



Perceptions on radioprotective garment usage and underlying reasons for non-adherence among medical radiation workers from public hospitals in a middle-income Asian setting: A qualitative exploration



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ABSTRACT

Background: Radioprotective garments protect medical radiation workers from exposure to radiation at workplace. However, previous studies have found poor adherence to the use of radioprotective garments.

Objectives: We explored the perceptions and practices related to the use of radioprotective garments among medical radiation workers in public hospitals, and sought to understand the reasons for non-adherence.

Design and setting: A qualitative approach was applied by conducting face-to-face in-depth interviews with 18 medical radiation workers from three university hospitals using a semi-structured interview guide.

Results: Five themes emerged with respect to perceptions on the use of radioprotective garments: (i) the dilemmas in practising radiation protection, (ii) indication of workers' credibility, (iii) physical appearance of radioprotective garments, (iv) practicality of radioprotective garment use, and (v) impact on workflow. Actual lack of radioprotective garment use was attributed to inadequate number of thyroid shield and other garments, radioprotective garments' unsightly appearance including being dirty and defective, impracticality of using radioprotective garments for some nuclear medicine procedures, disruption of workflow because of workers' limited movements, attitudes of workers, and organisational influences.

Conclusion: Medical radiation workers demonstrated a definitive practice of using radioprotective aprons, but often neglected to use thyroid shields and other garments. Availability and hygiene are reported as the core issues, while unclear guidelines on practical use of radioprotective garments appear to lead to confusion among medical radiation workers. To the best of our knowledge, this is the first qualitative study of its kind from a middle-income Asian setting.

1. Introduction

Medical radiation workers (MRWs) are exposed to ionising radiation during the course of their work, in either radiology or non-radiology-based departments. The primary source of occupational exposure comes from the scattered radiation produced by the radiation beam that strikes patients during procedures. Hence, patient dose optimisation is useful for reducing the overall occupational dose. In addition to this administrative control measures, it is necessary for MRWs to apply all radiation protection principles, including justification and limitation, in order to avoid unnecessary exposure and to maximise their occupational safety [1]. These principles are combined with exposure-limiting factors to develop a hierarchy of control measures that involves engineering

control such as isolation, administrative control such as reduction of exposure time and increasing the distance from radiation source and use of personal protective equipment like shielding [2].

One form of shielding is personal radioprotective garment (RPG) that needs to be used individually by the MRWs at appropriate times when working with radiation. Two compulsory protective items for MRWs when conducting interventional and fluoroscopic procedures are radioprotective aprons and thyroid shields. In addition, protective goggles, gloves and caps are vital for personnel who work near the radiation beam and the patient; these are usually interventional radiologists, doctors and assisting nurses [1, 3]. These garments should be used at all times during interventional or fluoroscopic examinations as outlined in the Basic Safety Radiation Protection Regulations under Act 304 (1984) [4] in

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Malaysia, which is established based on the guidelines of the relevant international authorities [5, 6, 7].

Complete adherence to use of RPGs is uncommon in radiology and non-radiology departments in some countries and regions. A number of quantitative studies among European and Turkish urology departments captured a list of reasons for lack of RPG use among its workers such as being heavy, not ergonomic, and not practical to put up/down [8, 9]. A study among urology workers in the US meanwhile identified reasons including items not being available, forgetfulness, lack of knowledge on options, and not caring to use [10]. However, in the radiology settings, the reasons for lack of adherence to RPG use are unclear [11, 12, 13, 14]. Inconsistent use of RPGs may lead to deterministic and stochastic harms such as radiation sickness, tissue damages and cancers [15].

It has been previously suggested that qualitative studies are conducted to gain in-depth insights on attitudes towards radiation protection and practices, as well as to further clarify the factors leading to poor radiation protection practice, particularly in the use of RPGs [14]. A qualitative study of radiation protection attitudes among nursing staff in a cardiac catheterisation laboratory had identified the discomfort associated with use of heavy lead clothing, and the failure of the employers to provide other protective devices, such as glasses and lead gloves as reasons for lack of adherence [16]. However, these findings need to be verified among other groups of MRWs in radiology settings. Particularly, evidence from middle-income settings is scarce, especially in Asia.

In the current study, we used a qualitative approach to gain an in-depth understanding on the attitudes and practices related to RPG use among MRWs working in radiology departments of public hospitals in a middle-income Asian setting. We posed these key questions: (i) How do MRWs perceive the use of personal RPGs? (ii) What are the reasons for lack of use of RPGs?

Findings from this study may also be inferred to other Asian radiology practices given that radiology education, syllabus, accreditation and training across most Asian countries are standardized [17, 18]. Notably, the radiological societies across these countries consistently interact through various international collaborations to discuss the challenges and the way forward to improve services [19].

2. Methods

2.1. Study design and setting

This qualitative study applied an in-depth interview method to gain greater understanding of the perception and practice of RPG use among MRWs. An invitation letter and a research approval letter were sent to the head of the imaging departments of all five public university hospitals in Malaysia. Three hospitals provided timely consent. Two of the three consenting university hospitals were located in Kuala Lumpur and had radiation-related departments that were large-sized and medium-sized (No. of MRW $\approx$ 400 and 200, respectively). The other hospital in Kuantan, Pahang had a much smaller department with about 60 employees. The interviews were conducted between August and November 2017.

2.2. Study informants

Purposive sampling was applied to recruit Malaysian MRWs aged 18 years and above, who were able to converse in either English or Malay and had at least one-year experience of working as an MRW. Eighteen MRWs from the three university hospitals were interviewed face-to-face until data saturation was achieved, when no new themes were found to emerge during the subsequent interviews with new respondents [20]. In accordance with maximum variation sampling [21], we interviewed MRWs from various designations to reflect a variety of perspectives and attitudes. The informants included nine radiographers, three nuclear medicine technologists, three staff nurses, two radiologists, and one medical assistant. Their primary service areas were in interventional radiology (fluoroscopy and angiography), surgeries with c-arm, nuclear

medicine, computed tomography scan, mammography, general radiography, ultrasound, and magnetic resonance imaging.

2.3. Interview design and process

An expert-validated semi-structured interview guide was used for data collection. The interview guide was reviewed by academic supervisors and an internal expert and an external expert. Two pilot interviews were then conducted with volunteer MRWs. The interview guide was then modified to improve the clarity and length of the questions as well as their relevance. A single interviewer conducted all the eighteen interviews. Questions were asked regarding the perceptions on use of RPGs that were available in their workplaces, as well as the advantages and disadvantages of these RPGs. To further understand their practices of using RPGs, the informants were also questioned about the facilitating factors and impeding factors of using RPGs. The discussion was not limited to any specific garment but included all RPGs available in their departments – e.g., one-piece apron, two-piece (vest-skirt) apron, thyroid shield, goggles and gloves (see Appendix A: Supplementary materials – Interview guide).

Informants were free to choose either to use Malay or English during the interviews. All interviews were audio-recorded and transcribed verbatim by a transcriber fluent in both languages. The transcriptions were then checked against the original audio-recording by the first author. The duration of the interviews varied between 30 to 45 min.

2.4. Data abstraction

Familiarisation and immersion of the transcribed data was achieved by reading through the transcripts numerous times with the aim of identifying main themes and sub-themes, based on meaningful categories of data. Quotes for each sub-theme were then organised and summarised, and pertinent quotes were identified to be used within this manuscript to best illustrate the themes. The list of coding, categories and themes were discussed with both the subject matter experts and methodology experts. The analysis in this study was performed using the Qualitative Data Analysis Software ATLAS.ti version 8 (Scientific Software Development GmbH, Germany).

2.5. Ethical considerations

The study was approved by the Medical Research and Ethics Committee from the respective institutions (UM2016104-4321; JEP-2017-593; IREC-2017-045). Participant information sheet and consent forms were prepared in both Malay and English languages. Verbal consent was obtained prior to the fixed interview dates, while written consent was gained from the participants on the day of the interviews.

3. Results

Eighteen informants were interviewed, including three male MRWs. The youngest informant was in her mid-twenties, while the eldest was in her early fifties. The longest duration of service in medical imaging was 20 years. Table 1 illustrates the characteristics of the study informants.

3.1. Themes reflecting the perceptions of using RPGs

Based on thematic analysis, five major themes were identified that reflected MRWs' perceptions of using RPGs: (i) the dilemmas in practising radiation protection, (ii) indication of workers' credibility, (iii) physical appearance of RPGs, (iv) practicality of RPG use, and (v) impact on workflow. Overall, all informants reported negative feelings about using RPGs, without dismissing the advantages and positive feelings that they had.

Theme 1 outlined the dilemmas reported by the informants. All participants were well informed of the protection conferred by the RPGs, but

Table 1
Summary of the study informants from the three university hospitals.

Variable	Hospital A (N = 11)	Hospital B (N = 3)	Hospital C (N = 4)
Gender			
Male	3	–	–
Female	8	3	4
Age (years old)			
21–25	–	–	1
26–30	6	–	3
31–35	1	1	–
36–40	3	–	–
41–45	–	1	–
46–50	1	–	–
51–55	–	1	–
Designation			
Radiologist	1	1	–
Radiographer	5	–	4
Assistant Medical Officer	1	–	–
Nuclear Medicine Technologist	2	1	–
Staff Nurse	2	1	–
Education Level			
Certificate	–	1	–
Diploma	7	1	4
Bachelor Degree	3	–	–
Postgraduate Degree	1	1	–
Experience in medical radiation (years)			
1–5	1	–	4
6–10	6	3	–
11–15	1	–	–
16–20	3	–	–

the garments were deemed as too heavy, irritating and troublesome. Four informants in this study were treated for prolapsed intervertebral disc and cervical spondylosis, believed to be related to the heavy garments, lifting patients and operating bulky X-ray machines. Sometimes, the number of RPGs was inadequate, while some were defective. The use of RPGs also has some psychological and physical effects on MRWs, for instances; the belief that heavyweight apron provides ample protection compared to lightweight apron, but heavyweight aprons require extra physical and mental efforts from the workers and contribute to their physical body pains.

Theme 2 described the use of RPGs as crucial in developing the credibility of MRWs within medical services in terms of practice, knowledge and management. By using RPGs, the MRWs believe that they are setting a good example of practice, reflecting adequate knowledge in medical radiation and managing the patient-oriented procedure accurately.

Theme 3 highlighted the physical appearance of the RPGs in the informants' workplace. The RPGs were exposed to biological fluids or contrast suspensions during procedures which compromise the cleanliness of the garments. It was also found that the old RPGs are still being used in their departments. The old garments are at risk of being defective and inefficient. In addition, big-sized RPGs are available most of the time, while the small-sized RPGs were very limited.

Theme 4 drew attention to the practicality of RPG use being determined by the types of radiation sources. The informants in this study reported the inefficiency of RPGs in their work scopes due to high-energy radionuclides they are dealing with. It was perceived that the penetrations of high-energy radionuclides were not reduced by any RPGs.

Last but not least, Theme 5 focused on the impacts of using RPGs in the MRWs' workflow. While the existence of RPGs was perceived as helpful in ensuring that procedures were carried out in a safe timely manner, the weight and design of the RPGs were thoughts as barriers that limit the MRWs' mobility during procedures. The themes, sub-themes and evidence analysed from the primary data are as shown in Table 2.

3.2. Reasons for non-adherence to use of RPG

The problems experienced by informants when using RPGs were the underlying reasons for their lack of use. The use of radioprotective aprons was recorded as excellent despite all the complaints related to them, but non-adherence was mainly reported for the use of thyroid shields, and to a lesser extent for other garments – i.e., radioprotective gloves, goggles and caps.

The reasons for non-adherence were categorised into six themes: (i) inadequate number of RPGs, (ii) unsightly appearance of RPGs, (iii) impracticality of using RPGs for certain procedures, (iv) disruption of workflow, (v) attitude of workers, and (vi) organisational influences. All responses are shown in Table 3, together with the evidence quotes, frequency and the number of sources.

The main reason for non-adherence in using the thyroid shields is due to inadequate number of items being made available in the workplace. The thyroid shield was considered as important as the radioprotective apron in interventional and fluoroscopic procedures, and thus a lack of thyroid shields was deemed unacceptable. The separated-from-apron design of the thyroid shield worsens the situation, as they tend to get lost or misplaced. Moreover, their size makes them susceptible to damage if not handled with care, and they wore out easily. Financial limitations and the high cost for the replacement of RPGs were other sub-themes that emerged. Some MRWs voiced out their thoughts that the limited number of radioprotective gloves, goggles and caps was probably because these items were reserved for doctors who consistently worked near radiation sources.

The unpleasant condition of RPGs – particularly of the thyroid shield, as it is in direct contact with the user's skin – was another major drawback. The design of the thyroid shield is not user-friendly, and this was cited as another reason for MRWs not being in favour of using it.

The impracticality and disruptive nature of using RPGs during some procedures also contributed to the non-adherence. The informants in our study involved in nuclear medicine reported non-use of RPGs regardless of the radiopharmaceuticals used even though there is a guideline to use them in certain procedures. The informants stated that 'word of mouth' from their peers and some reading materials increased their awareness about the inefficiency of RPGs for their work context.

In addition, workers' attitudes and organisational influence also appeared on the list of non-adherence factors in RPG use. The MRWs admitted that their own attitudes influenced their behaviour towards RPG use. They used the words 'lazy', 'prioritising other things' and 'taking things lightly' to describe their attitudes.

At the organisation level, some informants stated that priority for RPG use is given to the doctors near the primary beam. However, even when doctors do not use RPGs, informants do not use them either because they do not want to be portrayed as over-reacting or simply because they tend to accept it as the norm of the department's culture. An informant described an experience of being a junior radiographer influenced by working with senior skilled surgeons who never practised protection of the thyroid area. Over time, the informant decided not to overlook the acknowledged risk by bringing a thyroid shield from her department to the surgery room every time she was assigned there.

4. Discussion

Our findings among MRWs indicate that heavy-weight aprons and the associated discomfort were still identified as the disadvantages of RPGs, but the adherence for usage was very excellent among the informants. However, this study reported the lack of availability of thyroid shields as a factor preventing MRWs from adhering to standards. This is similar to a previous study which reported a universal use of radioprotective apron but not the thyroid shield [10]. The thyroid shield usually comes with the radioprotective apron, but it is easily worn out or misplaced. Replacing lost or damaged garments has great financial implications, as they are

Table 2

Themes and sub-themes identified in the exploration of MRWs' perceptions of using RPGs in their workplaces.

Themes	Sub-themes	Meaning	Evidence
1. The dilemmas in practising radiation protection	Trust the protection ability but it is too heavy	Informants reported the confidence they had in RPGs, in addition to the knowledge they gained from their studies. The weight of the protection apparel was considered a major disadvantage by the informants, especially the earlier one-piece apron design.	'The bad thing is they are heavy. Burdensome. In terms of protection, it is good. In terms of... you know, the thing is heavy. That's the drawback.' – P6, staff nurse, 6 years in medical imaging 'That one-piece apron, it was so heavy, so it somehow demotivates you to wear it, but you have to wear it.' – P11, radiologist, 12 years in medical imaging
	Confident of the protection but it is always irritating	Informants acknowledged the thyroid organs as radiosensitive; however, the inflexible design of the thyroid shield irritates them as users.	'RPGs are able to protect vital parts, like the thyroid and so on—so, that is where our organs are so sensitive, and it is the most important protection for ourselves.' – P1, senior radiographer, 17 years in medical imaging 'In the fluoroscopy unit, the thyroid shields are hard, uncomfortable. In this area (showing the neck region), it is hard. So, honestly, sometimes, I do not even wear one.' – P3, radiographer, 7 years in medical imaging
	Know the ability to reduce risk but it is troublesome	Informants mentioned the hassle they faced in using the radioprotective gloves, such as finding them time-consuming.	'We can't simply wear the latex gloves after we wear the protection gloves, as they will be powdered. So, we have to cover them with plastic gloves first. It obviously takes time to wear multiple layers of gloves, but if you have been doing this for years, you are used to it.' – P9, nuclear medicine technologist, 16 years in nuclear medicine
	Preference for the new lightweight aprons for comfort, but with reduced confidence	The latest designs of RPGs are made of materials that replaced the lead (Pb), which was proven to be the best radiation shield.	'I prefer the lighter apron if available. It is hard for me to work with the heavy ones. But, I wonder, if the apron is light, I assume the lead content must be less, right? Then the exposure is higher. So, the lighter the apron, the less protection it provides, I'm afraid.' – P8, assistant medical officer, 5 years in medical imaging
	Preference for the one-piece apron for psychological need, but with reduced comfort	The improvement of RPGs' weight and design affected the mindset of the users; thus, they continued the use of conventional RPGs.	'I prefer the overall apron that covers you from the top through to the bottom part. I am not really into the vest-and-skirt apron... because I am a big guy, you see.' – P4, radiographer, 7 years in medical imaging 'It's a good thing that they have the lightweight aprons, although sometimes, it has a psychological effect in a way, like, "Eh, is it good enough to protect me?" I always wear big clothes, so I opted for the big-sized apron during my work. But I have to be aware... (of the weight distribution and loose parts of the aprons).' – P11, radiologist, 12 years in medical imaging
	Preference for the one-piece apron to avoid strain on the lower back	Informants who suffered lower back pain have to carefully choose the appropriate RPGs.	'After being discharged on a 3-month sick leave, I am more cautious in using the apron since coming back to work. I used to love the apron with the skirt, but now I've changed to the one-piece apron and avoid the skirt apron because it puts pressure on my waist.' – P7, staff nurse, 6 years in medical imaging
	Attempting full self-protection but having inadequate facilities	The majority of the informants reported the inadequate availability of the thyroid shields for most of the time, and aprons when there are too many staff and students.	'There aren't enough thyroid shields for all staff. We will find them (thyroid shields) for the doctors. After we prepared the procedure set, we just observe from the console. When the doctors stop screening, we go into the room to provide assistance, and then we go out again.' – P13, staff nurse, 10 years in medical imaging 'When I'm left with no more thyroid shields, I have to be in the OT room with just a lead apron. We have to prioritize the thyroid shield for the doctors, as they are closer to the X-ray source.' – P17, radiographer, 1 year in medical imaging
	Attempting full self-protection but having defective facilities	Informants experienced using defective radioprotective aprons that are folded and torn, and possibly allow radiation through.	'Lead aprons in the OT room are not in good condition, actually. I noticed the aprons were folded, and the lead sheets were shattered and got bulked at the bottom of the aprons. It means no full protection there. I used it anyway, because only those were available... just to feel safe, I know I am not protecting myself.' – P3, radiographer, 7 years in medical imaging
	Safe working environment but the decreased quality of well-being.	Informants were provided with protective equipment to avoid occupational hazards, but the available equipment decreased their sense of well-being.	'Even if it (RPGs) is lighter, the material is not fabric. The suffocating issue is still there, ventilation issue... because the new material is lead-equivalent, the materials are still thick and hard. Not as soft as our usual fabrics. The comfort is still affected.' – P1, senior radiographer, 17 years in medical imaging 'Sometimes, the procedure takes a few hours, and if you are doing an angiogram, like for 8 h, like for the rest of the whole day, then... at the end of the day, you are going to get backache. Also, I have been doing this for a couple of years, and you are sure to get backache'. – P12, radiologist, 12 years in medical imaging
	Setting a good example of practice	The use of RPGs is obligatory and part of MRWs' responsibilities.	'It is their responsibility (to use RPGs). It must be worn. The safety is number two. The first thought is it is "compulsory to wear the garments." Because we want to complete clinical procedures in time.' – P3, radiographer, 7 years working experience
2. Indicators of workers' credibility			

(continued on next page)

Table 2 (continued)

Themes	Sub-themes	Meaning	Evidence
3. Physical appearance of the RPGs	A reflection of knowledge in medical radiation	Not all RPGs are effective in all radiological procedures.	‘...except in nuclear medicine, it is not effective to use an apron, because the nuclear radiation energy can still go through the apron. We only need to keep our distance from an irradiated patient, limit the time and optimise the dose. The apron will only burden you, and it does not function fully in nuclear medicine.’ – P5, radiographer, 8 years in medical imaging
	Good procedure management and patient care	The complete use of RPGs is the initial key step for radiation protection practice.	‘When we all wear the lead aprons, automatically we can start the case and the doctors can start screening. The procedure can be completed in time. We will remind people to wear them, even if everyone is already in their garments.’ – P3, radiographer, 7 years in medical imaging
	Cleanliness	The RPGs were exposed to biological fluids, contrast suspensions, etc. during procedures.	‘We really need to disinfect the RPGs frequently, because we are sweating while working, creating an unpleasant smell and inviting germs there ...’ – P1, senior radiographer, 17 years in medical imaging ‘Cleanliness of the apron is not expected. We share the garments, so if anything splashes onto the aprons, we have to accept it. Because we cannot wash them... they will be damp and smelly, maybe. As far as I’m aware, the garments have never been cleaned.’ – P5, radiographer, 8 years in medical imaging
	Old garments	Old RPGs are still being used in hospitals.	‘One of the shortages in RPGs is, we do not know the accuracy of... is the material really absorbing the radiation? Is it being tested (in this department)? Is there any proof? Like I said, I have been working for 7 years, and I used the same garments in the OT room. I do not know if the thing is still protective anymore... I do not know if the radiation already penetrates my body. I feel that is the drawback.’ – P4, radiographer, 7 years in medical imaging ‘We have a quite old fluoroscopy machine, almost 20 years old. So whatever protective garments you have there are the same age as the machine. That is why... and, no quality control.’ – P11, radiologist, 12 years in medical imaging
	Improper sizing	Big-sized RPGs are available most of the time, while the small-sized RPGs were very limited.	‘It is fine if I get my own size lead apron but, as usual, many people need them (first come, first served). We have no personal apron. So, when I get an XXL size with the double weight for my size, combined with hours of procedure, my back inevitably became sore.’ – P15, radiographer, 1 year in medical imaging ‘All sizes are available – S, M, L, etc. However, the bigger sizes are plentiful, while the small sizes are not as common. You have to “rush” for it.’ – P18, radiographer, 1 year in medical imaging ‘Even the doctor used a wrong-sized thyroid shield. He has a high neck and used the smallest thyroid shield. What is he covering? I suggested he use the bigger one.’ – P6, staff nurse, 6 years in in medical imaging
4. Practicality of RPG use		The RPGs were not essential in nuclear medicine procedures.	‘FDG produces a very high energy, so this one doctor said the lead apron might reduce only 1% of the radiation, while we are still exposed to 99%. Rather than harming our backs with the garments, we maintained our distances and times. Plus, we used an auto-dispenser to work with FDG, not manually dispensed bare-handed like we used to with technetium.’ – P10, nuclear medicine technologist, 6 years in nuclear medicine
5. Impacts on the workflow	Aids the workflow	Having complete RPGs aids the MRWs in initiating a procedure in a timely manner.	‘We won’t allow an initiation of a procedure unless everyone is protected by the RPGs. If someone uses RPGs wrongly, inform that person. Usually I will say “Please wear your protection accordingly, only then will I proceed with this case, so that I can keep you safe, and I am protected too”.’ – P5, radiographer, 8 years in medical imaging
	Limit the workers’ movements during procedures	It was claimed that the design and weight of the RPGs were limiting workers’ movement during procedures.	‘When it (apron) is heavy, it limits my movement. If during an angiography or fluoroscopy, while handling the machine, if the patient is suddenly restless or about to fall, I have to move fast (to hold the patient).’ – P4, radiographer, 7 years in medical imaging ‘The radiation protection gloves are hard and thick, which “freeze” our hands, thus, the preparation gets done more slowly because... well, it is a radioactive substance, we were afraid it would spill. It slows down our work, patients had already waited... It is a stressful thing. At the end, we opted to use the ordinary latex glove.’ – P9, nuclear medicine technologist, 16 years in nuclear medicine

expensive. Additionally, MRWs like nurses and medical assistants also felt that other RPGs like gloves, goggles and caps should also be made available to them, and that they should not be limited to be used only by specialists or doctors. According to the Basic Safety Radiation Protection Regulations Act 304 (1984), it is a responsibility of the employer to provide adequate and suitable RPGs to their employees who are at risk of radiation exposure [4].

Despite complaints about the radioprotective aprons being heavy and uncomfortable, MRWs put in the physical and mental effort required to

use them. The radioprotective apron, which weighs around 6–10 kg [22] when worn for 2–8 h leads to body aches and other physical complications. Four informants in this study were treated for prolapsed intervertebral disc and cervical spondylosis, believed to be related to the heavy garments, lifting patients and operating bulky X-ray machines. They were instructed to return to work after their sick leave, but they were restricted to performing light duties – e.g., completing paperwork and scheduling patients’ appointments – for a certain period of time. Complaints of back pain, neck pain, shoulder pain, and sciatica due to using RPGs have been

Table 3

The underlying reasons for non-adherence in using RPGs among MRWs.

Main factor	Sub-factors	Supportive quotes	f	n
Inadequate number	Not enough/Worn out	'I think mostly it is not because of lack of awareness, it's just that the facility is not there.' – P11, radiologist, 12 years in medical imaging. 'These devices are expensive, and we don't have enough allocation for that.' – P4, radiographer, 7 years in medical imaging	51	16
	Separated garment pieces	'The problem occurs just for the thyroid shield; sometimes, it goes missing. Let's say you are in a room with many people who are using it, you might end up having just the lead apron, and not the thyroid shield.' – P11, radiologist, 12 years in medical imaging. 'It is supposed to be enough, but people misplace it, so the set is not complete. The apron–thyroid shield pair is not there anymore.' – P5, radiographer, 8 years in medical imaging	23	9
	Priority for others	'There are just a few goggles, which is not enough. Just give them to the bosses. If they have extra, then we can use them.' – P6, staff nurse, 6 years in medical imaging	8	6
Unightly appearance	Dirty and irritating	'I sweat a lot. I have to take out the thyroid shield and wipe it with tissues ... that's why I don't use it most of the time.' – P4, radiographer, 7 years in medical imaging. 'It is not comfortable at all. My neck here will get red and I get some marks.' – P4, radiographer, 7 years in medical imaging	10	6
Impractical	Less effective in nuclear medicine	'There was one doctor who said that lead aprons will reduce only 1% of the exposure in nuclear medicine, so 99% surely gets through to us. Using a heavy apron affects the back, so it is better to not use it ... just play with the timing and distance. One more thing, FDG is dispensed by the auto-dispenser, not manually.' – P10, nuclear medicine technologist, 6 years in nuclear medicine	19	5
Disruption of workflow	Limits workers' mobility	'The radiation protection gloves are thick, which limits the movement of the hands ... preparation gets done more slowly ...' – P9, nuclear medicine technologist, 16 years in nuclear medicine	11	4
Self-attitude		'My attitude towards myself. Maybe we just take it lightly. For me, I want to work fast, and ... the apron is heavy. It affects the willingness to wear it ... maybe if there are fewer iodine patients, I can use it.' – P9, nuclear medicine technologist, 16 years in nuclear medicine. 'Okay, in terms of PPE, for me, I'll use the lead apron, goggles, and thyroid shield. But, (sigh) sometimes ... if ... I feel very lazy ... but the lead apron is a must.' – P12, radiologist, 12 years in medical imaging. 'When we use gloves, we know the hands are protected. Radiation did not hit the hands. When we don't use them, we know our hands are exposed. But, well, it's just the hands ... I'm not saying it's not important, but our mentality is that we prioritise other organs.' – P10, nuclear medicine technologist, 6 years in nuclear medicine	7	6
Organisational influences	Norms in the workplace	'Regarding the other extra equipment, only a few pieces are available. So, if I use it when the others don't, they will look at me as if I am over-reacting. So, I will just use an apron and thyroid shield.' – P4, radiographer, 7 years in medical imaging. 'When I first worked here, I did not use a thyroid shield, because everyone in the OT here did not wear one. I was affected, I was influenced ... despite the fact that I know it is not right.' – P16, radiographer, 1 year in medical imaging	4	3

Note: f = code frequency; n = number of informants; RPGs = radioprotective garments; PPE = personal protective equipment; FDG = fluorodeoxyglucose; OT = operating theatre. The same informant may have provided more than one code/item occurrence.

reported previously, with absence from work being one of the outcomes [23, 24, 25]. It is suggested that a fit test should be conducted to avoid any additional harm from use of RPGs. The availability of aprons was not an issue in this study. A lack of aprons occurred only when there were too many staff or interns in the procedure room, two or more procedures were in progress concurrently, or when a training workshop was held. In this situation, sound judgement should dictate who needs to be in the examination room.

Hygiene factor also contributed to discomfort when using RPGs. Informants reported that using dirty aprons was bearable, because it does not involve direct contact with the user's skin, but this is not the case with the thyroid shield. Some informants opted to leave their neck unprotected during procedures due to the unhygienic look and smell of the thyroid shields. One study suggested that such garments tend to collect germs, as 84% of the tested aprons and thyroid shields had colonies of *Staphylococcus* sp. and *Tinea* spp [26, 27]. Unhygienic RPGs create a risk of skin infection for MRWs, and at least one informant in this study reported developing redness on his neck. According to previous research, the use of sprays, sanitisers, wipes, and normal washing may simply spread the germs' biofilm rather than completely removing the biofilm matrix from the surface [28]. A cleaning recommendation has been issued by the Centers for Disease Control and Prevention, advising an initial use of friction before a second step of sanitisation/disinfection [29].

MRWs who participate in nuclear medicine procedures deal with radioactive nuclides which produce higher energies compared to other radiography procedures. In the early years, it was recommended that RPGs be used especially when dealing with technetium-99m

radiopharmaceuticals but not for iodine-131 radiopharmaceuticals [30, 31, 32]. This study finding indicates conflicting practices among the MRWs especially among those handling iodine-131, suggesting a lack of understanding of the standard practices and guidelines. The United States Radiologic Technologists cohort study reported a dramatic decrease in the use of aprons in nuclear medicine from 81% in 1964 to only 7% in 2009 [33], and this can be related to this current finding. Moreover, the improved built-in shielding and protection devices like the lead syringe shield are suggested as being adequate and ergonomic for their protection. Therefore, continuous education must be delivered with thorough inspections. These measures could help to keep the workers updated with current best practices, reduce their exposure, and minimise any malpractices.

Regarding the use of radioprotective gloves, one informant described their utilisation in fluoroscopic procedures, while another described using them in the preparation of radiopharmaceuticals. As stated in the latest local guidelines, it is best to keep MRWs' hands away from the primary beam rather than using radioprotective gloves. Placing gloves in the primary beam will increase the scatter radiation in the area [5, 34, 35]. A laboratory finding showed that, in some cases, using RPGs increases the energy of the photons; thus, the MRWs may be unconsciously exposed to a larger dose of radiation than generally believed [30, 32, 35]. It is recognised that the updated guidelines are not well communicated among MRWs, and therefore there is an urgent need to do so. Other nuclear technologists informed of non-utilisation due to difficulties in handling radiopharmaceuticals, as the gloves are 'hard'. Rutherford et al. also noted the complaint of losing tactile sense, and even suggested cutting the

fingertips off the disposable lead gloves [36, 37].

While exploring MRWs' perceptions of RPGs, it was found that their own attitudes influenced their behaviour towards RPG use, where individuals implement their own values resulting in a dichotomy of practice [38]. In addition, another study found that the theory-practice gap in radiation protection was caused by individual and group characteristics, as well as social influences [39]. With regards to the latter factor, Owens and Valesky explain that organisational culture comprises the 'rules of behaviour which have been accepted as legitimate by a group' and that is 'informal, unwritten, but highly explicit and powerful in influencing behaviour' [40]. It is also worthy of note that inappropriate use of RPGs or using unfitted or damaged RPGs might lead to a false sense of security while exposing MRWs to excessive radiation.

4.1. Strengths and limitations of the study

Conducting qualitative research provides an opportunity to capture a range of first-hand data from MRWs, and allows access to their unique perspectives, which deliver rich data regarding their practices. The involvement of small, medium and large-sized departments, respectively of workers in the participating departments can justify a good sampling variation. The representation of the various designations of MRWs helped the researcher to gain a wider point of view. To the best of our knowledge, this is the first qualitative research investigating the reasons for non-adherence to RPG use among MRWs in a middle-income Asian setting.

Data bias may exist due to the way in which the informants were recruited for the study. The informants were approached directly by the researcher with departmental approval or were assigned personally by the departments' managers. The informants chosen by their managers may be the ones who practice good compliance.

4.2. Future directions and suggestions

The findings could be triangulated using a validated survey tool to identify the proportion of MRWs who do not adhere to RPG use, to determine the extent of the problem, and to quantify the reasons behind nonadherence. The verdicts could help in planning training activities as well as detailing funding to ensure adequate availability of RPGs.

5. Conclusion

MRWs demonstrated a definitive practice of using radioprotective aprons, but often neglected to use thyroid shields and other garments. Availability and hygiene are reported as the core issues for non-adherence, while unclear guidelines on the practical use of RPGs lead to confusing practices. Given the physical complications associated with heavy-weight apron usage, organisations should consider purchasing lightweight aprons for their MRWs. Nonetheless, it is essential to perform quality control test of the garments to verify its compliance with the attenuation requirements at different diagnostic energies. Management should be vigilant in providing an adequate supply of RPGs that are suitable and safe for the workers' defined work scopes, customising the individual garments to each MRW and communicating updates in radiation protection best practices for radiology and non-radiology departments that use ionizing radiation. All these measures could help to instil good occupational safety culture among workers in the medical radiation field.

Declarations

Author contribution statement

Siti Farizwana Mohd Ridzwan: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

Nirmala Bhoo-Pathy: Conceived and designed the experiments; Analyzed and interpreted the data; Wrote the paper.

Marzuki Isahak: Conceived and designed the experiments; Wrote the paper.

Wee Lei Hum: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data; Wrote the paper.

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Competing interest statement

The authors declare no conflict of interest.

Additional information

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