



Assessment of radiation exposure measurements using the Ceiling-Mounted Geiger Müller (GM) detector and handheld survey meter in high dose radioactive ¹³¹I (RAI) therapy facility

Kai Wei Chuah¹ · Muhammad Taufiq Azman¹ · Meelashini Letchumanan¹ · Alex Cheen Hoe Khoo¹

Received: 7 January 2025 / Accepted: 13 March 2025 / Published online: 24 March 2025

© The Author(s) under exclusive licence to International Union for Physical and Engineering Sciences in Medicine (IUPESM) 2025

Abstract

Purpose Handheld survey meter is commonly used to measure radiation exposure in patients receiving radioiodine (RAI) therapy prior to discharge. However, it requires staff to be in close proximity to the patients, potentially increasing radiation exposure towards staff and lack of ability to provide real-time monitoring. This study introduces a ceiling-mounted Geiger Müller (GM) detector, aiming to evaluate the effectiveness in assessing radiation exposure compared to handheld survey meter in clinical settings.

Methods 74 patients who received high-dose RAI therapy (80 mCi, 100 mCi and 150 mCi) were retrospectively selected in this study. Radiation exposure at 48 h post-RAI intake was measured at a consistent 1-m distance from neck region of patients using both the ceiling-mounted GM detector and handheld survey meter in the isolation room and the results were being compared. Additionally, the radiation exposure was measured in real-time using ceiling-mounted GM detector.

Results A maximum variation of $9.9 \pm 2.7\%$ was observed between the radiation exposure measurements from the detectors. The ceiling-mounted GM detector had a statistically significant relationship with handheld survey meter using Pearson's correlation test (p -value < 0.001). The ceiling-mounted GM detector recorded radiation exposure rates under 50 $\mu\text{Sv/hr}$ at 25, 29 and 37 h following 80 mCi, 100 mCi and 150 mCi RAI doses, respectively.

Conclusions Both detectors provided consistent and comparable results for measuring radiation exposure at 48 h post-RAI intake. The ceiling-mounted GM detector demonstrated reliable real-time monitoring capabilities, offering a practical and effective alternative to handheld survey meter post-therapy radiation monitoring.

Keywords Radioiodine · Radiation safety · Radiation exposure · Ceiling-mounted Geiger Müller detector · Handheld survey meter

1 Introduction

According to the World Health Organisation (WHO), thyroid cancer is a prevalent endocrine malignancy, it is ranked the 10th most common cancer in women and the 16th in men in Malaysia as of 2022 [1]. Radioiodine (RAI), particularly

iodine-131 (¹³¹I) has been used for over 50 years to treat thyroid cancer, effectively ablating residual cancer after thyroidectomy [2]. Due to its relatively long half-life of 8.05 days, ¹³¹I can pose both external and internal radiation hazards as patients may emit radiation that can expose to family members, caregivers and hospital staff [3]. Therefore, strict safety precautions are required to limit radiation exposure to the public. These precautions are informed by guidelines that vary between countries due to different socio-economic and cultural factors, but most are based on the residual activity of RAI and the measured radiation exposure rate [4]. According to the Basic Safety Radiation Protection Regulations (BSRP 2010) under the Atomic Energy Licensing Act 1984 (Act 304), patients can be discharged if the radiation exposure from post RAI therapy remains below a threshold of 50 $\mu\text{Sv/hr}$ at 1 m distance to the public, ensuring

✉ Meelashini Letchumanan
meelashini@pah.com.my

Kai Wei Chuah
chuahkaiwei@pah.com.my

Muhammad Taufiq Azman
taufiq@pah.com.my

Alex Cheen Hoe Khoo
alexkhoo@pah.com.my

¹ Penang Adventist Hospital, Georgetown, Penang, Malaysia

that the total exposure does not exceed 1 mSv for the public or 5 mSv for caregivers [5]. The radiation emissions from patients undergo RAI therapy was measured through radiation exposure monitoring.

Radiation exposure monitoring plays a crucial role in the safe use of nuclear technologies across various sectors, including nuclear facilities, hospitals and any activities involving radioactive materials. It helps assess the risk of exposure to radiation while allowing society to benefit from its applications [3, 6]. To balance the advantages of nuclear technology with safety, the International Commission on Radiological Protection (ICRP) promotes the As Low As Reasonably Achievable (ALARA) principle [6–8]. In line with the ALARA principle, radiation exposure levels of the high dose RAI patients were carefully managed to balance safety with the effective use of radiation.

Traditionally, radiation monitoring involves manual methods where personnel carry radiation detectors to measure the radiation exposure of patients' post-RAI therapy prior discharge. While these methods provide high spatial resolution, they also expose personnel to radiation [6]. To mitigate this risk, the ICRP recommends reducing exposure time, increasing distance from the source and using protective measures like lead aprons [8]. Ideally, technologies that allow remote radiation monitoring without compromising the accuracy and efficiency of data would alleviate these concerns [6, 9]. In response to these challenges, ceiling-mounted Geiger-Müller (GM) detector has been introduced. It wirelessly collect and transmit radiation exposure data to a server in real-time, thereby minimising direct exposure to personnel.

Despite the widespread use of radiation measurement devices, research on the ceiling-mounter radiation detection technologies has been limited. This study aims to compare the effectiveness of a ceiling-mounted GM detector in measuring radiation exposure from patients undergoing high-dose RAI (80 mCi, 100 mCi and 150 mCi) with that of a handheld survey meter. By evaluating the effectiveness of the detector, we aim to enhance the safety protocols for discharging

patients treated with ^{131}I and ultimately minimise radiation exposure to the surrounding community.

2 Materials and methods

2.1 Ceiling-Mounted Geiger Müller detector

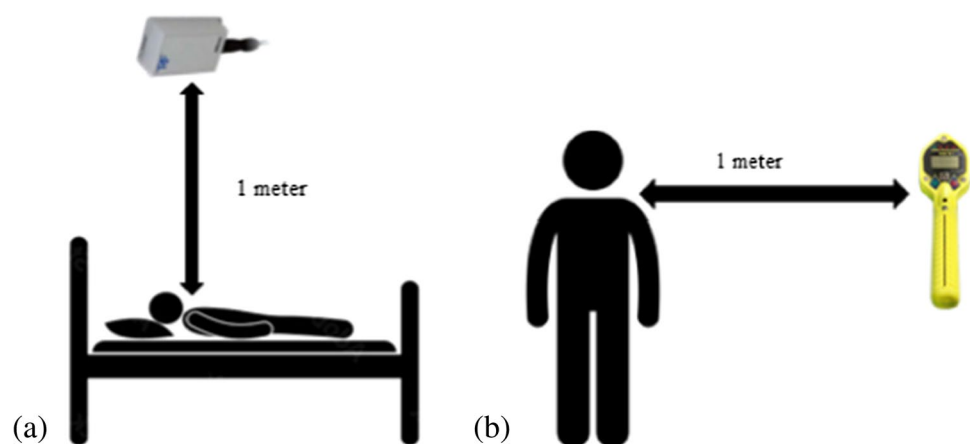
The GM Rady 7 (TRF, Zaragoza, Spain) radiation area monitor features a display unit installed outside the isolation room with the GM detector mounted at the ceiling inside the room. The stationary ceiling-mounted GM detector which positioned 2 m from the patient was designed to extrapolate the exposure measurements to an equivalent value at 1 m. The detector able to record dose rate in real-time, ranging $0.1 \mu\text{Sv/hr}$ to 20 mSv/hr at a distance of 1 m. The monitor continuously displays the real-time dose rate. The system is connected to a personal computer (PC) located in the Nuclear Medicine Center via Ethernet connection that allow users to remotely monitor patient's exposure rate without needing to enter the isolation room.

2.2 Radiation exposure measurement

74 patients who received high-dose RAI therapy were retrospectively selected for this study. The patients were isolated in the isolation room during the therapy. The radiation exposure in the treatment area was being monitored in real-time by the ceiling-mounted GM detector throughout the therapy. The detector system connected to a PC enabled continuous acquisition of patients radiation exposure levels until discharge.

Besides, the radiation exposure was measured simultaneously at a consistent distance of 1 m from the neck region of each patient at 48 h of RAI administration, using both the ceiling-mounted GM detector and handheld Ludlum 26–1 survey meter (Ludlum Measurements Inc., Texas, USA) as shown in Fig. 1. The exposure rates recorded by

Fig. 1 Radiation exposure from patient was measured using **a** ceiling-mounted GM detector and **b** handheld survey meter at a constant distance of 1 m



the ceiling-mounted GM detector were compared with handheld survey meter and the percentage difference between the two detectors were being analysed. Pearson's correlation test was applied to perform the statistically analysis between the radiation exposure measurement between the ceiling-mounted GM detector and handheld survey meter. Both of the detectors were calibrated by secondary standard dosimetry laboratory (SSDL) in Malaysia.

3 Results

3.1 Radiation exposure measurement

Figure 2 showed the comparison of exposure rate readings measured by ceiling-mounted GM detector and handheld survey meter across 74 patients at 48 h of RAI intake. For most patients, the GM detector tends to have slightly higher exposure rate readings compared to handheld survey meter. The maximum variations of up to $9.9 \pm 2.7\%$ was noted in radiation exposure measurements between the two detectors. It was also observed that the exposure rates vary widely among patients with range between $10 \mu\text{Sv/hr}$ up to $40 \mu\text{Sv/hr}$.

Table 1 presented average exposure readings at 48 h post-RAI therapy for doses of 80 mCi, 100 mCi and 150 mCi using ceiling-mounted GM detector and a handheld survey meter. Across all RAI doses, the ceiling-mounted GM detector consistently reports higher exposure readings than the handheld survey meter. The average percentage difference between the detectors was relatively small for lower dose but increased at higher dose.

Figure 3 showed a scatter plot comparing the exposure rate measurements by ceiling-mounted GM detector and handheld survey meter. Pearson's correlation test was

Table 1 Average exposure readings at 48 h of RAI intake using ceiling-mounted GM detector and handheld survey meter for 80 mCi, 100 mCi and 150 mCi

RAI Dose (mCi)	No. of Patients	Average Exposure Reading at 48 Hours of RAI Intake ($\mu\text{Sv/hr}$)		Average Percentage Difference (%)
		Ceiling-Mounted Geiger Muller	Handheld Survey Meter	
80	5	16	15.9	0.6
100	15	22.7	22.6	0.4
150	54	27.5	26.6	3.4

applied in this study. The data exhibited a strong positive correlation, indicating that as the readings from the ceiling-mounted GM detector increased, the readings from the handheld survey meter increased proportionally. The p-value of <0.001 indicated a statistically significance of the correlation between ceiling-mounted GM detector and handheld survey meter.

Figure 4 showed the radiation exposure rate measured using ceiling-mounted GM detector post therapy in isolation room over time. The patients that received the highest dose (150 mCi) had the highest initial exposure rate, flowed by 100 mCi and 80 mCi. The exposure rates decreased exponentially over time, with decay curves that were initially steep, reflecting rapid clearance or decay in early hour and gradually plateau as time progressed. The horizontal line indicated the threshold of $50 \mu\text{Sv/hr}$ where patient can be discharged to the public. The average time required to reach this threshold from patient were 25, 29 and 37 h of RAI intake for 80 mCi, 100 mCi and 150 mCi RAI dose, respectively.

Fig. 2 Exposure rate reading between ceiling-mounted GM detector and handheld survey meter for 74 patients at 48 h of RAI intake. The error bar indicated 10% percentage difference

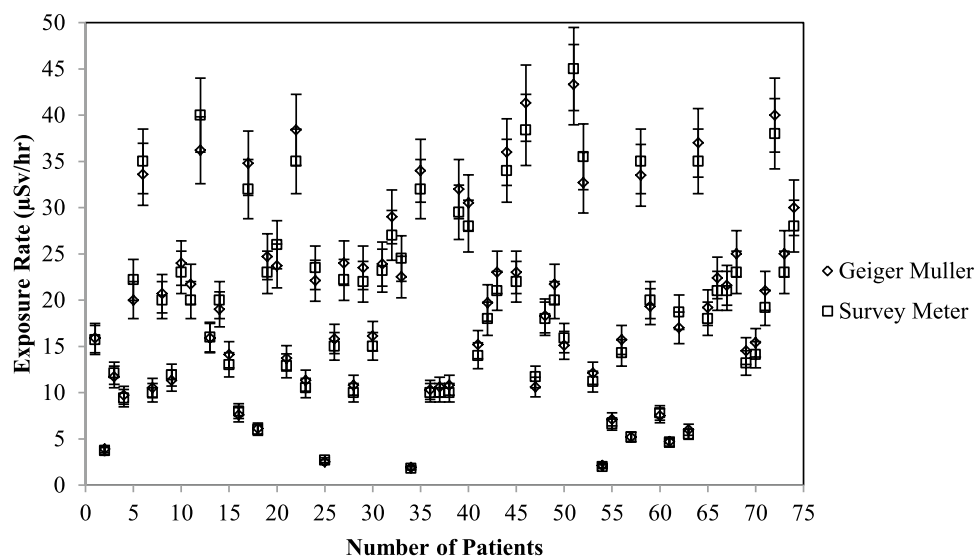


Fig. 3 Exposure rate measurement by ceiling-mounted GM detector and handheld survey meter

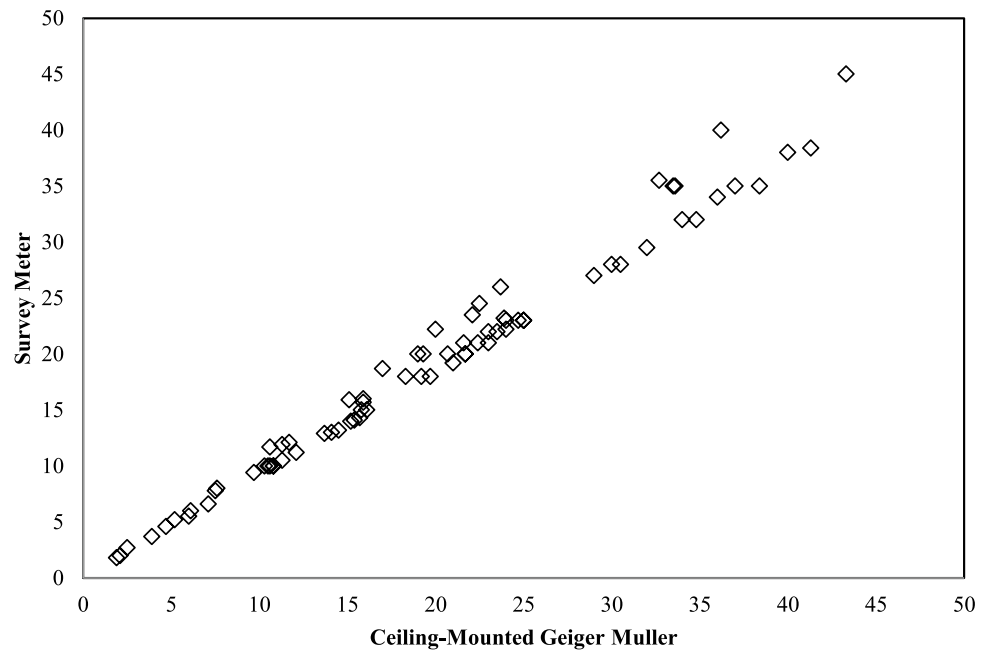
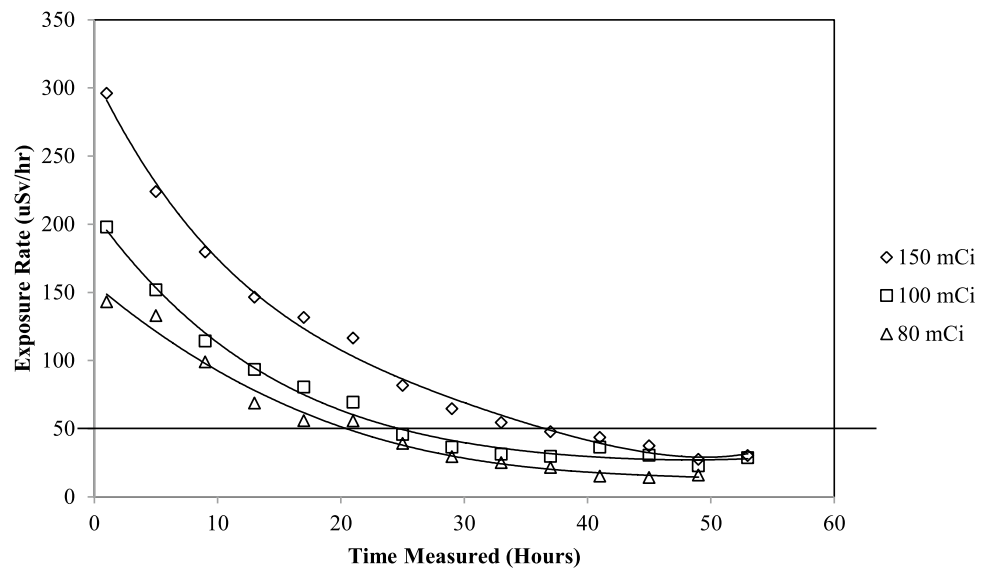


Fig. 4 Exposure rate over time for patients receiving RAI with 80 mCi, 100 mCi and 150 mCi doses



4 Discussion

In this study, the ceiling-mounted GM detector consistently recorded higher exposure rates compared to the handheld survey meter across all RAI doses. At lower doses (80 mCi and 100 mCi), the percentage differences between the two detectors were minimal with 0.6% and 0.4%, respectively, while at higher doses (150 mCi), the discrepancy increased to 3.4%. The higher radiation exposure rate reading by the ceiling-mounted GM detector may be due to the differences in placement and sensitivity of the detector. The stationary ceiling-mounted GM

detector that was positioned 2 m from the patients and designed to extrapolate the measurements to an equivalent value at 1 m, was more likely to capture scattered radiation from the environment, lead to an overestimation in exposure rates. In contrast, the handheld survey meter that was positioned closer to the patient, primarily measured direct radiation exposure emitted by the patients, provided a more accurate radiation exposure rate. Although differences existed between the two detectors, the percentage differences in their readings were relatively small.

The Pearson's correlation test revealed a strong positive correlation between the measurements of the ceiling-mounted GM detector and the handheld survey meter with

high correlation coefficient and a statistically significant p -value (<0.001). This affirmed the consistency of the two detectors in measuring radiation exposure levels. This showed that the ceiling-mounted GM was equally good as handheld survey meter in measuring the patients' radiation exposure level prior discharge.

The exposure rates for all administered doses decreased exponentially over time, reflecting the combined effects of ^{131}I physical decay and biological clearance from the body [9]. The average times for patients' radiation exposure rate to drop to allowable discharge rate of $50\text{ }\mu\text{Sv/hr}$ were 25, 29 and 37 h of RAI intake for 80 mCi, 100 mCi and 150 mCi RAI dose, respectively. Notable variations on radiation exposure rate among patients were observed, with range from $10\text{ }\mu\text{Sv/hr}$ to over $40\text{ }\mu\text{Sv/hr}$. This variability can be attributed to differences in the administered RAI dose, individual body clearance rates and patient positioning during measurements. Furthermore, radiation exposure rate readings increased proportionally with the administered RAI dose for both detectors, which aligned with the expected relationship between radioactive activity and exposure rate. Based on this study, the ceiling-mounted GM detector was capable of monitoring radiation in real-time, providing continuous exposure rate readings throughout the decay process.

In this study, we found that the ceiling-mounted GM was equally good in measuring the patients' radiation exposure compared to the handheld survey meter. Besides, the ceiling-mounted GM detectors may be more effective for real-time exposure rate monitoring in fixed settings while the handheld survey meter is better suited for portable and localized assessments. The consistency of the two detectors in measuring radiation exposure supports adherence to safety protocols in healthcare settings utilising nuclear technologies. Regular cross-validation between the detectors could further improve the accuracy and reliability of radiation monitoring particularly in clinical environment.

5 Conclusion

This study provided a strong positive correlation between the two radiation detectors in monitoring exposure rates of patients receiving varying RAI doses. Their complementary applications make them suitable for different scenarios, with the ceiling-mounted GM detector excels in continuous fixed radiation monitoring while the handheld survey meter is ideal for portable and localized assessment. Standardising measurement protocols and regular cross validation for ceiling-mounted GM detectors could further improve accuracy and consistency in exposure monitoring. A limitation of this study was lack of previous research comparing between the ceiling-mounted and handheld radiation detectors, which made it difficult to

draw direct comparisons with existing studies. This gap in the literature highlights the need for further investigations into the relative performance of the ceiling-mounted radiation detector.

Acknowledgements The authors would like to thank Mr. Ahmad Fikri bin Hasim for his invaluable assistance with the statistical analysis, which significantly contributed to the completion of this study.

Authors contributions All authors contributed to the study design and conceptualisation and had read and approved the final manuscript.

Funding Not applicable.

Data availability Not applicable.

Code availability Not applicable.

Declarations

Ethical approval Not applicable.

Consent to participate Not applicable.

Consent for publication Not applicable.

Conflicts of interest The authors have no relevant financial or non-financial interests to disclose.

References

1. Ferlay J, Colombet M, Soerjomataram I, Parkin DM, Piñeros M, Znaor A, Bray F (2021) Global Cancer Observatory: Cancer Today. Lyon, France Int Agency Res Cancer 149(4):778–789. <https://doi.org/10.1002/ijc.33588>
2. Asli IN, Baharfard N, Shafiei B, Tabei F, Javadi H, Seyedabadi M, Nabipour I, Assadi M. Relation between clinical and laboratory parameters with radiation dose rates from patients receiving iodine-131 therapy for thyroid carcinoma. Radiat Prot Dosimetry. 2009;138(4):376–81. <https://doi.org/10.1093/rpd/ncp269>.
3. Park K, Kim K (2016) Comparison of the Measured Radiation Dose-rate by the Ionization Chamber and GM (Geiger-Müller) Counter After Radioactive Iodine Therapy in Differentiated Thyroid Cancer Patients. J. Radiol Sci Technol 39(4):565–570. <https://doi.org/10.17946/JRST.2016.39.4.11>
4. Adjadj E, Schlumberger M, de Vathaire F. Germ-line DNA polymorphisms and susceptibility to differentiated thyroid cancer. Lancet Oncol. 2009;10(2):181–90.
5. Atomic Energy Licensing (Basic Safety Radiation Protection) Regulations 2010. 1984.
6. Ahmad MI, Mohd MH, Nordin R, Mohamed F, Abu-Samah A, Abdullah NF. Ionizing radiation monitoring technology at the verge of internet of things. Sensors. 2021;21(22):7629. <https://doi.org/10.3390/s21227629>.
7. Dehkordi F, Rasuli B, Mahmoud-Pashazadeh A. An evaluation of deviation from the international atomic energy agency-international commission on radiological protection proposed equation for calculation of radiation dose rate emanating from the patients with differentiated thyroid cancer undergoing radioiodine (^{131}I) therapy. World J Nucl Med. 2017;16(02):150–5. <https://doi.org/10.4103/1450-1147.203078>.

8. Recommendations of the International Commission on Radiological Protection. ICRP publication 103. Ann ICRP. 2007;37:2–4. <https://doi.org/10.1016/j.icrp.2007.10.003>.
9. Klain M, Nappi C, De Risi M, Piscopo L, Volpe F, Manganelli M, Caiazzo E, Bianco D, Schlumberger M, Cuocolo A. Whole-body radioiodine effective half-life in patients with differentiated thyroid cancer. *Diagnostics*. 2021;11(10):1740. <https://doi.org/10.3390/diagnostics11101740>.

Publisher's Note Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

Springer Nature or its licensor (e.g. a society or other partner) holds exclusive rights to this article under a publishing agreement with the author(s) or other rightsholder(s); author self-archiving of the accepted manuscript version of this article is solely governed by the terms of such publishing agreement and applicable law.