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Estimation of radiation exposure to family members of I-131-treated patients in Tanzania using PHITS simulations

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Abstract:

Radiation therapy using Iodine-131 (I-131) is a widely employed treatment for thyroid disorders; however, it poses potential radiation risks to patient caregivers due to gamma emissions from treated patients. This study estimates the radiation doses received by family members of patients undergoing I-131 therapy in Tanzania, where cultural practices and living conditions complicate adherence to international safety guidelines. Using the Particle and Heavy Ion Transport Code System (PHITS), exposure scenarios during hospitalisation and post-discharge phases were modelled, accounting for proximity, activity levels, and caregiver-patient interactions. These models were used to quantify the radiation exposure to family members of patients treated with I-131 in Tanzania. Results indicate that family members assisting dependent patients during hospitalisation received doses of 1.53, 2.33, and 2.99 mSv for 3700, 5550, and 7400 MBq, respectively. These doses are below the 5 mSv per episode limit but exceeding the 1 mSv annual public dose limit recommended by the International Commission on Radiological Protection (ICRP). Post-hospitalisation, the doses decreased significantly, with the highest exposure caused by close-contact activities. Meanwhile, transportation scenarios showed the exposure to be less than 1 mSv/year for short durations. Nevertheless, strict adherence to maintaining a one-metre distance and minimising the duration of close contact is emphasised. These findings provide critical insights for maintaining public health while ensuring effective thyroid cancer treatment.

Keywords: **caregiver safety, family members, Iodine-131 therapy, PHITS simulation, radiation exposure, Tanzania, thyroid cancer.**

Classification numbers: **2.1, 3.6**

1. Introduction

Radiation therapy using the Iodine-131 (I-131) radionuclide is a well-established method for treating thyroid disorders, including hyperthyroidism and differentiated thyroid cancer [1, 2]. In this treatment technique, I-131 is either ingested or intravenously injected into the patient. Since iodine has a strong affinity for the thyroid gland, it becomes trapped in the thyroid [3]. Once inside the body, the radionuclide I-131 remains for a specific period until it completely decays to the stable element Xenon-131 or is removed from the body through biological processes, including excretion, sweating, and saliva [2, 4]. As the radioiodine decays, it emits beta particles along with energetic gamma rays that damage cancerous cells, as these cells are more sensitive to ionising radiation than their normal counterparts [5]. Beta particles, being less penetrating, interact with cancer cells within a few millimetres and locally deposit all their energy within the tumour site, destroying the cancerous cells with minimal effects on the nearby organs [6]. This makes use of radioiodine therapy an effective method of treating thyroid cancer with minimal risk of developing secondary malignancies or recurrence of the disease.

Despite its effectiveness in treating thyroid cancer, radioiodine therapy is not without hazards, as it requires patients to ingest or receive an intravascular injection of penetrating I-131. Since the isotope emits highly penetrating gamma rays, during the treatment period, the patient becomes a significant source of gamma radiation, primarily from the thyroid [2, 4]. These rays may irradiate surrounding individuals, including children, partners, parents, or friends who interact with the patient during or after hospitalisation. This poses potential radiation risks to family members and caregivers due to close contact during the post-therapy period [7]. As nuclear medicine services expand in Tanzania, ensuring radiation safety for the public, particularly patients' family members and caregivers, is a critical concern [8].

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International safety standards, such as those established by the recommended by the ICRP, require that the dose received by the public should not exceed 1 mSv/year. The International Atomic Energy Agency (IAEA) recommends that the discharge dose rate measured at 1 metre from the patient should be less than 70 μSv/h, ensuring the public dose does not exceed 5 mSv/year. Furthermore, the European Union Regulation states that patients treated with I-131 should be released from the hospital with a dose rate of 20 μSv/h measured at one metre. These regulatory bodies have also established a special form to be discussed by doctors, patients, and their family members [2, 9-11]. This form incorporates recommended radiation protection guidelines for both radioiodine-treated patients and their family members and caregivers [12, 13]. However, adherence to these guidelines in low-resource settings may be influenced by factors such as living conditions, patient release protocols, and awareness of radiation safety measures [14].

In Tanzania, challenges in adhering to international guidelines are exacerbated by cultural and lifestyle factors. Many people live in extended families with shared household facilities [15], making it difficult to separate patients from other family members as required by international guidelines. Moreover, in Tanzania, caring for a patient at home is the responsibility of family members, who often spend extended periods with the patient. Consequently, with limited knowledge of ionising radiation, family members may be exposed to significant radiation. This underscores the need to evaluate radiation dose exposure to family members and caregivers of radioiodine-treated patients in Tanzania. Despite the growing use of I-131 therapy in the country, there is limited data on the actual radiation exposure levels experienced by family members of treated patients.

This study seeks to estimate the radiation exposure to family members of patients undergoing I-131 therapy in Tanzania, assessing compliance with existing safety protocols and identifying potential risk factors. However, this is not a straightforward task, as monitoring each movement of patients and their caregivers is challenging. Therefore, simulation using the Particle and Heavy Ions Transport Code System (PHITS) was employed to conduct the investigation. By quantifying exposure levels and evaluating current practices, this research aims to inform evidence-based recommendations for optimising radiation protection measures for the Tanzanian public. The findings are instrumental in enhancing national regulatory frameworks and ensuring the safe use of radioiodine therapy while minimising risks to the public.

2. Materials and methods

2.1. Materials

This simulation study was conducted using PHITS version 3.2, a 3D Monte Carlo code written in Fortran, capable of transporting various particle species over a wide energy range. Photons with a cut-off energy of 1 keV were simulated alongside a reference phantom of a full human body, with the volume, density, and mass for each tissue. To balance simulation time and statistical uncertainty, variance reduction techniques were employed to account for uncertainties [4, 16]. In the source section, I-131 was modelled as a point source relative to the size of the thyroid, with activity levels varying from 3700 to 7400 MBq, reflecting the radiopharmaceutical activity used at the Ocean Road Cancer Institute (ORCI), depending on whether surgery had been performed. The output quantity from the simulation was obtained using the [T-Deposit] tally, and the unit used was appropriately defined.

2.2. Creating the geometrical simulation

In line with the study's aim to address patients with thyroid cancer, the Mathematical Reference Computational Phantoms for both adult male and female (MRCP-MA and MRCP-FA) were utilised within the PHITS simulation programme. One phantom of either sex was designated as a family member, while the other represented the patient. The radiation source was positioned at the neck of the patient phantom, simulating the thyroid, while detectors, referred to as output tally [T-deposit], were placed in each organ of the phantom representing the family member. The standard PHITS calculation (icntl=0) was employed to determine the effective dose rate to which the family member phantom was exposed, at varying distances from 10 to 200 cm, in 10 cm increments. From the effective dose rate obtained in the simulation, the effective dose in microsieverts was calculated as the product of the effective dose rate and time. Various patient-family-member positions were specified to account for different scenarios considered in this study, covering all seventeen days of treatment, including four days of hospitalisation and two weeks at home post-discharge.

2.3. Simulation scenarios and distance between patients and other people

The study considered two categories of patients: those requiring substantial care, referred to as totally dependent patients, and those requiring only routine assistance, referred as self-supportive patients. For totally dependent patients, a distance of 10 cm, termed 'close', was assumed between the patient and the assisting family member. The

activities performed by the caretaker in this scenario include assisting the patient with bowel movements, feeding, changing clothes, emptying and replacing the urinary bag as well as assisting the patient with bathing [17]. In contrast, when attending to self-supportive patients and performing routine daily monitoring, a standing distance of 100 cm was assumed, which corresponds to the recommended distance for radiation safety [18].

In another scenario, patients were assumed to travel home using either a taxi or public town buses, commonly known as "daladala". When travelling by public bus, the patient could be seated adjacent to another passenger, with a separation distance of less than 100 cm. This distance is referred to as the close distance and is considered the zero mark. For a passenger seated behind the patient's seat, the distance was estimated to be 30 cm, termed the normal distance. In cases where the patient travels by taxi, the distance between the patient and another person was assumed to be approximately 50 cm. This position was defined as the social position, and the entire journey was estimated to take two hours, covering to a distance of about 45 km from ORCI.

Another scenario considered the first two weeks following the intake of radioiodine. During this period, the patient was assumed to interact with others at varying distances, as social distancing is uncommon in the Tanzanian context. With this in mind, two standing positions were considered in the simulation environment. The first position was the close position, which would result in maximum exposure, and the second was the recommended position according to international guidelines. This approach was adopted to estimate the dose absorbed by a family member standing at any distance between 0 and 100 cm from the patient. For all standing positions in the specified scenarios, the transformation approach was utilised, employing Eq. 1 as a general transformation format.

$$\begin{pmatrix} x' \\ y' \\ z' \end{pmatrix} = R_3 R_2 R_1 \begin{pmatrix} x - X_C \\ y - Y_C \\ z - Z_C \end{pmatrix} + \begin{pmatrix} X_C \\ Y_C \\ Z_C \end{pmatrix} + \begin{pmatrix} X_0 \\ Y_0 \\ Z_0 \end{pmatrix} \quad (1)$$

where (x, y, z) and (x', y', z') are coordinates before and after transformation, respectively, X_C, Y_C, Z_C are x, y, z components of centre coordinates for the rotation, X_0, Y_0, Z_0 are x, y, z components of translation and R_3, R_3, R_3 are rotation matrices around x, y, z axes specified by θ_1, θ_2, θ_3 and A_3, A_3, A_3 as the angle and axis of rotation, respectively.

Across all scenarios, two cases were considered during simulation. In the first case, the caregiver was oriented perpendicular to the patient, and in the second case, the caregiver was parallel to the patient, as illustrated by Figs. 1 and 2. Fig. 1 depicts situations in which the caregiver is sitting or standing perpendicular to the patient, while Fig. 2 represents scenarios where the caregiver and patient are sitting, standing, or sleeping parallel to one another. When standing parallel to the patient, the family member receives direct radiation exposure, as the distance between their chests or backs is shorter than the distance between their bodies in a perpendicular position relative to the thyroid's location.

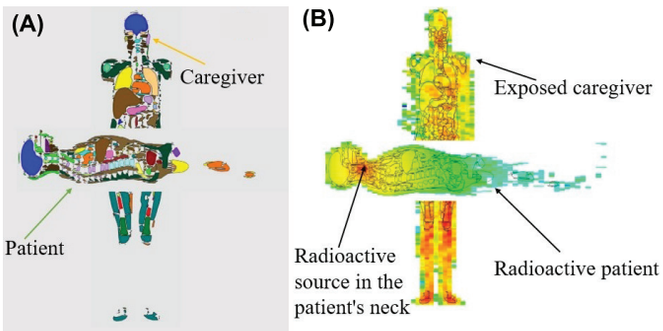

Fig. 1. The perpendicular orientation between the patient and the caregiver. **(A)** The simulated orientations of the patient and caregiver while; **(B)** The radiation dose distribution in the patient's body and caregiver's body.

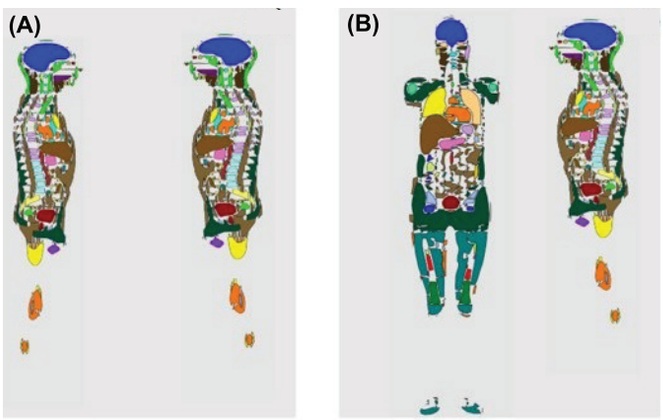

Fig. 2. The parallel orientation between the patient and the caregiver. **(A)** The scenario where the patient and the caregiver are facing each other while; **(B)** The scenario where the caregiver faces the patient sideways. Note that, in both cases of the parallel orientation, when the caregiver is standing parallel to the patient, their exposure to radiation is higher since the distance between the patient's thyroid location and the caregiver's chest or back is shorter than it was in the case of perpendicular orientation.

2.4. Simulating influence of radiopharmaceutical activity

It is also important to note that the activity of the ingested radiopharmaceutical decreases exponentially each day. Therefore, to determine the retained activity from a particular administered activity for each day, the decay Eq. 2, with the effective half-life adopted from [19], was used.

$$A(t) = A_0 e^{-\left(\frac{\ln 2}{T_{1/2E}}\right)t} \quad (2)$$

where $A(t)$ is the radioisotope activity at a given time, A_0 is the initial activity of the radioisotope, $T_{1/2E}$ is the effective half-life of the radioisotope, t is the elapsed time, ln is natural logarithm, and e is exponential function.

During the first four days, the decay rate is very high and gradually decreases with the number of days after administration. Therefore, the current study adopted an effective half-life of 14 hours during hospitalisation and 106 hours after the patient was discharged from the hospital [19]. The adopted effective half-life takes into account both physical and biological half-lives for all cases.

3. Results and discussion

3.1. Effect of standing position and radiopharmaceutical activity on the dose absorbed by the family member

The simulation results indicate that during the first 24 hours following the administration of radioiodine, radiation exposure to family members is affected by two primary factors: the activity level of the administered radioiodine and the family member's standing position, which is determined by their distance from the patient. Fig. 3 illustrates the impact of these factors on the dose rate received by the family member within this initial 24-hour period.

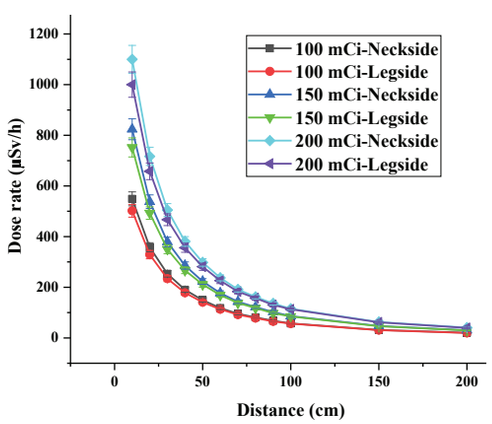

Fig. 3. The radiation dose rate received by the caregiver standing at different positions when assisting the patient treated with 3700, 5550 and 7400 MBq radioiodine.

According to Fig. 3, it is evident that 24 hours post-administration of I-131, family members standing for one minute close to patients treated with 3700, 5550, and 7400 MBq were exposed to doses of 9.2, 13.7, and 18.3 μSv, respectively. Conversely, when the family member stood for one minute at the patient's leg level, the received doses were 8.4, 12.5, and 16.7 μSv for patients administered with 3700, 5550, and 7400 MBq, respectively. These results clearly highlight the necessity for adhering to international guidelines and avoiding close proximity to the patient immediately after radiopharmaceutical administration [20]. Furthermore, since I-131 preferentially accumulates in the thyroid over other body parts [14], standing near the patient's neck resulted in a higher dose than standing by the patient's leg side. The results also indicate that at equal distances and times, family members are exposed differently depending on the initially administered activity [21]. It was observed that those assisting patients with 7400 MBq were more highly exposed compared to those with lower doses, particularly 3700 MBq. Finally, as the distance between the patient and the family member increased, the dose received decreased, with the highest dose at one metre in one minute being 1.9 μSv. This suggests that a safe distance for family members is one metre or more away from the patient.

3.2. Exposure rate to family members during hospitalisation

Family members who cared for their patients during the hospitalisation period experienced significant radiation exposure for all therapeutic activities at close proximity, particularly on the first day. On subsequent days, the exposure rate decreased to nearly half of the initial day due to the high excretion rate of the patients, resulting in reduced exposure intensity. Additionally, the dose rate diminished when the standing position was adjusted to the recommended distance of one metre. Consequently, family members whose patients were self-sufficient experienced less exposure, even when the patients were treated with high radiopharmaceutical activity. Conversely, family members of dependent patients, who needed to remain in close proximity, received a substantial radiation dose. Fig. 4 illustrates the variation in exposure rates to family members concerning the radiopharmaceutical activity, standing positions, and days post-ingestion.

These findings underscore the importance of restricting family members from assisting nuclear medicine patients, regardless of the circumstances. Such measures are crucial to minimise radiation exposure and ensure the safety of both patients and their families.

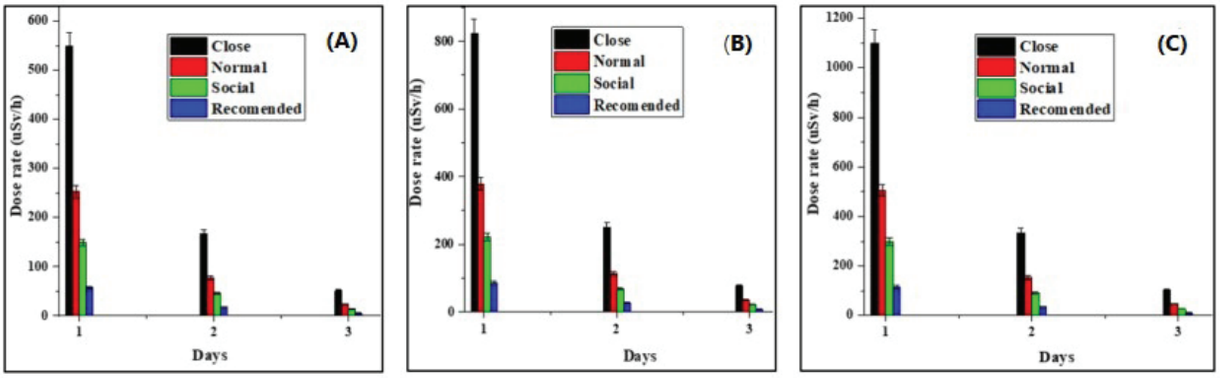

Fig. 4. The drop in the exposure rate to the family members for three days of nursing a patient treated with (A) 3700 MBq, (B) 5550 MBq, (C) 7400 MBq during hospitalisation.

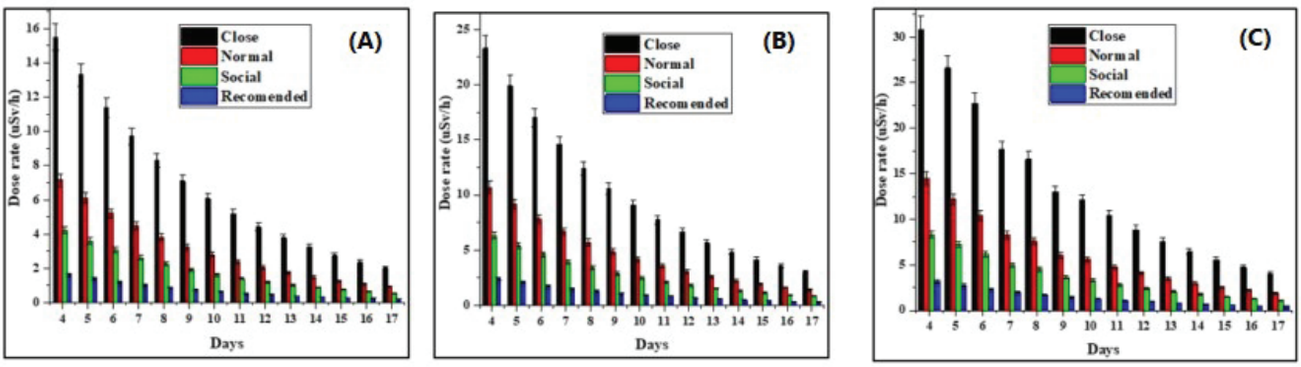

Fig. 5. The drop in the rate of exposure to family members for two weeks of nursing a patient treated with (A) 3700 MBq, (B) 5550 MBq, (C) 7400 MBq at home.

3.3. Exposure rate to family members after hospitalisation

Radiation exposure to family members was also estimated for the period when the patient is at home following hospitalisation. This was achieved by determining the daily radiation exposure over a two-week duration, commencing on day 4, as illustrated in Fig. 5.

A similar trend of decreasing exposure rates was observed among family members when the patient was at home. However, the rate of decline was more gradual compared to the first three days. This may be attributed to lower excretion rates, possibly caused by reduced water consumption at home. Nevertheless, despite the smaller decrease in exposure rates, the radiation dose to family members significantly diminished even at close distances. In this context, family members can remain with the patient for extended periods at the recommended distance while experiencing minimal exposure.

3.4. Dose received by a family member from the patient during hospitalisation

After determining the rate of radiation exposure to family members, this rate was used to quantify the radiation dose received by a family member designated to nurse the patient during hospitalisation. The quantification process was based on the activities assumed to be performed by the family member when caring for a bedridden patient. Table 1 outlines the caregiving activities assumed to be undertaken by the nursing family member when attending to helpless patients, along with their corresponding exposure doses. For each activity outlined in Table 1, the associated dose was calculated using Eq. (3). Since emptying and replacing the urinary bag results in double exposure (from both the urine and the patient), the time was doubled for a single event.

$$D = \dot{D} \times t \tag{3}$$

where D_T is the radiation dose absorbed by the family member, D' is the radiation dose rate and t is the exposure time.

Table 1. The radiation dose absorbed by the family member when performing various nursing activities for a dependent patients treated with 100, 150, and 200 mCi during hospitalisation.

Caring activities	Dose received (mSv)			Time (min)	
	3700 MBq ($\times 10^{-4}$)	*5550 MBq* ($\times 10^{-4}$)	*7400 MBq* ($\times 10^{-4}$)	*Interval*	*Spent*
Helping the patient with bowel removal	0.35 (4.47)	0.52 (4.47)	0.65 (4.47)	10-40	15
Tube feeding	0.38 (8.94)	0.56 (8.94)	0.79 (8.94)	15-40	30
Changing diapers for bedridden patients	0.38 (4.47)	0.56 (4.47)	0.79 (4.47)	15-30	15
Emptying and replacing the urinary bag	0.19 (4.47)	0.35 (4.47)	0.38 (4.47)	15-30	15
Assisting patient with bathing	0.23 (5.97)	0.34 (5.97)	0.38 (5.97)	15-30	20
Total	1.53 (13.25)	2.33 (13.25)	2.99 (13.25)		285

From Table 1, it is observed that the total dose received by family members attending to completely dependent patients during hospitalisation does not exceed the dose limit of 5 mSv per episode, although the public dose limit of 1 mSv was exceeded. This dose is considered safe only for a family member designated to care for the patients; otherwise, it may be harmful to other members, especially children and pregnant women. The estimated time to interact with the patient without exceeding the dose limit did not surpass seven hours. Conversely, the radiation dose received by the designated family member of self-supporting patients did not exceed 19 μSv for the entire hospitalisation period. Consequently, even members of the public can be allowed to visit and care for the patient without exceeding the dose limit of 1 μSv per year. Based on these observations, it is evident that family members assisting dependent patients are more exposed to radiation than those assisting self-supported patients. This is because the former requires the nursing family member to spend extended periods with their patients at a closer distance, resulting in a larger radiation dose than in the latter case.

3.5. Dose received by taxi driver, bus driver, and passengers during the patient's journey home

After being discharged from the hospital, a patient may choose to travel home using a private motor vehicle, a taxi, or public transport, either alone or with an accompanying person. This research considered patients who used either a taxi or public transport. The travel time was estimated to be two hours for a distance of 45 km from ORCI. Table 2 outlines the dose received by the taxi driver, bus driver, and fellow passengers seated in various positions relative to the patients.

Table 2. The dose received by taxi driver, bus driver, and passengers during the patient's journey home.

Person status	The dose received (Sv)			Time spent (h)
	3700 MBq ($\times 10^{-4}$)	*5550 MBq* ($\times 10^{-4}$)	*7400 MBq* ($\times 10^{-4}$)	
Taxi driver	8.44 (0.03)	12.64 (0.03)	16.66 (0.03)	2
Bus driver	3.24 (0.06)	4.88 (0.06)	6.34 (0.06)	2
Passenger at close position	31.00 (0.99)	46.60 (0.99)	61.60 (0.99)	2
Passenger at a normal position	14.30 (0.33)	21.40 (0.33)	29.00 (0.33)	2

Although the dose received by these individuals remains below the stipulated dose limit of 1 mSv per year, the person seated close to the patient could be highly exposed if the journey extends beyond two hours. In this regard, it is acceptable for nuclear medicine patients to use any means of transport, provided the travel time is limited to two hours. For longer travel distances, it is advisable for the patient to switch seats periodically to prevent overexposing the same individual.

3.6. Dose received by the family members from the self-supported patients two weeks after hospital discharge

During the two-week monitoring period post-discharge, family members who maintained a close distance with the patient received a higher radiation dose compared to those who adhered to the recommended one-metre distance. Table 3 details the activities undertaken by family members at close proximity and the corresponding absorbed doses. In contrast, Table 3 outlines the activities performed while maintaining the recommended distance, highlighting a

significant reduction in exposure. These findings emphasise the importance of maintaining a safe distance to minimise radiation exposure, ensuring the safety of family members while providing necessary care to the patient.

Table 3. Dose received by family members from self-supported patients at a close distance during two weeks of monitoring at home.

Caring activities	The dose received by the caregiver (mSv)			Time spent (h)
	3700 MBq ($\times 10^{-4}$)	*5550 MBq* ($\times 10^{-4}$)	*7400 MBq* ($\times 10^{-4}$)	
Sleeping together (single bed)	1.370 (0.554)	2.060 (0.554)	2.740 (0.554)	8
Dining together	0.142 (0.103)	0.213 (0.103)	0.281 (0.103)	1.5
Watching TV together	0.095 (0.069)	0.142 (0.069)	0.187 (0.069)	1
Total	1.607 (0.568)	2.415 (0.568)	3.208 (0.568)	147

Table 3 indicates that the dose received by family members remains well below the dose limit of 1 μSv per year. However, the dose significantly increases when a family member shares the same bed with the patient throughout the night, contributing to nearly 85% of the total absorbed dose. Therefore, if it is necessary to sleep in the patient's room, it is advised that the family member should not share the same bed with the patient. Due to the prevalent negligence among many Tanzanians and their lifestyle, which may lead to perceptions of discrimination against patients, it is strongly emphasised that patients should not share a bed with their loved ones. Conversely, Table 4 shows the dose received by a family member who cares for the patient while maintaining the recommended distance. The absorbed dose in this scenario is minimal, indicating that the safest way to care for the patient without excessive exposure to ionising radiation is to maintain the recommended distance.

Table 4. The dose received by caregivers at a 1-metre distance when assisting self-supported patients for two weeks at home.

Caring activities	The dose received by the caregiver (mSv)			Time spent (h)
	3700 MBq ($\times 10^{-4}$)	*5550 MBq* ($\times 10^{-4}$)	*7400 MBq* ($\times 10^{-4}$)	
Sleeping together in a single room but separate beds	0.079 (1.859)	0.119 (1.859)	0.158 (1.859)	8
Dining together	0.015 (0.349)	0.022 (0.349)	0.030 (0.349)	1.5
Watching TV together	0.010 (0.234)	0.015 (0.234)	0.020 (0.234)	1
Total	0.104 (1.906)	0.156 (1.906)	0.208 (1.906)	147

3.7. Radiation risk to family members when nursing patients during and after hospitalisation

When family members care for completely helpless patients during and after a hospital stay, they are exposed to overall doses of 1.76 (0.04) mSv, 2.68 (0.04) μSv, and 3.45 (0.04) μSv from patients treated with varying levels of radiopharmaceuticals. Although these doses do not exceed the limit of 5 μSv per episode, they are still concerning, especially if the same individual is repeatedly

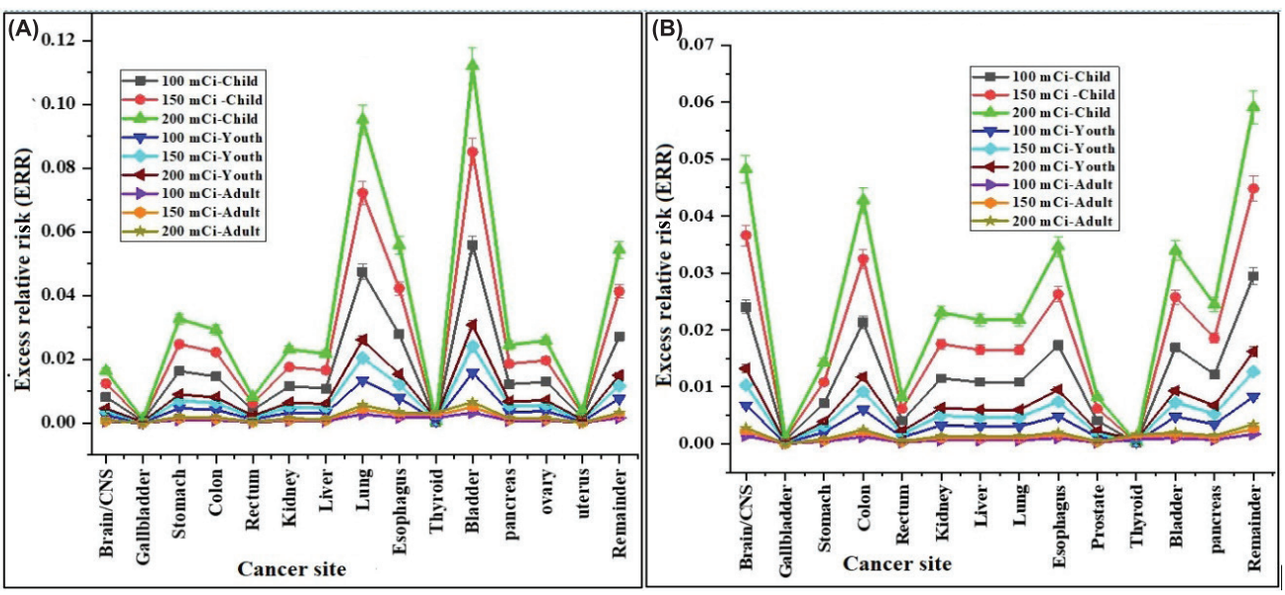

Fig. 6. Probability of (A) female and (B) male family members to develop cancer in some organs one month after exposure from patients treated with various therapeutic activities.

exposed. Therefore, it was essential to assess the health risks associated with the radiation dose absorbed by family members of nuclear medicine patients. The risk assessment was conducted for males and females across all age groups (child, youth, and adult), assuming that a family member was in close proximity to the patient from the day of radiopharmaceutical injection or ingestion. Since radiation risk is significantly influenced by the age at exposure and the attained age after exposure, assessing risk one month post-ingestion provides a prediction of potential risks related to the absorbed radiation dose. The excess relative risk was employed as a statistical method for the radiation risk assessment. Fig. 6 illustrates the probability that a family member may develop one of fifteen cancer types one month after exposure to radiation from the treated patients.

It is observed that, for all radiopharmaceutical activities of I-131, the likelihood of developing any type of cancer for both adult males and females was almost negligible. However, the probability of developing cancer increases as the age at exposure decreases from adults to young children. Female children are at a higher risk of developing lung cancer and bladder cancer compared to any other group. Meanwhile, younger boys exhibit a greater likelihood of developing cancer in the brain, colon, stomach, and bladder compared to any other age group. This finding aligns with the literature, which argues that children's cell cycles are faster, making them more susceptible to radiation effects, as cells are more sensitive to radiation during division [22].

4. Conclusions

This study has presented a comprehensive assessment of radiation exposure risks to family members and caregivers of patients undergoing radioiodine therapy. The administration of radioiodine (I-131) for therapeutic purposes poses radiation exposure risks to family members who interact with patients during and after treatment. The study evaluated the factors influencing radiation doses, including proximity to the patient, administered activity levels, and caregiving activities, while also assessing potential health risks. The findings reveal that both distance from the patient and the administered radiopharmaceutical activity significantly impact radiation exposure. For example, standing within close range of a patient treated with 7400 MBq of I-131 for just one minute resulted in a dose of 18.3 μSv, whereas maintaining a distance of one metre reduced the dose to 1.9 μSv. This demonstrates the critical role of distance in mitigating exposure. Higher administered activities such as 7400 MBq consistently led to greater doses compared to lower activities like 3700 MBq, reinforcing the need for stringent precautions in high-dose cases. During hospitalisation, family members caring for dependent patients faced elevated radiation doses, with total exposures reaching up to 2.99 μSv for high-activity treatments. Caregiving activities such as tube feeding and changing nappies contributed significantly to cumulative doses. In contrast, caregivers of self-sufficient patients received minimal exposure (≤19 μSv), highlighting the reduced risk when patients require less direct assistance. Generally, the exposure was observed to be highest during the first 24 hours after the radioiodine administration, with the risks diminishing significantly thereafter due to patient excretion patterns. Post-hospitalisation, the radiation exposure decreased but remained measurable, particularly during prolonged close contact. For instance, sleeping in the same bed as the patient accounted for approximately 85% of the total dose received at home, emphasising the need for separate sleeping arrangements. Besides, maintaining a one-metre distance during daily activities, such as dining or watching TV, may further reduce exposure to negligible levels. During transportation, patients travelling by taxi or public transport posed minimal risk to drivers and fellow passengers, provided the journey duration remained under two hours. However, passengers seated near the patient received higher doses, suggesting the need for rotating seat positions on longer trips to distribute exposure more evenly. It is important to note that, while the absorbed doses for adult caregivers generally remained below the 5 mSv per episode limit, children exhibited higher susceptibility to radiation-induced health effects due to their rapidly dividing cells. Female children were at greater risk for lung and bladder cancers, while male children showed increased vulnerability to brain, colon, and stomach cancers. These findings align with established literature on the heightened radiosensitivity of rapidly dividing cells in younger individuals. Therefore, the study emphasises finding the balance between providing necessary patient support and maintaining radiation safety standards, particularly for vulnerable populations. To achieve this delicate balance, it is recommended to strictly adhere to distance guidelines, carefully plan caregiving schedules to limit individual exposure times, provide special protections for vulnerable groups, particularly children, and offer comprehensive patient and family education programmes on radiation exposure and its risks. By implementing these evidence-based recommendations, healthcare providers can ensure that the benefits of treatment are not offset by unintended radiation exposure to those providing care and support.

CRediT author statement

Penina George Mbago: Conceptualisation, Methodology, Data curation, Writing; Innocent Jimmy Lugendo: Study supervision, Reviewing, Editing.

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COMPETING INTERESTS

The authors declare that there is no conflict of interest regarding the publication of this article.

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