

# Dosimetry during iodine-131 therapy — a technical point of view from a single centre’s own experience

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## Abstract

**Background:** Nuclear medicine uses radionuclides in medicine for diagnosis, staging, therapy, and monitoring the response to therapy. The application of radiopharmaceutical therapy for the treatment of certain diseases is well-established, and the field is expanding. Internal dosimetry is multifaceted and includes different workflows, as well as various calculations based on patient-specific dosimetry.

**Aim:** The objective of this study was to introduce the technical issues which might occur during iodine-131 (<sup>131</sup>I) dosimetry performed in nuclear medicine departments.

**Material and methods:** Retrospective analysis was performed on a group of 44 patients with papillary thyroid cancer who between May 2021 and October 2021 underwent a <sup>131</sup>I treatment: 80–100 mCi (2200–3700 MBq, based on the previous medical history and stage of the disease). Patients underwent a series of <sup>131</sup>I therapy scans using gamma camera Discovery NM 670 CT. Whole body scan (WBS) was performed 2, 4, 24 and 48 hours after <sup>131</sup>I administration. Additionally, after 24 hours of single photon emission computed tomography/ computed tomography, two fields of view (SPECT/CT 2-FOV) were performed from the mid-head to the bladder.

**Results:** During the dosimetry procedure, several issues arise. Firstly, after receiving therapeutic doses of <sup>131</sup>I, patients should remain in their rooms until the appropriate activity is achieved before being transported to the diagnostic room. Secondly, the walls between examination rooms meet the requirements for accurate diagnosis but not for therapy, leading to the occurrence of artefacts in patients examined behind the wall, potentially influencing the examination results. Thirdly, personnel in the control room also experience additional exposure (10 times greater than in the case of standard diagnostic procedure).

**Conclusions:** The dosimetry in patients in whom therapeutic procedures are performed with the use of isotopes is mandatory according to Polish and European law, technical issues which occur during the dosimetry procedures might influence the organization of the work in departments.

**KEYwords:** dosimetry; iodine therapy; guidelines; single photon emission tomography/computed tomography

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## Introduction

Thyroid cancer represents the most common endocrine malignancy and ranks 11<sup>th</sup> place in terms of diagnosis and mortality in 2020 (586,202 new cases and 43,646 deaths in 2020) [1, 2]. In Poland, in 2018 there were 4,193 new cases and 338 deaths caused by thyroid cancer. The majority of the new cases and deaths are shown in females [3].

The most frequent diagnostic imaging tool in the diagnosis of changes in the thyroid gland is ultrasonography (USG). If this imaging modality shows suspicious lesions, then a fine needle biopsy (FNB) of the thyroid and any suspect thyroid nodules is performed to confirm or deny malignant tissue [4]. Other imaging modalities like computer tomography (CT) or magnetic resonance imaging (MRI) are inferior to ultrasound and small lesions nodules might remain undetectable using these modalities [5]. The role of positron emission tomography combined with computed tomography (PET/CT) with the most frequently used radiotracer: 2-deoxy-2-[<sup>18</sup>F]fluoro-D-glucose (2-[<sup>18</sup>F]FDG) in the staging of the primary thyroid cancer is unclear, because of the low specificity in the differentiation of benign and malignant lymph nodes and thyroiditis [5]. In addition to the anatomical

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changes obtained by the above-mentioned techniques, thyroid scintigraphy is usually performed to visualize the active thyroid tissue and suspected for metastases lesions [6]. Moreover, an iodine-123/iodine-131 ( $^{123/131}\text{I}$ ) whole-body scan (WBS) is also used in the post-surgery approach to show residual or metastatic lymph nodes in the neck and mediastinum [5].

Malignant thyroid tumours can be divided based on the histopathological type:

- papillary carcinoma — 90%,
- follicular carcinoma — 6%,
- undifferentiated and anaplastic carcinoma — 1%,
- medullary carcinoma — 2% [7].

Other thyroid cancers like sarcoma, malignant lymphoma or squamous cell carcinoma (SCC) are rare (less than 1% combined) [7, 8].

Commonly used doses for radioiodine treatment are ranged from 30 to 150 mCi (1110–5550 MBq) and they depend on the severity/stage of the disease, the radicality of the surgical treatment, the purpose of treatment and can be divided into 3 main groups:

- adjuvant treatment for the differentiated thyroid cancer,
- ablative treatment for differentiated cancers,
- palliative treatment.

According to the Polish law patients after radioiodine administration should be isolated in the rooms with separate sanitary facilities and they communicate with the medical staff via intercom. Both doctors and nurses have a visual view of all rooms, which is provided by a system of cameras connected to the nursing point. Three days from the administration of the isotope, post-therapeutic WBS is performed, after a bathing of the whole body along with washing the head in order to eliminate skin impurities. Afterwards, the dosimetry measurements of the amount of radiation are performed. The radiation protection inspector, based on the received results decides about the possibility of terminating the patient's isolation. If the radiation emission standards are exceeded — i.e. above 800 MBq, the isolation of the patient in the ward is extended until the desired values are achieved [9, 10].

In April 2021, the new Disposition of the Ministry of Health is published and said that optimization in nuclear medicine is obligatory, especially in the therapeutic approach. Doses obtained in nuclear medicine procedures are a part of doses which patients receive during diagnostic procedures/imaging and radiotherapy [11, 12].

Based on their preliminary experience, in this note, the authors would like to introduce the technical issues which might occur during  $^{131}\text{I}$  dosimetry performed in nuclear medicine departments.

## Material and methods

A retrospective analysis was performed on a group of 44 patients with papillary thyroid cancer (after surgical resection of the thyroid gland), who between May 2021 and October 2021 underwent a  $^{131}\text{I}$  treatment: 80–100 mCi (2200–3700 MBq, based on the previous medical history and stage of the disease). Endogen stimulation was performed before the treatment patients were administered to the Department of Endocrine Oncology and Nuclear Medicine.

Patients (after they gave their informed consent) underwent a series of  $^{131}\text{I}$  therapy scans using gammacamera Discovery NM 670 CT (GE Healthcare). WBS (scan speed 25 cm/min, matrix

$256 \times 1024$ ) was performed 2, 4, 24 and 48 hours after  $^{131}\text{I}$  administration. Additionally, after 24 hours SPECT/CT 2-FOV (25 s of view, matrix  $128 \times 128$ ) was performed from the mid-head to the bladder. Before the WBS, also blood samples from the patient were collected to assess the blood dosimetry.

An analysis of the blood of patients (2 mL in the synergy) after  $^{131}\text{I}$  therapy was performed on the ATOMLAB 500.

Additionally, the measurements of the background in the control room were performed when the  $^{131}\text{I}$  patient was examined and during standard nuclear medicine procedures. Moreover, in 5 patients measurements of dose rate were performed with a CoMo 170 radiometer.

## Results

Dosimetry procedures caused several issues which affected the whole nuclear medicine department. All patients underwent a total of 4 examinations and this caused the first problem because according to Polish law, patients after receiving the therapeutic doses of  $^{131}\text{I}$  should stay in their room as long as the appropriate activity is achieved, thus when they are transported to the examinations from the iodine therapy department to the department of nuclear medicine, they violate the restrictions. Moreover, the medical staff (mostly the nurses and technicians), who transfer the patient into the examination room, receive radiation exposure as well as the patients who are waiting for the standard nuclear medicine examinations, for example, WBS. Dosimetry patients were an additional dose exposure for other patients and medical staff, moreover, nurses also received an extra exposure during the blood sampling.

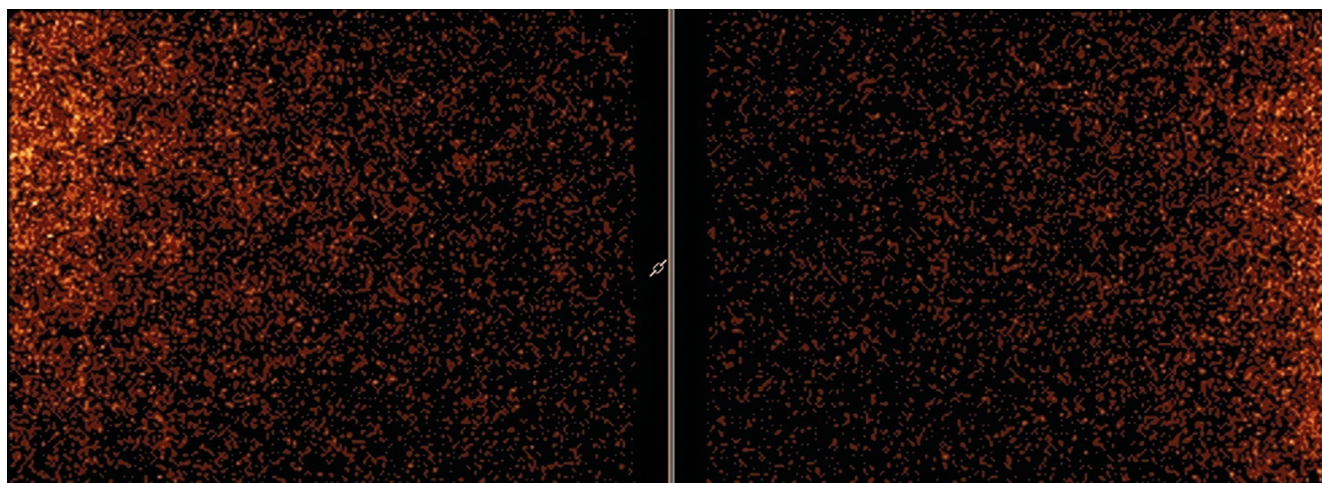
The second problem occurred when patients were in the examination room. The walls between the examination rooms, where the gamma cameras are placed, were insufficiently covered with lead for therapeutic doses (Fig. 1). This resulted in the appearance of artefacts in the patient examined behind the wall and might have an influence on the examination result (Fig. 2). Consequently, the gamma camera located behind the wall was turned off at that time.

Moreover, the personnel in the control room also receive extra exposure. It turned out that the measurement is 10 times greater than in the case of standard work with diagnostic patients (Tab. 1).

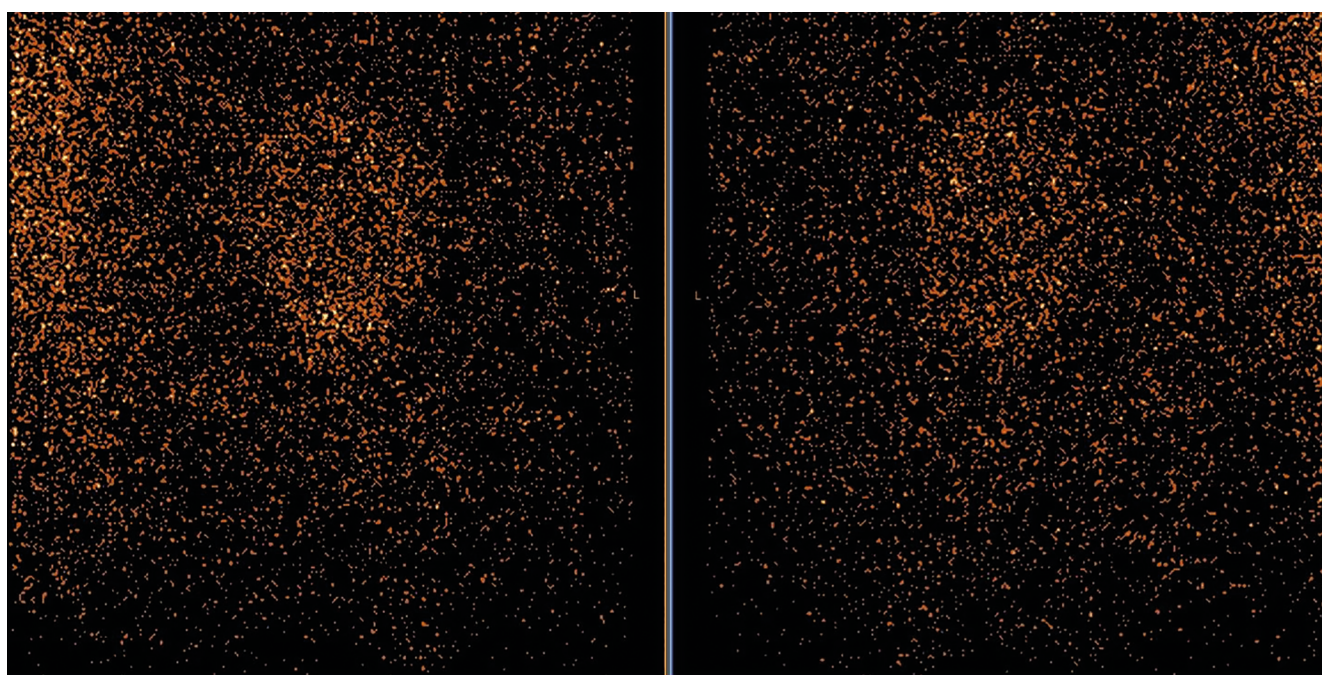
Both above-mentioned problems are caused because the shield design was not designed for therapy — it meets the requirements for the appropriate diagnosis purpose, but not for the therapy. Additionally, as shown in Table 2, the dose rate is considerably higher during the first day after  $^{131}\text{I}$  administration compared to the other two.

The third problem was a SPECT/CT acquisition time. The standard examination least approximately 1 hour per patient (25 sec/view) in the study department, which causes additional issues: the medical staff who performed the SPECT/CT examination was exposed to radiation obtained from the patient (as shown in Table 1).

Another minor problem occurred during the analysis of the dosimetry images. It was highly dependent on the used software [13]. Most of the available software requires at least one SPECT/CT image. However, some of them for the dosimetry evaluation also need extra scans, which also cause additional exposure for the patient and the medical staff in the control room. In the study department, because of a high number of  $^{131}\text{I}$  patients who had



**Figure 1.** Background measurement during the WBS scan, while an  $^{131}\text{I}$  patient was examined next room



**Figure 2.** Artefacts occurring during the WBS scan in the room next to the examination of the  $^{131}\text{I}$  patient

undergone dosimetry procedures, it was decided to use MIM Software to reduce the exposure, because it did not require additional scans (besides 3 WBS and 1 SPECT/CT).

## Discussion

The dosimetry procedure makes the work at the Department of Nuclear Medicine much more difficult and hinders the organization and standards of work. The physician must inform the patient that the dosimetry procedure has been performed. Moreover, the nuclear medicine departments with a small number of gamma cameras may not be able to perform the dosimetry for all patients (including  $^{131}\text{I}$ ,  $^{177}\text{Lu}$ ), because this means that

gamma cameras are locked by these patients and standard procedures need to be moved to the different time. In the study department, there are 5 gamma cameras, however, only one has a diagnostic SPECT/CT and appropriate collimators for the iodine energy. Even thus, performing more than 2 dosimetry patients per day is difficult and requires reorganization of the normal work plans. Additionally, because it is not routinely performed in all patients, patients chosen for the dosimetry evaluation might not give informed consent for an extra examination. This might be caused by several reasons: procedure time duration, additional exposure to radiation from SPECT/CT imaging, health problems that may make the patient unable to lay still during the examination and cause artifacts etc.

**Table 1.** Doses received by a technician in the control room while <sup>131</sup>I patient is examined compared to the normal operating mode

Time	Dose 3700 MBq		Normal operating mode	
	Control room [cps]	Examination room [cps]	Control room [cps]	Examination room [cps]
2 h	232.3	77.0		
4 h	183.4	59.2		
24 h	158.6	21.6	20.8	18.5
48 h	106.6	20.9		

cps — counts per second

**Table 2.** Values of doses rate depend on the time after <sup>131</sup>I administration

Patient NO	Dose rate [ $\mu$ Sv/h]			
	2 h	4 h	24 h	48 h
1 2220 [GBq]	65	40	11.4	5.40
2 2220 [GBq]	53	43	4	1.01
3 3700 [GBq]	86	61	13	2.91
4 3700 [GBq]	98	84	17	3.40
5 3700 [GBq]	125	91	15	2.50
Mean $\pm$ SD	85.4 $\pm$ 28.25	63.8 $\pm$ 23.21	12.08 $\pm$ 4.98	3.06 $\pm$ 1.63

GBq — gigabecquerel; SD — standard deviation;  $\mu$ Sv/h — microsieverts per hour

It is worth noting that it is not recommended to use different dosimetry software packages interchangeably in a clinical setting or a trial, as there are differences in methodology and hence in the results obtained. Additionally, the obtained results will depend on various (software-required) acquisition protocols, time and pharmacological behaviour of the radiopharmaceutical [14]. For the same reason, before all dosimetry procedures will start, physicians should be familiar with the acquisition requirements. In their department, the authors have two different software for the dosimetry and there are some differences: for example one software requires an additional 2 scans, which makes the procedure last longer and hence — increases the exposure of medical personnel as was shown in Table 1. Moreover, because of the existing artefacts caused by insufficient shield wall, performing appropriate dosimetry procedures requires a new project that takes into account therapeutic activities and rebuilds the nuclear medicine department, which is very expensive and time-consuming.

The standard procedure for the <sup>131</sup>I patients, (before the announcement of the changes to the Atomic Law on April 6, 2021) suggested that patients should undergo examination 48 hours after the administration of a therapeutic dose of iodine. During the entire stay in the hospital, the patients did not leave the rooms until they were measured by the radiological protection inspector. As shown in measurements of dose rates by the <sup>131</sup>I patients, the doses decrease substantially over time, thus performing dosimetry on the first day after <sup>131</sup>I administration causes major issues in the organization of the plan work and higher radiation exposure to medical staff. Right now, the Law has changed and to the best of the authors' knowledge, there is no agreement in the guidelines provided by the Polish Society of Nuclear Medicine if releasing a patient from the therapeutic department for performing the dosimetry procedures is right or might cause an extra exposure to medical staff as well as for the patients waiting for other examinations.

The recently published EANM paper about the basic safety standards for nuclear medicine therapy indicates three

levels of compliance to the optimization principle in the basic safety standards directive [15]. This indicates that dosimetry should be obligatory in level 3 (mostly clinical trials and in children), and in <sup>131</sup>I therapy in differentiated thyroid cancer as well as in benign thyroid disease is optional.

The following study confirmed that performing dosimetry in all patients treated with <sup>131</sup>I can cause more problems than benefits. Nonetheless, this type of procedure might bring some benefits to patients with distant metastases. However, further multicentre studies are needed to confirm or deny the present findings from a single centre.

## Conclusions

Dosimetry is imperative for patients undergoing therapeutic procedures involving isotopes, as mandated by both Polish and European laws; any technical complications arising during dosimetry procedures can impact the operational workflow within departments. Thus consideration of the appropriate criteria for using dosimetry in nuclear medicine therapy is of great interest.

## Article information and declarations

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None.

### Author contributions

Conceptualization — PC; methodology — PC, WCh, AM and ES; Investigation — PC, WCh, AM and ES; writing — original draft preparation: PC, WCh, AM and ES; writing — review and editing — AS and MD; supervision — MD; WCh and PC contributed equally to this study.

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### Data availability statement

The data presented in this study are available in the article.

### Conflicts of interest

The authors declare no conflict of interest.

### Supplementary material

None.

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