# The Overview of Occupational Radiation Monitoring Management: Challenging Issues and Future Improvements

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## ABSTRACT

Personal dosimeters are the primary devices for occupational radiation monitoring program among radiology personnel. Previous studies reported the behaviour of the workers towards the radiation monitoring practices. However, there was no exploration from the management key person's views in charge of the program. Key-informant interviews were conducted to explore the management's perspectives of dosimetry administration, identify the challenges faced in implementing radiation monitoring program, and outline future strategies to strengthen the program in Malaysia. Semi-structured interview guide was utilised to obtain rich views of the six key informants. All recruited key informants have involved in the dosimetry program for more than ten years. According to the administration's basic elements introduced in 1917, a thematic analysis was carried out using Atlas.ti software. The workflow of the dosimeter administration is relatively uniform and standardised. However, the key informants faced some issues at the stage of commanding, coordinating and controlling involving the dosimeter vendor and the workers as the end-users. Mishaps were found for the monthly exchange of dosimeters and the device usage consistency. The assignment of a working unit supervisor helped in the distribution and returning of dosimeters. Strong coordination is needed between the dosimeter vendor and the institutions for the delivering and returning process. The key informants also need to strengthen their capability in controlling the program structures. It can be concluded that a paradigm shift between the vendor, management personnel of the institutions, and the end-users is required, and may serve as a significant parameter to enhance the radiation monitoring program.

**Keywords:** Occupational ionising radiation; personal radiation monitoring; management; medical radiation worker; dosimeter

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## INTRODUCTION

Medical radiation workers (MRWs) are exposed to ionising radiation in their daily tasks. Prolonged exposures can contribute to major health effects. Therefore, surveillance of dose exposure among MRWs must be applied by employers using personal radiation dosimeters. Individual radiation monitoring ensures the dose limits are not exceeded. The monitoring results can be an indicator of a good radiation protection practice in the workplace.

Act 304 (1984) highlighted this for the employers in Section 25 (Protection of workers) that they are required *"…to provide and require such worker to wear approved personnel-monitoring devices, to keep records of dose and type of ionising radiation to which such worker has been or is likely to be exposed and to install or use monitoring devices in workplaces to record the amount of ionising radiation present and to keep records thereof…"*. These requirements are also elaborated in Sub-regulation 22 and 23 of the Basic Safety Radiation Protection Regulations (2010).

Using dosimeter should be a norm among MRWs. However, the practices are believed to be neglected by some of them in the population. Many studies have identified the factors that may lead to poor radiation protection practices among the MRWs (McCulloch et al., 2018; Rose et al., 2018; Mohd Ridzwan et al., 2019; Mohd Ridzwan et al., 2021). The radiation monitoring practice is related to the MRWs' knowledge, attitude, and behaviour. Some MRWS also revealed a few factors related to organisational management and supervision in previous studies (Botwe et al., 2015; Mohd Ridzwan et al., 2021). However, there is yet an exploration of the occupational radiation monitoring practices from the perspective of administration and management, which derived the conduct of this study.

Therefore, we aim to explore the real phenomena of occupational radiation monitoring management from the perspectives of the management key persons in Malaysia. The exploration is expected to answer what administrative steps are taken in occupational radiation monitoring management, the issues faced by the key persons in charge of the monitoring program, and future improvements to enhance the program.

## BACKGROUND

### Diagnostic Imaging in Malaysia

The core provider of healthcare services in Malaysia is the Ministry of Health (MOH), through its 144 public hospitals and special medical institutions, alongside non-government hospitals such as five army hospitals, five university hospitals, and 187 private medical centres (MOH, 2017a). These non-government hospitals are subject to other bodies' jurisdiction, such as the Ministry of Defence, Ministry of Higher Education, and self-owned by the board of directors. Nevertheless, they are restricted to the MOH's rules and regulation in order to be licensed to provide any medical services.

Diagnostic imaging is a medical service provided in most of the hospitals listed above. Healthcare personnel stationed at a medical imaging department and registered with the regulatory board are termed medical radiation workers (MRWs). In Malaysia, MRWs and their employers are subject to the National Law, Atomic Energy Licensing Act (1984) to operate and deliver the medical services associated with ionising radiation and radioactive substances in medical imaging and nuclear medicine. Following the requirements of Act 304, the Atomic Energy Licensing Board (AELB) was established and acted as an enforcement body on Act 304 and subsidiary legislation made under the Atomic Energy Licensing Act (1984).

The rules to be complied with are stated explicitly in the BSRP (2010) under Act 304 (2010). This regulation is accompanied by established guidelines and circulars updated regularly by the Medical Radiation Surveillance Division (MOH 1999, 2016a, 2016b, 2017b). Sub-regulation 7 under the BSRP (2010) outlined the dose limit for all involved parties; "*Every licensee shall ensure that no worker, apprentice, student or member of the public receives exposure from a practice that exceeds the relevant dose limit".* The document elaborated on the dose limit for workers, members of the public, apprentices and students, and limit in exceptional circumstances.

### Personal Radiation Dose Monitoring

Secondary Standard Dosimetry Laboratory (SSDL), a service centre under the Malaysian Nuclear Agency (MNA) is a pioneer vendor of a personal dose monitoring device in this country from the 1980s until 2011 (Mod Ali, 2011; Sangau et al., 2013; Abd Kadir, 2019). The first independent private agency was established to provide dosimeters in Malaysia in 2011, followed by another private agency established later in 2016. The monitoring device used in Malaysia was improved from the old film badge (Agfa Gevaert, Belgium) to the Thermoluminescence Dosimeters (TLD), Radio-Photoluminescence (RPL), and the latest sophisticated Optically Stimulated Luminescent Dosimeter (OSL) (Sangau et al., 2013). The use of OSL has been commenced since July 2015 to replace the film badge in most Malaysian government hospitals. MRWs in university hospitals and private medical centres are among the TLD and RPL users in Malaysia for the time being (Sangau et al., 2011).

The instruction of using the dosimeter is documented in the radiation protection program manual for medical facilities. The listed instructions are as follow (MOH, 2017b):

(i) Dosimeter is unique for individual and not exchangeable between workers,
(ii) Dosimeter is not allowed outside the premise under normal circumstances except for maintenance,
(iii) Dosimeter must be returned monthly,
(iv) Lost/Damaged dosimeter must be reported to the radiation protection officer,
(v) Dosimeter must be clipped between the neck and waist of the worker.

**Basic Managerial Elements in Administrative Management Theory**

The management of an entire organisation was explained earlier by the administrative management theory introduced by Fayol (1917). According to the managerial principles, the top management should perform these five basic functions to achieve the organisation's objective: planning, organising, commanding, coordinating, and controlling.

A managerial key person should determine the organisation's objective in the planning stage and develop a structured plan to achieve it. The plan should include identifying what, how and when the tasks will be done, including specific responsibilities for the execution.

Organising is the next step once the plan of action is created. The key person must assign the workforce sources with appropriate tasks, besides providing necessary things to execute the plan and establish the responsibilities. As the key person, the manager requires extraordinary interpersonal skills to perform the next step, commanding. They must direct and order the subordinates accordingly to ensure the plan is implemented appropriately. The ability to command with motivations, inspirations and understandings can support and balance the subordinates with the productions needed.

To fulfil the organisation's objective, the manager must also coordinate all different levels of subordinates or units. Coordinating various levels and units is essential to harmonise and synchronise all the planned activities. Finally, the manager must control the workflow to achieve the objective by closely monitoring the actual milestones and comparing them with the planned tasks. Improvement must be swiftly directed when a deviation is found to achieve the objective successfully (Shresta, 2011; Sage Publisher, 2022).

## METHODOLOGY

**Study Design**

A qualitative approach was deemed crucial for this study since there is yet any exploration regarding the issue. The approach allowed incoming new in-depth findings that will be useful for further research and evaluations. This qualitative study applied an in-depth interview approach using a semi-structured interview guide to understand the management of occupational radiation dose monitoring in Malaysia.

An in-depth interview is the most suitable method for this study, as it includes sensitive topics related to an organisation's information, processes and reputation. Hence, potential bias can be reduced by this method compared to other methods such as focused-group discussion. Management key persons in the area were invited from government, university and private hospitals.

**Key-informants & Study Sites**

All key informants were recruited through convenience sampling. Application letters to conduct interview sessions were sent to the heads of the radiology department in government general hospitals in the Klang Valley, two major university hospitals in Kuala Lumpur, and private medical centres around peninsular Malaysia, according to the institution list under the ministry's record. Five institutions provided timely consent and returned their feedback completed with the key informant's contact details.

A single key informant from a government hospital, three key informants from two university hospitals and two key informants from different private hospitals were agreed to participate in the interview. They were considered eligible for the interview if they worked in a managerial role that involved dosimetry management in the medical imaging department for more than three years. All key informants were from the hospitals located in Kuala Lumpur except one private hospital in the north of Malaysia, Penang.

## DATA COLLECTION

The interview sessions were held between August 2017 to November 2017. An interview guide was built using the five basic elements in administrative management theory. The questions included the occupational background, workflow in radiation monitoring administration, the MRWs' cooperation level, and the difficulties faced in radiation monitoring management (Table 1). Probing questions were applied in gaining further understandings of the statement by the key informants.

**Table 1**: Interview guide used in the data collection.

| Phase | Construct | Question | Possible Probing Question |
|---|---|---|---|
| Consent and demographic data | Consent | Name, age, gender, designation, length of service, audio-tape permission | - |
| Introductory | Occupational background | What is your main role in the department? | - |
| Focused topic | Basic elements in the administration | What is the workflow of radiation monitoring in the department? | Distribute dosimeter<br>Collect dosimeter<br>Return dosimeter |
| | Workers' cooperation | How good the workers' adherence to occupational radiation monitoring? | Would you explain that?<br>Why do you say so?<br>Please give an example.<br>What can be done to overcome it? |
| | Difficulties in administration | What problems do you face in administrating the radiation monitoring? | |

The primary conduct of language in the interview was the Malay Language with some mixture of English terms. The interview guide, information sheet for the informant and informed consent form were prepared in Malay Language and English. Informants were given the flexibility to choose either version of the languages. They were briefed about the study before the interviews and debriefed at the end of the session. The duration of the interview varied between 30 to 40 minutes. The data collection was continued until a saturation point when new information produced little or no change to coding and thematisation.

## DATA ANALYSIS

All interviews were audio-recorded and transcribed verbatim by a transcriber who was fluent in English and Malay languages. The transcriptions were then checked against the audio by the first author. The author conducted the analyses familiarised herself with the transcribed data by reading through the transcripts numerous times to identify sub-themes and main themes, based on codings and data categories. Field notes were used to complement the process. Quotes for each theme were translated, organised and summarised.

Qualitative data analysis in this study was performed using the Atlas.ti V.8 Qualitative Data Analysis Software (Scientific Software Development GmbH, Berlin, Germany).

### Data Trustworthiness and Reliability

In order to ensure the accuracy and validity of the data analysis, we triangulated the findings with field notes from a meeting with a key representative from the major dosimeter provider in Malaysia. He agreed with the reached themes and stated that the findings fit with their customers' feedback. We also received an informant's feedback from a member checking activity after the analysis was completed, suggesting no further adjustment on the findings.

### Ethical Considerations

The study was approved by the local ethics committee of the institutions involved: NMRR-17-1029-35730, UM2016104-4321 and JEP-2017-593(FF-2017-386).

## FINDINGS

### The Key-informants

Semi-structured interview questions were utilised to seek general practice on medical radiation dosimetry management in Malaysian hospitals. The key informants involved in this study are the managers in charge of the department's radiation monitoring program. They shared their experience in managing radiation monitoring in the workplace. There was no new theme emerged during the fifth and sixth interview in this study; thus the sample size for this study was justified to six key informants. Table 2 describes the characteristic of the key informants. All key informants basically had work experience for more than ten years.

**Table 2:** The characteristics of the key informants.

| Informant ID | Type of hospital | Gender | Designation | Years of service |
|---|---|---|---|---|
| **G1** | Government | Female | Science Officer | 12 |
| **U1** | University | Female | Science Officer | 15 |
| **U2** | University | Female | Science Officer | 25 |
| **U3** | University | Male | Medical Physicist | 30 |
| **P1** | Private | Male | Imaging Manager | 11 |
| **P2** | Private | Female | Imaging Manager | 15 |

### Overview of Dosimetry Management in Malaysian Hospitals

Malaysian hospitals are found implementing the similar and standardised procedure in managing occupational radiation monitoring, regardless of the type of hospitals. This is because they are restricted to the same Ministry of Health's regulations in order to be licensed to operate and deliver the healthcare services associated with ionising radiation.

Overall, passive personal dosimeters are the primary device to carry out personal radiation monitoring. To date, all hospitals have changed the use of conventional film badge to the latest personal dosimeters. The dosimeters came in a few types, and the local authority suggested the thermoluminescence dosimeters (TLD), radio-photoluminescence (RPL) dosimeter and also optically stimulated luminescent (OSL) dosimeter. These types of dosimeter are as shown in Figure 1. Each dosimeter possesses different criteria in terms of material, measurement principles, detectable dose range, device cost and analysis cost.

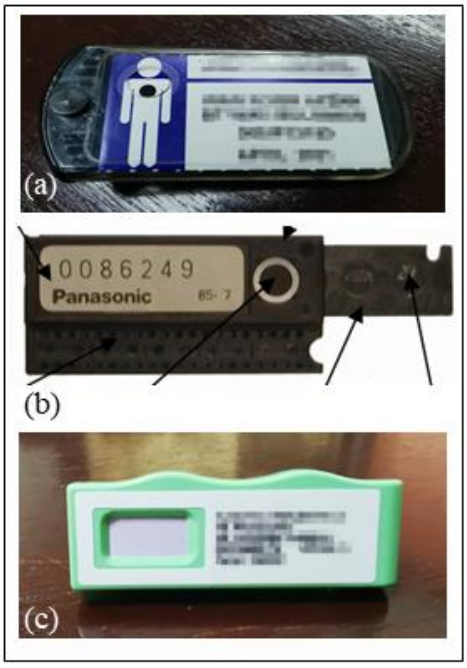


**Figure 1**. Types of passive personal dosimeter used in Malaysia; (a) OSL; (b) TLD (Source: US Army Dosimetry Center, 2008) and (c) RPL.

All the management challenging issues in occupational radiation monitoring in this study were organised accordingly to Henri Fayol's principles (1917) as the main themes with these basic elements: planning, organising, commanding, coordinating, and controlling. These themes were associated with every monitoring program stage, such as program documentation and implementation, device supply, device distribution and collection, and dose report dissemination—all the issues followed by the suggestion of further improvement of the matter in the discussion part.

**Theme 1: Guided Planning and Organization of Medical Dosimetry Program**

The management must plan and organise all the available options they have to provide the MRWs with the monitoring device. The ultimate decision of the type of dosimeter used in an organisation depends on its procurement process through direct purchase or quotation mode. Earlier, the supply of dosimeters was handled solely by a government agency. However, recently the private vendors are also joining the chain. The vendors will provide the devices, received the used dosimeters for dose analysis and readings, and produce the dose reports.

The dosimeters are used to monitor personnel exposure for a month duration. Thus, the frequency of returning and delivering the dosimeters is on a monthly basis as well, for all hospitals in Malaysia. Routinely, MRWs should return the used device to their managers and collect a new monitoring month's dosimeter. In getting the new month's dosimeter, MRWs can know their previous dose measurement from the report received by the manager-in-charge.

Usually, the manager in a bigger hospital or department will assign one person as a representative to the working unit. For example, one person in the CT scan unit and another person in the angiography unit will directly deal with the manager-in-charge to exchange the dosimeters on behalf of others working in the respective unit. As for the smaller hospital, all MRWs directly deal with the manager since the number of workers is manageable.

Figure 2 illustrates the general workflow of occupational radiation monitoring for MRWs in Malaysian hospitals.

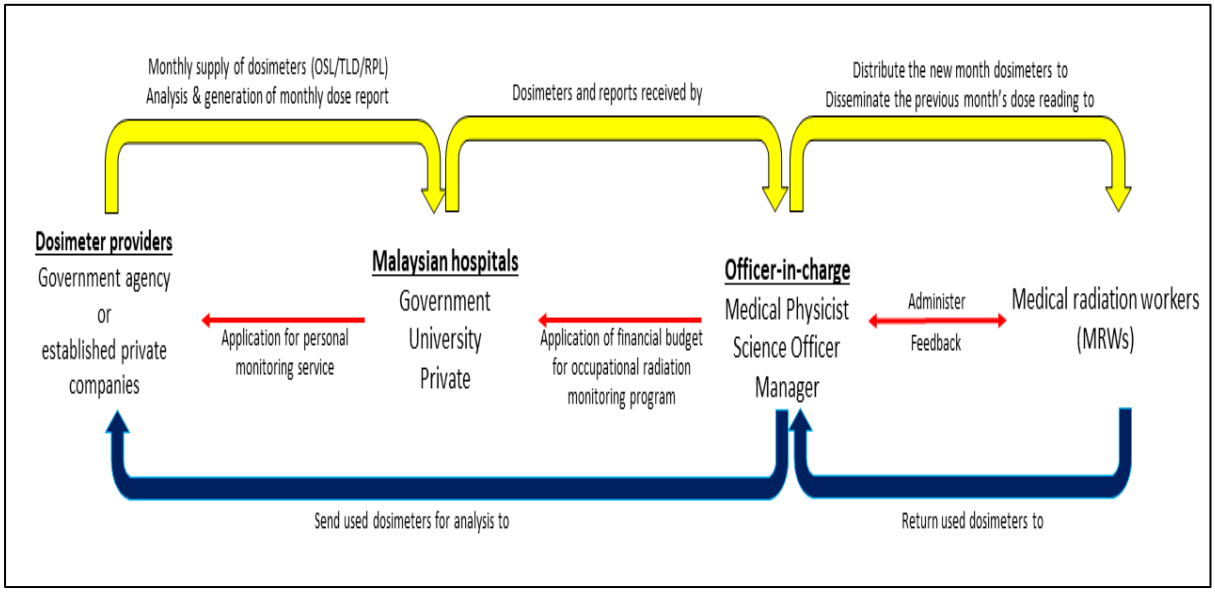


**Figure 2**. A general workflow of occupational radiation monitoring services for medical radiation workers in Malaysia.

**Theme 2: Commanding Skill of Manager-in-charge for Medical Dosimetry Program**

**(i) Monthly dosimeter exchange**

When a new month arrives, MRWs must return the used dosimeter to the manager-in-charge to receive the new month's dosimeter. The managers must collect all the old dosimeter and return them to the vendor for further analysis. Usually, the managers will announce when the new month's dosimeters are already available and remind the MRWs to exchange the device.

> *"Rarely you (I) can find a worker who voluntarily comes and asks if it is time to exchange the dosimeter yet. You (I) have to make it a monthly routine to announce 'hey, change the dosimeter now'. It is an unwritten task for you (me). Then only they will come to you (me) personally for that purpose."* (G1, female, government hospital)

However, this is not always the case. Usually, the MRWs ended up keeping and using the same dosimeter for more than a month even though the new dosimeter is available. In the interview, the key informants were found quoting 'the workers ignore the reminder for dosimeter exchange'.

> *"Some of them will just ignore the reminders I gave. I informed them through a medium like Whatsapp groups. Only 20 - 30 percent of them will return the dosimeters and collect the new ones [showing a name list with only a few signatures who collected the device]."* (U1, female, university hospital)

> *"They know it is time to change the dosimeter, but somehow, maybe they are too busy and forgot about it. When they suddenly remembered and came to exchange, it has already passed the month and the dosimeter has already returned to the supplier. They need to continue using the old one until another new month's dosimeter comes…"* (U2, female, university hospital)

**(ii) Consistent use of dosimeter**

From the interviews, it can be observed that there were no standardised practices for the manager-in-charge to ensure compliance with dosimeter use among the MRWs. The level of MRWs' cooperation in using the dosimeters also varied across every institution. The managers will do their very best within their abilities to ensure all MRWs were provided with the dosimeter as outlined in the regulation. Nevertheless, to ensure they put it consistently across daily working hours is beyond their capabilities. The manager-in-charge agreed the attitude is very individual and they cannot control every worker's behaviours.

> *"When there is an audit to be carried out in my department, I will be in trouble if they are not using (dosimeter). I will bring all dosimeters to the front area and tell them to collect the device."* (U1, female, university hospital)

> *"Since day one, they came to this department, I have warned them that I will be eyeing them for the dosimeter. I will jot down names without dosimeter and send a letter to the head of department. I am not around the clinical area so often, so when I am around, I can feel they are very concern with the dosimeter because they do not want to receive the 'love letter'."* (U2, female, university hospital)

> *"It's their attitudes. To simplify, it is just being lazy. This thing (dosimeter) is not a necessity for them, unlike their smartphone. You (They) will turn back to where you (they) have left the phone... Will you (they) turn back home to get the left OSL? No."* (U3, male, university hospital)

> *"As you can see here (a name list), many workers never have a record of exchanging the dosimeters for months/years. It indirectly indicates they are not using it at all. We wasted up the institution's fund for analysing every dosimeter, including the dosimeters not in use."* (U1, female, university hospital)

**Theme 3: Coordination of the Distribution, Collection and Returning of Dosimeters**

To harmonise the activities within the occupational radiation monitoring program in big departments, managers coordinated distributing, collecting and returning the dosimeters by building up a team to ensure the process is smooth.

**(i) Assignment of a supervisor at a unit level**

The appointment of certain representatives from each unit of modalities in the department adds on a great aid to ensure the dosimeters reach its user. The existence of this representative ensures the consistency of collecting and distributing of dosimeter in the given interval.

Every unit in the department must be represented by a supervisor who will be easily contacted by the managers-in-charge when getting a new month's dosimeter. The supervisor will then distribute the dosimeters to all MRWs under the unit and at the same time collect the old dosimeters from the MRWs. When all the old dosimeters were collected, the supervisor must hand them over to the manager-in-charge.

While the process of distribution and collection of dosimeters seems smooth by this approach, one drawback was recognised from this practice. All the MRWs did not receive their previous dose reading unless they meet the manager-in-charge personally.

> *"Things get easy when you have a trusted, responsible person who can handle things for his/her unit. Who is always efficient, responding very fast and act very quickly. Instead of seeing 20-30 workers, I deal with this one person only."* (P1, male, private hospital)

> *"We will monitor their readings every month. If everything is usual, we just keep the record. But if somehow, in a particular month, the reading for this one worker just out of his previous readings trend, we will call him up."* (P2, female, private hospital)

> *"Whoever personally come to me and ask his/her reading, I'll let them have a look and tell them not to worry about any over-exposure, because I will let them know if there is such thing."* (G1, female, government hospital)

**(ii) Workplace setting**

The other factor contributing to the MRWs' level of cooperation in exchanging the dosimeters is the distance from their work station to the dosimeter-exchanging collection room. The manager room location and its distance from the MRWs' workstations play a major role in the dosimeter exchange rate. One key informant shared how the department units' arrangement in her institution disturbed the workflow for this particular device. Another key informant stated that her room is just behind the clinical area, yet the returning rate is poor.

> *"Please imagine, my Unit is on level 12 in this tower. The radiology office is on a different level. The Angiography unit is in another tower, and nuclear medicine is in a different tower. Do you think they will happily come just to collect this tiny device? Difficult. It is difficult for them... and for me!"* (U2, female, university hospital)

> *"It takes them to pass-by my room to get triggered of returning the dosimeter. Or if I am around their working area, then just they remembered about dosimeter when they saw my face."* (U1, female, university hospital)

**(iii) Returning of dosimeters for analysis**

Next, in order to return the dosimeter to the vendor for further monthly analysis, the manager-in-charge will arrange a courier service to get the box of dosimeters despatched to the vendor. However, the dosimeter postage incurred a risk of contamination or over-exposure during the transportation if not well-handled. It could result in inaccurate reading due to external exposures or the physical damage on some of the dosimeters, if not all. Also, the dosimeter's postage must go through a few steps in the department administration since the cost must be bear by the department. Thus, it usually delays the dosimeter returning process, besides the late returning of dosimeters by the MRWs.

> *"Earlier, the supplier provides a service to collect our dosimeter box from us. Over time, maybe the worker who collects it complaints of the car parking issues in this hospital. They do not want to personally collect it anymore. They ask us to post it over courier service. We are paying for the courier now."* (U1, female, university hospital)

> *"It happened once; several dosimeters were analysed with high dose readings. We scrutinised the holders of the dosimeters but could not found any over-exposure activities by them. We suspect the handling during the posting went awful or they became exposed to something. It is a risky transaction."* (U1, female, university hospital)

**Theme 4: In Control of Occupational Radiation Monitoring Program**

Manager-in-charge should be in control of all activities under the occupational radiation monitoring for the institution. It is to ensure the policies and objective set by the ministry and institution can be met. Hence, the managers need to observe and report any deviations from the planned and organised workflow and take initiatives to correct any mishaps.

A key informant reported that her department is moving towards improving the management of dosimetry program by customising each and every MRWs work rotation and risk level to categorise them into high-risk or low-risk for over-exposure. This step can further develop the monitoring program as it will be done more holistically.

> *"We are now in the process to see who is high-risk and who is not. Those who are low-risk can opt for 3-monthly monitoring instead of one-monthly monitoring. We are also revising our radiation leave to see who can really get the privilege."* (U2, female, university hospital)

Two key informants said the only effective way to get everything in place is by imposing a penalty for not using the dosimeter or late dosimeter exchange or losing the dosimeter. By this measure, the MRWs will be more rigid in complying with the ministry requirements.

> *"We have already done our job by providing the dosimeters to the workers, but they take it for granted. The only way is to penalised them if they did not use it or lose it. When it comes to money, only then people be aware."* (P2, female, private hospital)

On the other hand, some out of control situations have also occurred. A key informant who is also in charge of another department's dosimeters shared it is challenging to get engaged in another department's officer. There are workers in other departments who did not know they are provided with dosimeters; even their officer has been informed.

> *"Your email inviting them to join this research created some havoc, you know. They said they didn't have a dosimeter, so they are not eligible to join. Later, they questioned me, why they do not have dosimeters? Their dosimeters are here in my room, and no one comes to collect them even I have contacted their staff."* (U1, female, university hospital)

## DISCUSSION

This current study has provided a unique perspective and a deep understanding of Malaysia's management of medical radiation monitoring from the key persons' views. The value of the findings is considered invaluable, especially when it comes from the very experienced key persons. It can significantly be observed that the program implementation level is closely related to its cooperation from the top management, administration level, supervision level, and the workers.

It can be seen that it is not difficult for the managers to plan and organise the occupational monitoring program as the Ministry of Health has well established it through its Quality Assurance Program in Radiological Services (MOH, 2019). The key persons need to comply and send required reports to the ministry as scheduled. In the institutions themselves, they have already had a strong mission and objective for this running program. They also have an internal team or committee to ensure the program goes well. In addition, they also have a reputable relationship with the suppliers, top management and the MRWs. So far, all activities under these stages are under control and achievable by the key persons.

However, the difficulties were found at the stage of commanding, coordinating, and controlling the program's activities. In terms of exchanging the dosimeters, the managers' command worked out by the announcement made to the MRWs and reminders given repeatedly to the MRWs. Nevertheless, that would not guarantee the efficiency of the MRWs in carrying out the task. A recent study with the MRWs admitted that announcements and reminders were a great help. However, some of them expect someone who can directly and personally exchange it for them (Mohd Ridzwan et al., 2021). This is where a supervisor's assignment is important in the coordination stage to distribute the device to the MRWs. By having a specially assigned person, the manager can delegate the task accordingly, especially in big hospital settings, because late dosimeter exchanging was also contributed by each working point's distance.

In practising or implementing certain program activities, levels of supervision played an influencing role. Findings from Allan (2014) stated that the behavioural changes could be monitored when the workers have knowledge that they are being observed or supervised by someone. It is suggested for the department to enforce the scrutinisation of dosimeter using a role of highly influential supervisor, regardless of the designation. One of the participants who were already practising this convinced that it helps to a certain extent. The rules must be emphasised in the first induction or orientation program for the new MRWs. Without strict enforcement, the MRWs can only be commanded for a particular reason, like an audit program informed by the key informant in this study and supported by a worker in a previous study (Mohd Ridzwan et al., 2021).

Our current study identified a contradiction in opinions between the management team and the MRWs on the monthly dosimetry report. A few studies mentioned that the MRWs become unmotivated to use dosimeters and not change them regularly because they do not know their previous dose readings and lose the purpose of using the device (Botwe et al., 2015; Mohd Ridzwan et al., 2021). Meanwhile, for the management's key persons, the dose reports are safe with them and nothing to be worried about as long as the dose is below the limit.

With regards to the above, it is suggested that the dosimetry report is made available to the MRWs. It was reported that the dosimeter vendor is moving towards an online electronic system to improve their quality service (Mod Ali, 2011). Thus, it would be beneficial to extend the functions for every MRWs to access their dose by logging into the designated system. This has been successfully done by a vendor in the United States, as described by the University of Michigan, which took effect in 2018, where the practice of delivering dosimetry reports via postage had been discontinued (University of Michigan, 2017; Landauer®, 2018). The transition enhances the protection of client's information and data privacy. As a capable developing country, it is believed that we can also practice this in our monitoring program.

Another issue in executing this monitoring program is returning and receiving the dosimeters from the vendors. These problems still reflect the report in 2010, where the end-users gave the lowest satisfaction rating for dosimeter delivery, dosimeter condition, and knowledgeable personnel (Mod Ali, 2011). The distribution and collection of dosimeters is a massive hassle for big institutions. Thus, an intervention can be implemented by the vendor. They can take the initiative by appointing certified personnel in handling and transporting dosimeter back-and-forth from the vendor to the end-user. To be specific, the delivery to and collection from the end-users should be by their working units, not directly to one particular person for the whole institution. This could ease the dosimeter's distribution and collection, increasing the rate of on-time dosimeter returning and perhaps the consistent practice of using dosimeter, too.

As an in-charge, the key person should control all program activities under the occupational radiation monitoring to ensure the program policies and objectives can be met. They are responsible for observing and reporting any deviations from the planned and organised workflow and taking initiatives to correct any mishaps (Fayol, 1917). Key informants from the private institutions imposed a penalty towards the MRWs' misbehaviours to improve the monitoring program. The practice is not carried out in the government or university hospitals may be due to some administrative policies. However, it is not impossible to apply for the top management's permission if it can be proven efficient.

Moreover, the authority set the frequency of monthly dosimeter returning as a guideline only. The manager in control can apply for a change of frequency from the regulatory board, from monthly to three-month intervals, for example, along with a reasonable justification. The reading of the exposure will not be affected. It will be run with standard as certified in the lab (unpublished meeting data, Nuclear Malaysia, 2017). Additionally, a less-known fact is that the employer can review the status of MRWs, and a decision can be made (Muhd Sarowi et al., 2014). By reassessing the status, the key person can classify the MRWs into high or low-risk workers. This step has been initiated by one key informant in this study, and perhaps other institutions can consider it. The status review could reduce the number of radiation workers, save time and energy from doing unnecessary work in monitoring and managing the other radiation workers' requirements, and will be economical for the employers.

**Theoretical and Practical Contributions**

Even after more than 100 years since Fayol (1917) introduced the five basic elements in management activities, they are still just as relevant as to date. We managed to extend the application of these principles to an unexplored area, i.e. occupational radiation monitoring management. From the findings, we found that managers in radiation monitoring could not solely take appropriate corrective action specified in the controlling element because of their

limited power and authority. This step in that particular element needs to be examined further, considering the discovered restriction.

Putting the key informants' suggestions to tackle all the challenges into a writing document could help accelerate further actions from the top authorities. This study also serves as an eye-opener to some issues for the government authority and dosimeter providers: the program outlines are perfect, the facility provided is adequate, the device is sophisticated and up-to-date, but sadly, the implementation is still not comprehensive and imperfect.

**Strengths and Limitation of the Study**

This is the first descriptive qualitative studies investigating dosimetry management among the key persons in Malaysia to the best of our knowledge. This approach provided an opportunity to capture a range of first-hand data between the management personnel during the interviews. Another strength includes the representation of the various types of institutions; government, university and private hospitals. The findings, however, were captured from minimal sample size and very focused on big institutions. However, we believe the evidence is robust since the data reached its saturated point.

## CONCLUSION

The management of occupational radiation monitoring in Malaysian medical institutions can be further improved as more robust and practical approaches are needed to boost the practice. The key persons are encouraged to increase their commanding, coordinating and controlling skills to achieve optimum program outputs. An integration paradigm between the vendor, management of the institutions, and the end-users is needed. It may serve as a significant parameter to enhance the radiation monitoring program.

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