(13)]. Presently, research on staff's radiation safety in both interventional radiology and cardiology focused mainly on the main operator with no studies examining attitudes and uses of the entire interventional team members, including technicians and nurses towards RP measures.

Although medical regulations across countries have broadly shown similar reforms towards better quality and safer healthcare, these countries are different in their strategies, periodic assessments of competence, early identifications of poor performance as well as the stages of evolution [(14)]. In addition, a recent research suggests that different countries utilize clinical departments differently [(15)]. Currently, there are no data available on the practice of RP for interventional professionals in Saudi Arabia. The primary objective of the present study was to identify any significant differences between Saudi Arabia and Australia regarding the use of protection devices and the attitudes of interventional professionals (i.e., radiologists, cardiologists, vascular surgeons, medical imaging technicians, and nurses) towards RP. The secondary objective was to determine any relationship between training in RP and the professionals' attitudes and use of protection devices. We hypothesized that there exist significant differences between Saudi Arabian and Australian hospitals in terms of interventional RP and lack of RP training can affect professionals' attitudes and compliance negatively.

Materials and Methods

Questionnaire design

This study was designed by taking a reference from the questionnaire developed by Lynskey et al. [13] (see reference for details of the study design), which comprised of eight comprehensive questions. However, the survey used in their study targeted mainly the interventional radiologists. While in the current study, this was modified to make some changes including deleting two questions from the list (Q5 and Q6) and reformatting and transferring Q8 to a demographic variable. These questions are "Q5, How often are the other personnel in the room protected with following devices (residents and fellows)", "Q6, How often are support personnel in the room protected with the following devices? (Nurses, technicians, anesthetists)" and "Q8, How many years have you been in practice since becoming an attending physician?" Additionally, labels of the protective devices were reordered and reduced from nine to eight by merging two devices together into one label. Some choices were also added to Q3 in order to change it from an open-ended to a close-ended format. Specific demographical variables (i.e. age, gender, occupation, experience, and training level) were also added to the survey. The amended survey questionnaire was then presented to four radiologists for content and face validation, with two of them being academic staff and the other two clinical interventional consultants. This study was approved by Institutional Review Boards of Curtin University and other relevant clinical centers.

Participants

After obtaining sites' participation approval and by using a cross-sectional design, hard copies of the anonymous survey were distributed to clinical departments that have interventional laboratories in the Eastern province of Saudi Arabia and metropolitan hospitals in Perth, Western Australia, Australia. In Saudi Arabia, 10 out of 12 eligible hospitals, and in

Western Australia six out of eight eligible hospitals agreed to participate in the study. Eligible participating hospitals included private, public and military hospitals. Furthermore, interventional professionals including radiologists, cardiologists, vascular surgeons, medical imaging technicians and nurses must work regularly in these clinical practices. Temporary workers in interventional procedures (e.g., anesthetists, physicians and nurses from other departments) were excluded from the study. The study was focused on the specific population of healthcare professional delivering an interventional service to patients; thus, the convenience sampling technique was followed. A reminder was given one week before collecting the questionnaires. 485 copies of questionnaires were distributed to both study population (255 in Australia and 230 in Saudi Arabia). The questionnaire comprised seven general questions and five comprehensive questions focusing on operators and other healthcare professionals' use and attitudes towards RP devices (see Appendix 1).

Statistical analysis

Using the IBM Statistical Package for Social Science (SPSS) software, version 22.0, two-way frequency tabulations were tested for contingency by the Chi-squared test. Categorical variables were presented as frequencies or percentages. In terms of hypothesis testing, $p < 0.05$ was considered to be statistically significant.

Results

Percentage of response rates in both countries

The overall response rate was 43% (n=110) in Australia (20% interventionists, 29% technologists and 51% nurses) and 64% (n=147) in Saudi Arabia (21% interventionists, 31% technologists and 48% nurses). 99% of the Australian participants and 68% of the Saudi participants had received training in RP.

Comparison of the frequency of usage of protective devices

Saudi participants versus Australian participants

The results showed no significant differences between the Saudi and Australian participants in terms of usage of lead aprons, thyroid shields, sterile lead equivalent patient mounted drapes and radiation-attenuating sterile surgical gloves (p=0.118, 0.566, 0.129 and 0.190, respectively). However, the percentages of participants who never used leaded eyeglasses were higher among the Australian participants than the Saudi participants (64% and 46% respectively, $p < 0.001$). The Australian participants tended to utilize the ceiling-suspended transparent screen more often than the Saudi participants did, at rates of 57% and 47%, respectively ($p < 0.001$). Additionally, 66% of the Australian participants used the lead drape suspended from the table in every case, while only 41% of Saudi participants used it in every case ($p < 0.001$). More than half of the Saudi participants (63%) never used the floor-based movable lead shield, compared with 25% of the Australian participants ($p < 0.001$). Figure 1 and Table 1 summarize the differences in these four factors between the two countries.

Trained versus untrained staff

There was highly significant difference between the staff who received training in RP and those who did not. The percentages of participants who never used leaded eyeglasses were higher among the untrained staff than the trained staff (67% and 51%, respectively; $p < 0.01$). The ceiling-suspended transparent screen was used in every case by 55% of the trained respondents, compared to 33% of the untrained workers ($p < 0.01$). The trained professionals also demonstrated more frequent usage of the lead drape suspended from the table in every case compared to the untrained staff (57% versus 29%, respectively; $p < 0.001$). Finally, 75% of the untrained respondents never utilised the floor-based movable lead shield, compared to 40% of the trained staff ($p < 0.001$). Table 2 shows the differences in these four factors between trained and untrained staff.

Comparison of differences within job categories

Figure 2(a) shows that higher percentage of nurses had never used the leaded eyeglasses compared to the technologists and doctors (68%, 49%, and 24%, respectively, $p < 0.001$). Percentage of nurses and technologists who never used the radiation-attenuating sterile surgical gloves was higher than the doctors (98%, 97%, and 79%, respectively, $p < 0.001$). Regarding the sterile lead equivalent patient-mounted drape, 90% of the technologists never used it, compared to 79% of the nurses and 68% of the doctors ($p < 0.01$). Higher percentage of nurses used ceiling-suspended transparent screen in every case compared to the technologists and doctors (53%, 51% and 44%, respectively, $p < 0.05$), (Figure 2, b). More than half of doctors (66%) and technologists (54%) used the lead drape suspended from the table in every case, whereas the percentage was lower among the nurses (45%, $p < 0.05$) (Figure 2 c). Finally, 50% of nurses, 43% of technologists, and 37% of doctors never used the floor-based movable shield ($p < 0.05$).

Comparison of factors affecting each protective device

Saudi participants versus Australian participants

The most common factors that can affect the use of protective devices in Australia are as follows: lack of availability for eyewear, patient mounted drape and radiation-attenuation surgical gloves; ease of use for ceiling suspended shield, the table hanging shield and floor based shield; and comfort for lead apron and thyroid shield. In contrast, in Saudi Arabia, the most common factor was the lack of availability of eyewear, table-hanging shield, floor based shield, patient mounted drape, and radiation-attenuation surgical gloves. The second common factor was comfort with respect to the use of lead apron, thyroid shield and ceiling suspended shield.

Trained versus untrained staff

Table 4 displays the differences between the most common factors given by the trained and untrained staff regarding their use of each protective device. The trained staff chose comfort as the reason for not using the lead apron and the thyroid shield. The ease of use was chosen for ceiling-suspended screen. Lack of availability was the dominant selected factor for the usage of the following devices: leaded eyeglasses, lead drapes suspended from table, floor-based movable shield, sterile lead equivalent patient-mounted drape, and radiation attenuating sterile surgical gloves. By contrast, untrained workers chose comfort and lack of availability more often than the other factors. Comfort was selected for the lead apron, thyroid shield and the ceiling suspended screen. However, lack of availability was selected most often for the following: leaded eyeglasses, lead drapes suspended from table, floor-based movable shield, sterile lead equivalent patient-mounted drape, and radiation attenuating sterile surgical gloves.

Comparison of respondents' attitudes towards the protective devices

Australian participants versus Saudi participants

Both countries showed similar attitudes towards using the lead apron and the floor-based movable lead shield. However, as shown in Figures 3(a) - 4(f), differences existed between the two countries with regard to other devices: 97% of the Australian participants answered that the thyroid shield was an essential device, whereas the percentage was slightly lower among the Saudi participants (90%, $p < 0.05$). More than half of the Saudi respondents (60%) responded by stating that the leaded eyeglasses were essential, while 51% of the Australian participants provided answers as optional ($p < 0.01$). More Australians than Saudis indicated that the ceiling-suspended screen was an essential safety tool, at 86% and 67%, respectively ($p < 0.01$). Similarly, 82% of the Australian participants and 57% of the Saudi participants said that the lead drape suspended from the table was an essential device ($p < 0.001$). In addition, more Australian participants than Saudi participants had no opinion regarding the sterile lead equivalent patient-mounted drapes (43% and 20% respectively; $p < 0.001$) and the radiation-attenuating sterile surgical gloves (38% and 18% respectively; $p < 0.001$).

Trained versus untrained staff

There were no significant differences between the opinions of the trained and untrained staff regarding six RP devices: the lead apron, thyroid shield, lead eyeglass, ceiling-suspended screen, lead drapes suspended from table, and the sterile lead equivalent patient-mounted drape. As shown in Figure 4(a), the majority of trained staff (52%) said these were optional devices, whereas the untrained staff (50%) said these were essential safety devices ($p < 0.01$). Additionally, a higher percentage of trained staff (40%) believed that the radiation-attenuating sterile surgical gloves were an optional device, while 46% of the untrained workers responded that they were an essential device ($p < 0.001$, see Figure 4, b)

Comparison within job categories

The analysis showed similar attitudes among the doctors, technologists, and nurses regarding the use of five of the eight protective devices: the lead apron, thyroid shield, lead eyeglasses, ceiling-suspended screen, and lead drapes suspended from table. With regard to the floor-based movable lead shield, 71% of doctors and 49% of technologists said that it was an optional device, while 48% of the nurses said that it was an essential safety device ($p < 0.001$). With regard to the sterile lead equivalent patient-mounted drape, the doctors' attitudes varied between optional (45%) and no opinion (41%), the nurses' opinions ranged between essential (31%) and optional (36%) and higher percentage of the technologists' responses stated that it was an optional device (39%) ($p < 0.01$). Finally, the responses within all professional categories indicated that the radiation-attenuating sterile gloves were an optional device (38% doctors, 42% technologists, and 34% nurses, $p < 0.001$).

Comparison of respondents' attitudes towards body parts

Saudi participants versus Australian participants

The Australian participants ranked the importance of the risk to body parts as follows: thyroid and gonads (60%) ranked first followed by eyes (44%), bone marrow (43%), skin (15%) and hands (14%). The Saudi participants ranked the importance of the risk to body parts as follows: 80% of participants chose the thyroid as the most important, followed by the gonads (78%), bone marrow (65%), eyes (62%), skin (41%) and hands (31%).

Trained versus untrained staff

The employees trained in RP showed the highest percentage of concern about the risk of radiation to body parts as follows: thyroid (69%), gonads (67%), eyes (53%), bone marrow (51%), skin (25%) and hands (21%). The untrained staff rated the risk of radiation to body parts as follows: thyroid and gonads (88%), bone marrow (75%), eyes (63%), skin (50%) and hands (31%).

Comparison within job categories

The body parts of most concern to the doctors were as follows: thyroid (64%), gonads (58%), eyes (53%), bone marrow (40%), skin (26%) and hands (24%). The technologists' concerns for the risk of radiation to body parts were as follows: gonads (77%), thyroid (70%), eyes (54%), bone marrow (47%) and hands (17%). The nurses' concerns for the risk of radiation to body parts were as follows: thyroid (76), gonads (72%), bone marrow (67%), eyes (55%), skin (35%) and hands (28%).

Discussion

The key findings of this study are summarized as follows. First, 99% of Australian participants were involved in RP training versus 68% of participants from Saudi Arabia. Second, a lack of availability was the most commonly cited factor as the barrier in using five protective tools in Saudi Arabia and three protective tools in Australia. Third, the Australian participants placed greater importance on protecting the entire head including the eyes than the Saudi participants. Fourth, trained participants were more positive about the effectiveness of the protective tools and showed better compliance accordingly than untrained participants.

RP training is considered by all international bodies as a key component for reducing medical radiation doses, while maintaining optimum imaging quality [16]. Recent studies have shown that cardiologists formally trained in RP are more aware of radiation safety than those who are untrained [17, 18]. A recent systematic review showed that RP training can efficiently raise the awareness of medical staff working in a catheterization laboratory and reduce their exposure to radiation doses [19]. The International Commission on Radiological Protection (ICRP) indicates that interventional procedures are mainly operator dependent with slight variances in techniques and roles existing among centers. Therefore, the ICRP underlined the importance of involving all individuals who perform interventional procedures in RP training. The commission further specified special recommendations for professionals working in the interventional laboratory: (1) the training should be higher in level than that designed for diagnostic radiology; (2) whenever new techniques or equipment are implemented, additional specific training is desirable; (3) a quality assurance program for IR facilities should be combined with RP training and dose control assessment techniques [20].

Lead apron and thyroid shield

This study found that lead aprons and thyroid shields were widely used by both the Australian and the Saudi participants. These two devices are universally known as standard practice for any profession in an interventional laboratory including physicians, technologists, and nurses [13, 21]. Worldwide regulations necessitate the use of a lead apron with at least 0.5 mm lead-equivalent, which can attenuate more than 90% of scattered radiation [22]. Although the best protection practice is to apply a thyroid shield at all times, it is typically an optional protective device recommended for personnel exceeding 4 mSv of monthly collar radiation monitor readings [23]. The risk of radiation-induced thyroid cancer is highly dependent on age, and thus, using a thyroid collar becomes less critical for workers over 40 years of age [24, 25]. The majority of participants from both populations (97% in Australia and 90% in Saudi Arabia) failed to answer correctly when they chose the option that the thyroid shield is an essential safety device. Most of the participants were unclear about the purpose of thyroid shield, although majority of them indicated they had received RP training, and this needs to be clarified. However, our study did not show whether they received the higher level of RP training recommended by the ICRP or attended a general level of RP events. Even after receiving training, they might have been confused as to the best safety practice in the interventional laboratory and the correct thought about the thyroid shield.

The dominant factor that affects the use of the lead apron and the thyroid shield in both countries is comfort. Klein et al. [9] stated that standing for long hours and carrying a heavy lead apron is usually uncomfortable. An appropriately fitted apron is essential for providing optimum RP and reducing ergonomic problems for operators and staff who regularly work in the interventional laboratory [21]. Currently, the highest selling protective apron is made from lightweight lead composite or lead free material (antimony, barium, tin and tungsten) which weighs only 30% of an equivalent thickness of lead and provides the same attenuation level [22]. Many operators prefer the configuration of the vest/skirt design, as it distributes the apron's weight between the wearer's shoulders and hips [21, 22].

In general, most participants from both countries displayed the best practice when using the lead apron and the thyroid shield in every case. Their attitudes towards the lead apron also represented a good awareness. However, thoughts about the necessity of the thyroid shield should be corrected, except for the 9% of Saudi participants and 2% of Australians who demonstrated a better understanding.

Lead eyeglasses, ceiling suspended transparent screen and sterile lead equivalent patient mounted drape

In 2007, the ICRP published a revised radiation protection document based on the 1990 commission's recommendations. The revised recommendations specified 150 mSv as the annual equivalent dose limit for the eye's lens which is the same as in the 1990s recommendations. However, this limit underwent revision by the task group of the ICRP, as many researchers have argued that the formation of radiation-induced cataracts may occur after exposure to a single dose of radiation (stochastic effect) rather than the threshold limit (7, 27, 28). Hence, a new statement has been released by the commission in 2011 reducing the equivalent dose for the lens of the eye to 20 mSv per year, averaged over periods of 5 years, with no single year exceeding 50 mSv (29). A busy interventional specialist performing around 800 procedures per year may reach the lens dose limit (30). It is thus preferable to employ the ceiling suspended shield in all cases, as it provides protection for the entire head, not only the eyes. However, in cases where this shield interferes with the interventionist's ability to perform the procedure, leaded eyeglasses with side shields should be worn (6).

Our study showed differences between the Saudi and Australian participants' use of lead eyeglasses and ceiling suspended screens. In every case, the Australian respondents (20%) used lead eyeglasses more than the Saudi respondents (12%). In addition, the Australian participants indicated using the ceiling-suspended transparent screen more often than the Saudi participants at rates of 57% versus 47% in every case, respectively, and 28% versus 15% in almost every case, respectively. According to the data analysis in this study, it is shown that the Australian participants use eye and head protection more than the Saudi Arabian participants. There are several possible explanations for these results: First, it could be due to the lack of RP training among Saudi participants, as about one third did not receive RP training compared with 99% of trained workers in Australia. This explanation is supported by the very significant difference found in our results between trained and untrained staff (Table 2). Lack of training could therefore lead to an insufficient understanding of the different optional protection devices.

Another possible explanation is that individuals' thoughts towards protective tools may reflect negatively or positively on his or her compliance. This interpretation is clearly illustrated by the data derived from the Australian participants. More professionals considered the ceiling suspended screen an essential device (82%) than those who considered the leaded eyeglasses essential (41%) (Figure 3). Subsequently, the Australian respondents utilized the ceiling suspended screen (57%) much more than the leaded eyeglasses (20%) in every case. Similarly, regarding the sterile lead equivalent patient mounted drape in both countries, more professionals either had no opinion on it or considered it an optional device (Figure 3); this contemplation could be caused by a lack of availability, as indicated by more than half of both countries (Table 3), and a belief that few will benefit from its value (Table 1). However, despite more than 60% of Saudi participants acknowledging the sensitivity of eyes to the hazards of radiation and agreeing with the necessity for leaded eyeglasses and ceiling suspended screens, their use of these devices is much more limited than that of the Australian participants. The limited usage of the leaded eyeglasses among Saudi participants could be due to the lack of availability indicated by around one-third of them. Therefore, unavailability or limited accessibility (available but not enough) could be a valid justification. However, it is still unclear why about 30% of Saudi respondents cited comfort affecting the use of such important device like the ceiling suspended screen. This may reflect a lack of good habits reinforced by the regulations mandating their use, as suggested by Lynskey et al. [(13)].

An additional possible explanation as to why opinions are varied about the above protective devices may be due to different hospitals having different policies and different staff having different roles. Our study supports this justification, as there are highly significant differences within job classifications (doctors, technologists and nurses), regardless of the country origin. A higher percentage of nurses (68%) had never used the leaded eyeglasses compared to the technologists (49%) and doctors (24%). In addition, the nurses (53%) displayed higher usages of the ceiling-suspended transparent screen in every case compared to the technologists (51%) and doctors (44%). Regarding the sterile lead equivalent patient-mounted drape, 90% of the technologists had never used it, compared to 79% of the nurses and 68% of the doctors.

Although scattered radiation decreases in proportion to the inverse squared distance from the irradiated area, combining various types of shielding leads to dramatic dose reduction [21]. This guarantee is either for the main operator or for assistance staff. However, not all laboratory suites contain all protective methods, and it is even possible to find different tools in different suites within the same unit. Therefore, an appropriate understanding of how to deploy the available shielding methods for maximal effective protection is critical [31]. A recent study declared that using the transparent lead glass screen can only achieve a 19-fold dose reduction to the eye [32]. Moreover, several phantom studies [30, 33, 34] have revealed that doses at the lens are undetectable when using a combination of lead eyeglasses and a lead suspended glass screen, and a 5- to 25-fold dose reduction occurs when utilizing leaded eyeglasses alone [30]. Similarly, in a small prospective controlled trial, the lead equivalent patient-mounted drape has been shown to considerably decrease radiation dose to interventionists by 29-fold for the hands, 26-fold for the thyroid and 12-fold for the eyes [35]. At the same time, the radiation dose to assistants is reduced to a negligible level without an additional dose to the patient [13, 21]. Another study showed a 23% total body dose reduction to the main operator with a bismuth-barium disposable drape [36].

In summary, the findings of this study suggest that the opinions towards lead eyeglasses and the ceiling suspended screen and acts according to these views are better among the

Australian participants than the Saudi participants. Employing the available protective tools effectively is fundamental in radiation safety. It is essential that all interventional team members have access to a range of protective devices according to their role.

Lead drape suspended from the table

Presently, lead curtains suspended from the table alongside the ceiling-suspended lead screen are considered the standard shields supplied with fluoroscopy systems for use in interventional laboratories [6]. One of the conclusions drawn from the European research project, Optimisation of RP of Medical staff (ORAMED), is that the leg doses are reduced by 4.5 to 6.8 times when applying the table shield [37]. However, a steep oblique or lateral position of the C-arm tube could prevent its availability [21, 22]. The uses and attitudes towards this important protective device from the Australian and the Saudi participants were highly different, thus adding another key finding to our results. Among the Australian participants, 82% considered the table suspended lead drape an essential device, resulting in 62% of them using it in every case; whereas, 57% of Saudi respondents considered it an essential device, resulting in only 41% using it in every case. The most obvious finding to emerge from the analysis is that comparing the responses between job categories showed that more doctors utilize this particular tool than technologists and nurses. Therefore, this may explain why utilizing the lead drape suspended from the table is limited in Saudi Arabia. In other words, different centers have different policies and each professional will act upon his role in the laboratory. The factors governing the lack of use of this protective tool were lack of availability in Saudi Arabia (34%) and ease of use in Australia (16%). Notably, trained professionals demonstrated much greater usage of this device compared to untrained staff. However, 39% of the untrained staff indicated unavailability as a limitation to their usage. As almost all the untrained staff were from Saudi Arabia, except one from Australia, it is likely that the Saudi participants had inadequate awareness of such an important device to benefit from its availability. However, our study did not intend to explore further reasons behind the shortages in supply in both countries. Therefore, lack of availability could also be a logical reason for the poor usage in Saudi Arabia.

Floor-based movable lead shield

Floor-based rolling and stationary shields constructed of transparent leaded plastic are useful for providing additional shielding for operators and staff. They are designed particularly to suit duties of nurses and anesthesia personnel [6]. The Australian respondents seemingly benefit from this device according to their role, as their responses are almost equally distributed between every case, almost every case, only selected cases and never (Table 1). The main barrier affecting their use of the floor-based movable shield is its ease of use. The Saudi participants cited lack of availability as the dominant factor (cited by 56%) preventing them from taking advantage of these shields, as 63% of them had never used one. Both countries had correct opinions towards this device, as greater percentages understood it is optional.

One of the interesting finding of this study is that training had an effect on the respondents' thoughts: 77% of the untrained staff indicated lack of availability as the main factor leading to their poor usage of these shields. However, the majority of them were unsure of its necessity (50% believed it to be an essential device and 21% had no opinion).

Radiation attenuating sterile surgical gloves

Compared with other body parts, interventionists' hands may be exposed to the direct beam resulting in high doses of radiation, especially during complicated procedures. Sterile protective surgical gloves are now available with attenuation levels ranging from 15%–30% [22]. Nevertheless, two factors may contradict the usefulness of this protective tool: first, applying any shield in the direct beam will increase the dose and x-ray technique factors, and second, wearing protective gloves may cause a false sense of security, subsequently increasing the dose [38]. Therefore, it is not recommended to use the leaded gloves when the operator's hands are placed in the primary radiation beam, but they may be of benefit if the hands are close to the beam. One expected finding is that doctors indicated their usage of protective gloves more often than technologists and nurses. This is normal, as most of the literature discusses using the protective gloves when placing the operator's hands into or close to the primary beam [21, 22].

Our study showed no differences in the usage of the sterile leaded gloves between the two countries or the trained and untrained groups. Lack of availability was cited as the main factor for the lack of use by most participants in both the populations. However, the Australian participants were slightly more cautious than the Saudi participants regarding the necessity of leaded surgical gloves, providing answers of "no opinion" (38%) and "optional device" (36%) compared to the Saudis' opinions of "essential device" (35%) and "optional device" (37%) (Figure 3). Notably, differences in attitudes also existed between the trained and untrained groups. The trained staff showed a better understanding than the untrained staff; however, this could be due to the fact that the Saudi participants' were influenced by the presence of more untrained respondents among them.

Respondents concerns towards body parts

Dose limits for occupational exposure adopted by most countries in the world and recommended by the ICRP are based on the sensitivity of the body part to the radiation (stochastic and deterministic effects) [22]. Dose limits for deterministic effects are expressed in equivalent doses, whereas the effective dose (E) is used to express the stochastic effects. Calculating the effective dose can indicate the overall effect of radiation on the exposed organs and tissues. To calculate the effective dose, the equivalent dose to any particular organ or tissue is multiplied by a tissue weighting factor.

Sufficient epidemiological information suggests that thyroid, gonads, and bone marrow are considered among the tissues and organs with high sensitivity to the tumorigenic effects of radiation (stochastic effects). The tissue weighting factors for these tissues are 0.04, 0.08 and 0.12 respectively [(7)]. Logically, the effective dose limit for these body parts should be low (20 mSv per year, averaged over defined periods of five years and not exceeding 50 mSv in any one year). Moreover, as mentioned earlier, the eye's lens maybe classified as stochastic and thus 20 mSv should not be exceeded in the annual dose limit. By contrast, because the tissue weighting factor (0.01) and the sensitivity of the skin and hands to the radiation is lower than the other body organs, they are classified to be deterministic and their equivalent dose limits are 500 mSv for the skin and hands [(7)].

One of the objectives of this study is to determine the differences between workers at the catheterization laboratory from both countries regarding the use of the protective tools based on their attitudes towards them. Concerns regarding the risk of radiation-induced health problems were rated similarly by all the different groups of our study's respondents. The thyroid and gonads were of the greatest concern followed by bone marrow and eyes, while the skin and hands were of least concern. Consequently, the lead apron and thyroid shield were used more often than the other protective tools. These two devices are known to be the fundamental tools to protect the thyroid glands, gonads and bone marrow, which are the top rated organs concerning our study's participants. As the hands were of least concern for our respondents, the least utilized protective tools were the lead equivalent patient mounted drape and the leaded surgical gloves. However, attention should be paid to the protection of the eyes, especially in Saudi Arabia. Although 63% of the Saudi participants ranked the eyes to be the most important body part compared to 44% in Australia, eye protection is seemingly better in Australia than in Saudi Arabia, as mentioned earlier.

Limitations

The generalizability of this study's results is subject to certain limitations. First, the small sample size, especially of the interventionists and technologists, did not allow for a comparison between each job category from the two countries. Further, the limited responses from doctors did not allow us to common on the working experiences by physicians. Second, the study did not intend to distinguish between practices such as public from private, public or military institutions, this data were analyzed collectively; therefore, it is unknown whether the practices are enforced by the policies at each of the selected hospitals. The study is also limited by the lack of information on the hospitals' accreditations, and this could further explain the variations reported between the Australian and Saudi Arabian respondents. Simplifying the answer by reducing the number of options in some questions could have ensured higher responses.

Conclusion

In conclusion, this study indicates that the trained interventional professionals in Australia (99%) tend to benefit from having an array of tools for personal RP more than the corresponding group in Saudi Arabia (68%). The different responses from the Saudi and Australian participants might be related to differences in clinical practice management between the two countries. Although the model for clinical practicum in Australia does not always need to be emulated, much can be learned from the comparative results of the data in this study. Overall, this study strengthens the idea that RP training must be considered for all medical practitioners according to their role in dealing with the ionizing radiation. Future studies could assess the reasons why some of the protective devices are not readily available for use.

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Figures and figure legends

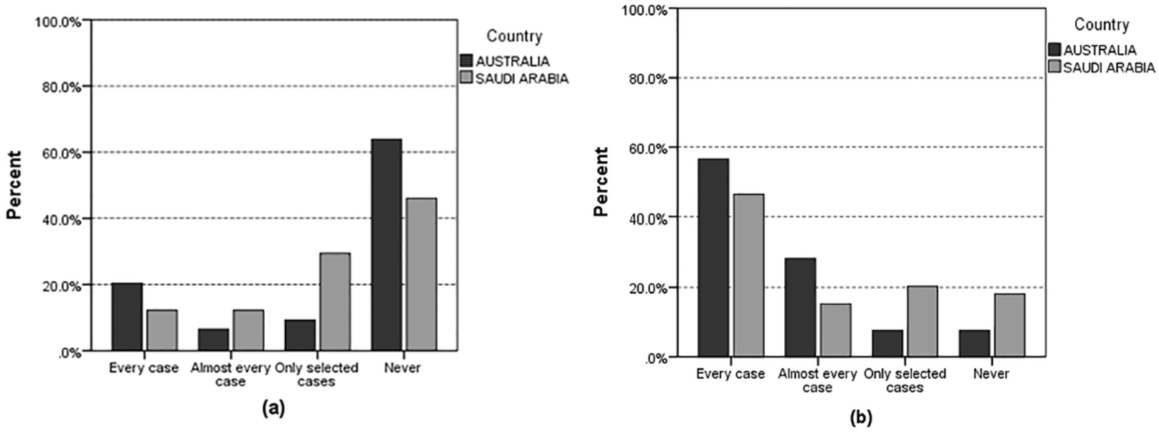

Figure 1: Comparison between Saudi and Australian participants' usage frequency of leaded eyeglasses (a) and ceiling suspended transparent screens (b).

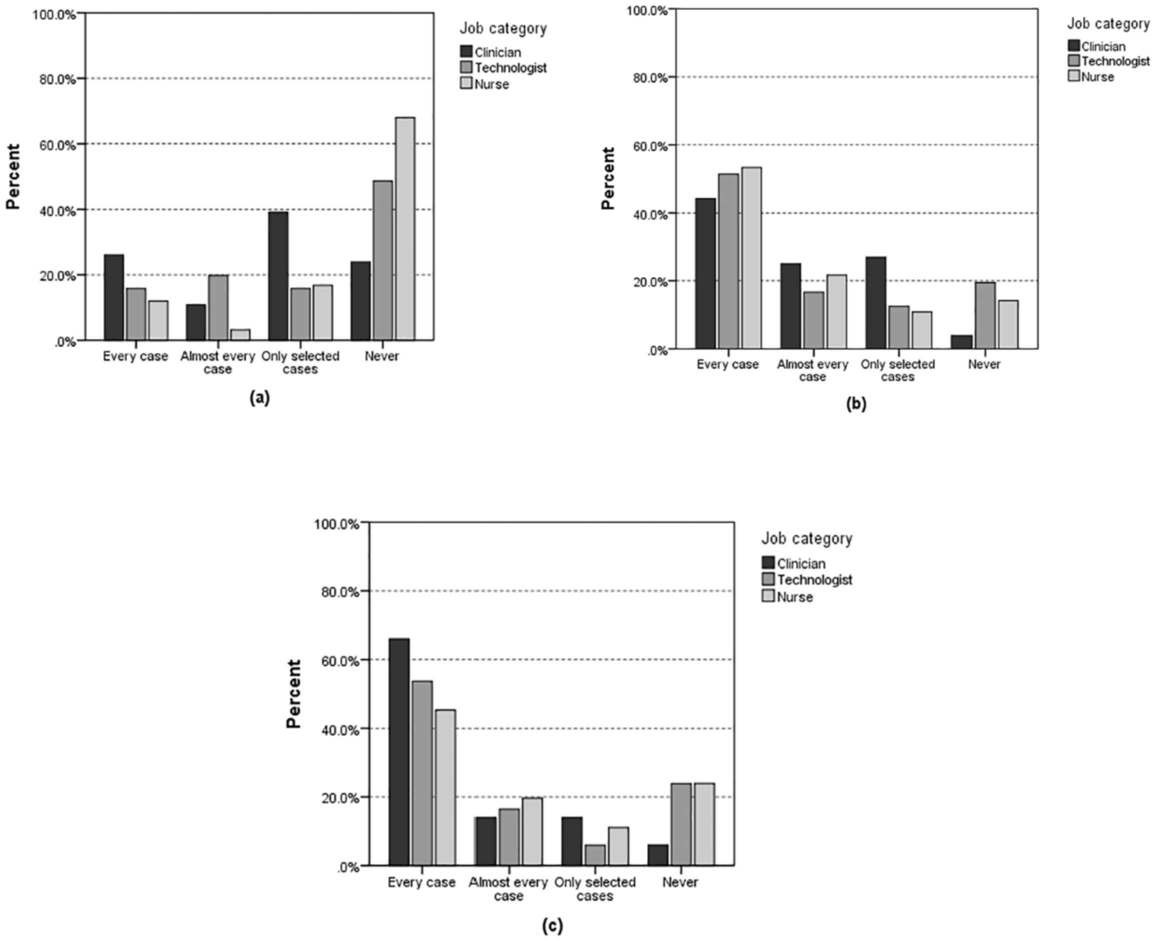

Figure 2: Comparison of the usage frequency by job type of (a) leaded eyeglasses, (b) ceiling suspended screen, and (c) lead drape suspended from the table.

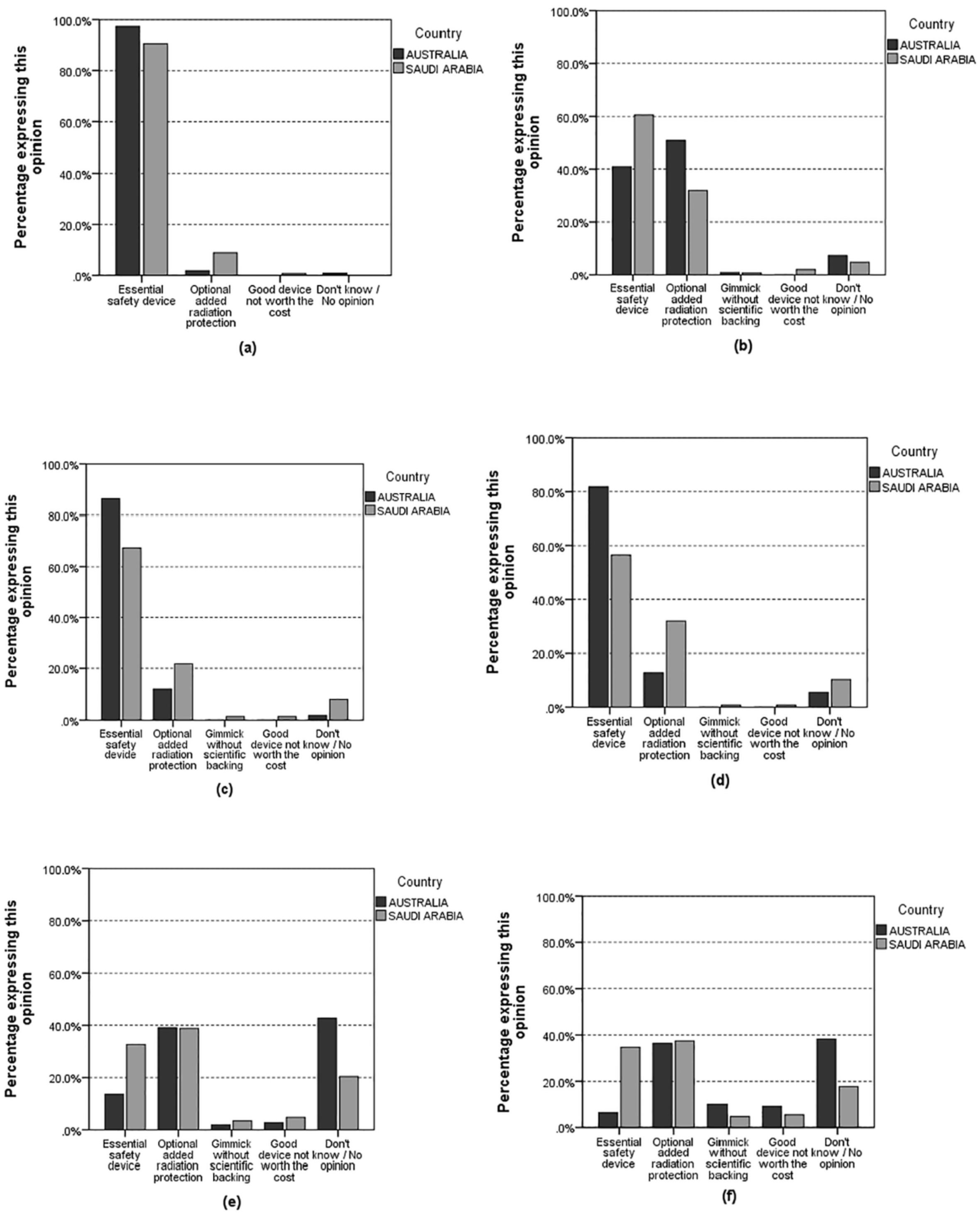

Figure 3: Comparisons of the Saudi and Australian respondents' opinions of the following protective devices: (a) thyroid shield, (b) leaded eyeglasses, (c) ceiling suspended screen, (d)

lead drape suspended from table, (e) lead equivalent patient mounted drape, and (f) leaded sterile gloves.

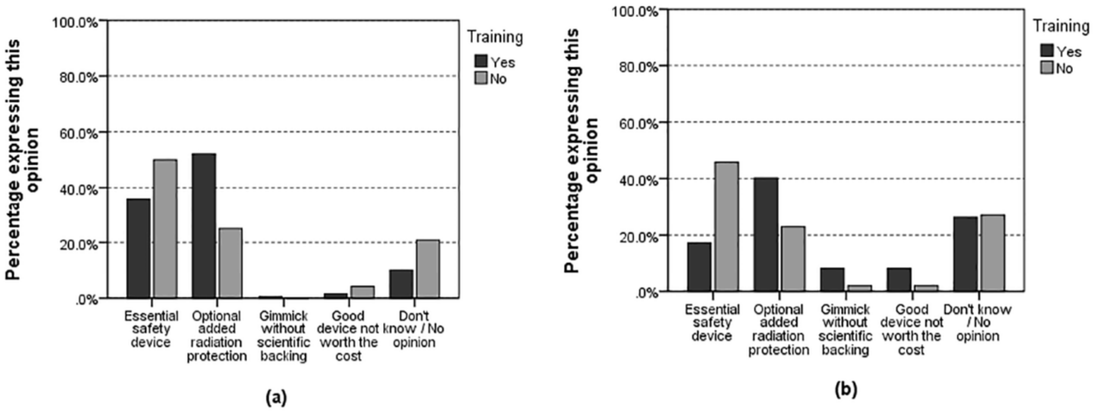

Figure 4: Comparison of the trained and untrained groups' opinions of (a) the floor based movable shield and (b) the leaded sterile gloves.

Table 1: Differences in protective device usage between between the Saudi and Australian participants

Protective devices	Country (Count + percentage within country)								p Value
	Australia				Saudi Arabia				
	Every case	Almost every case	Only selected cases	Never	Every case	Almost every case	Only selected cases	Never	
Leaded eyeglasses	22 20%	7 7%	10 9%	69 74%	17 12%	17 12%	41 30%	64 46%	0.000 $p < .001$
Ceiling-suspended screen	60 57%	30 28%	8 8%	8 7%	64 47%	21 15%	28 20%	25 18%	0.000 $p < .001$
Lead drape suspended from table	69 66%	19 18%	7 7%	10 9%	53 41%	22 17%	17 13%	37 29%	0.000 $p < .001$
Floor-based movable shield	28 28%	13 13%	35 34%	25 25%	16 13%	9 7%	21 17%	77 63%	0.000 $p < .001$

Table 2: Differences in protective device usage between staff trained in RP and staff untrained in RP presented as frequencies and percentages

Protective device	Trained staff				Untrained staff				*p* Value
	Every case	Almost every case	Only selected cases	Never	Every case	Almost every case	Only selected cases	Never	
Leaded eyeglasses	38 19%	20 10%	41 20%	103 51%	1 2%	4 9%	10 22%	30 67%	0.011 $p < .01$
Ceiling-suspended screen	109 55%	43 22%	26 13%	20 10%	15 33%	8 17%	10 22%	13 28%	0.003 $p < .01$
Lead drape suspended from table	109 57%	34 18%	17 9%	30 16%	13 29%	7 16%	7 16%	17 39%	0.001 $p < .001$
Floor-based movable shield	42 23%	18 10%	52 28%	74 40%	2 5%	4 10%	4 10%	28 75%	0.000 $p < .001$

Table 3: The most frequently selected factors affecting the usage of each device based on country

Safety device	Australia (110 respondents)		Saudi Arabia (147 respondents)	
	Usage factor	Frequency	Usage factor	Frequency
Lead apron	Comfort	31 (28%)	Comfort	77 (52%)
Thyroid shield	Comfort	26 (24%)	Comfort	91 (62%)
Leaded glasses	Not available	38 (34%)	Not available	56 (38%)
Ceiling-suspended screen	Ease of use	27 (24%)	Comfort	47 (32%)
Lead drape suspended from table	Ease of use	18 (16%)	Not available	50 (34%)
Floor-based movable shield	Ease of use	26 (24%)	Not available	82 (56%)
Sterile lead equiv. patient-mounted drape	Not available	64 (58%)	Not available	96 (65%)
Radiation-attenuating Sterile surgical gloves	Not available	68 (62%)	Not available	94 (64%)

Table 4: The most frequently selected factors affecting the usage of each device based on training

Safety device	Trained staff (209 respondents)		Untrained staff (48 respondents)	
	Usage factor	Frequency	Usage factor	Frequency
Lead apron	Comfort	81 (39%)	Comfort	27 (56%)
Thyroid shield	Comfort	85 (41%)	Comfort	32 (67%)
Leaded eyeglasses	Not available	67 (32%)	Not available	27 (56%)
Ceiling-suspended screen	Ease of use	57 (27%)	Comfort	18 (37%)
Lead drape suspended from table	Not available	39 (19%)	Not available	19 (39%)
Floor-based movable shield	Not available	64 (31%)	Not available	37 (77%)
Sterile lead equiv. patient-mounted drape	Not available	125 (60%)	Not available	35 (73%)
Radiation-attenuating Sterile surgical gloves	Not available	125 (60%)	Not available	37 (77%)