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# EVALUATING LONG-TERM EXTERNAL DOSES AT SHORT RANGE IN PATIENTS RECEIVING $^{131}$I TREATMENT FOR DIFFERENTIATED THYROID CARCINOMA

## DİFERANSİYE TİROİD KARSİNOMUNDA $^{131}$I TEDAVİSİ ALAN HASTALARDA KISA MESAFEDE UZUN DÖNEM EKSTERNAL DOZUN DEĞERLENDİRİLMESİ

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### ABSTRACT

**Objective:** Iodine-131 ($^{131}$I) treatment offers imaging advantages due to its emission of high-energy gamma radiation, despite concerns being raised regarding radiation safety. Various rules and standards for radiation protection have been established internationally and nationally. Patients undergoing this treatment can present a risk of external radiation exposure to the people around them. The purpose of this study is to measure the radiation dose rates around patients who have undergone treatment and to assess the effects of cumulative doses received by those who have been exposed.

**Material and Method:** The study includes a total of 44 patients who had undergone radioactive iodine therapy for differentiated thyroid cancer and measures their thyroid stimulating hormone (TSH) levels and 24-hour radioiodine uptake. The $^{131}$I doses administered to the patients were recorded. Following treatment, external dose rates (EDR) were measured at distances of 30 cm and 1 m from the patients at 0, 4, 24, 48, 72, 144, and 240 h post $^{131}$I treatment. Radiation exposure was calculated by considering three scenarios for those accompanying the patient.

**Result:** The study calculated the median TSH values of the 44 patients as 81.74±41.98 mIU/L, while the median of their 24-hour uptake values was determined as 6.39±8.42%. The mean administered treatment dose was 5.28 GBq (±1.3). A correlation was observed between the initial 24-hour measurements and the

### ÖZET

**Amaç:** İyot-131 ($^{131}$I) tedavisi, yüksek enerjili gama radyasyonu yayması nedeniyle görüntüleme avantajları sunmakla birlikte, radyasyon güvenliğine ilişkin endişeleri de artırmaktadır. Radyasyondan korunmaya yönelik uluslararası ve ulusal düzeyde çeşitli kurallar ve standartlar oluşturulmuştur. Bu tedaviyi gören hastalar, etraflarındaki kişilerin dışarıdan radyasyona maruz kalma riski oluşturabilir. Bu çalışmanın amacı tedavi gören hastaların yakınındaki radyasyon doz oranlarını ölçmek ve maruz kalanların aldığı kümülatif dozları değerlendirmektir.

**Gereç ve Yöntem:** Diferansiye tiroid kanseri nedeniyle radyoaktif iyot (RAI) tedavisi gören toplam 44 hasta çalışmaya dahil edildi. Tiroid uyarıcı hormon (TSH) düzeyleri ve 24 saatlik radyoiyot alımları ölçüldü. Hastalara uygulanan RAI dozları kaydedildi. Tedaviyi takiben $^{131}$I tedavisinden sonraki 0, 4, 24, 48, 72, 144 ve 240. saatlerde hastalardan 30 cm ve 1 m mesafeden eksternal doz oranları (EDR) ölçüldü. Hastaya eşlik edenlerin radyasyon maruziyetleri üç senaryo dikkate alınarak hesaplandı.

**Bulgular:** Kırk dört hastanın ortanca TSH değeri 81,74±41,98 mIU/L olarak hesaplanırken, 24 saatlik alım değerlerinin ortancası %6,39±8,42 olarak belirlendi. Ortalama uygulanan tedavi dozu 5,28 GBq (±1,3) idi. İlk 24 saatlik ölçümler ile uygulanan doz arasında korelasyon gözlendi. Ayrıca 24. saatten sonra alınan ölçümler ile 24. saatteki alım değeri arasında korelasyon bulun-

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administered dose. Furthermore, another correlation was found between the measurements taken after the 24th hour and the 24-hour uptake value. The radiation exposure for accompanying individuals was estimated to range between 0.4-1.62 mSv across three scenarios.

**Conclusion:** Patients receiving $^{131}$I treatment should be given comprehensive information about the importance of radiation protection after treatment and the precautions to be taken during isolation.

**Keywords:** Radiation safety, differentiated thyroid carcinoma, $^{131}$I , external dose rate, radiation protection

du. Eşlik eden kişilerin radyasyona maruz kalma oranının üç senaryoda 0,4 ila 1,62 mSv arasında olduğu tahmin edildi.

**Sonuç:** RAI tedavisi gören hastalara tedavi sonrasında radyasyondan korunmanın önemi ve izolasyon sırasında alınması gereken önlemler konusunda kapsamlı bilgi verilmelidir.

**Anahtar Kelimeler:** Radyasyon güvenliği, diferansiye tiroid karsinomu, $^{131}$I , harici doz hızı, radyasyon koruması

## INTRODUCTION

Since the first applications of nuclear medicine, radionuclides have been increasingly utilized in clinical diagnosis and treatment (1-3). Radioactive iodine ($^{131}$I) is widely used in the diagnosis and treatment of diseases, especially in the context of thyroid cancer therapy. The effectiveness of $^{131}$I treatment has been proven and successfully applied for ablation and adjuvant therapy following total thyroidectomy in patients diagnosed with thyroid carcinoma. This treatment increases the survival rate and reduces the risk of recurrence and metastasis after total thyroidectomy (1).

The $^{131}$I ablation treatment, commonly administered using empirical methods, is given in doses ranging from 1850 MBq-7400 MBq in line with the latest guidelines. The effective beta radiation emitted in the treatment also has 364 keV of gamma energy to provide an imaging advantage; however, this presents challenges concerning radiation safety, the importance of which remains significant due to the long half-life, high energy, and the quantity of activity administered in nuclear medicine applications. Because of the high gamma energy, patients undergoing treatment act as open sources, exposing nearby individuals to external radiation. Therefore, the International Commission on Radiological Protection (ICRP) has established strict rules for radiation protection in its ICRP Publication 60. In 2006, the International Atomic Energy Agency (IAEA) suggested a guideline for discharging patients, recommending an external dose rate (EDR) of 1200 MBq or 70 μSv/h at a distance of 1 meter from patients as a directive level. However, the specific regulations vary by country. According to European Union (EU) guidelines, the release of patients undergoing $^{131}$I treatment is specified to be permissible only if the retained body activity (RBA) is < 400 MBq and the EDR at a distance of 1 meter is < 20 μSv/h (3). According to the laws of the Turkish Energy, Nuclear and Mineral Research Agency (TENMAK) and the Turkish Ministry of Health, patients who are to be treated at levels exceeding 600 MBq must be treated in specially designed rooms in clinics possessing a radionuclide therapy license as per the rule for inpatient care. For patients to be discharged, the requirement is that the EDR must have fallen below 30 μSv/h at a distance of 1 meter from the abdominal region (4, 5). Even if the EDR falls below these levels, patients remain an open source of radiation until the activity in their bodies has been completely neutralized and thus are a source of external radiation (6-9). Close-range exposure to doses from patients undergoing treatment may lead to undesirable situations. This is particularly challenging in large cities with dense populations and cultures with limited living spaces, as isolating patients treated for radiation can pose dangers. Despite education provided to patients and their families regarding radiation protection and isolation prior to treatment, instances do occur where these recommendations are not followed. Understanding the exposure levels of individuals subjected to close-range dose exposure is crucial for various reasons, particularly regarding those who do not comply with radiation isolation rules. Many studies have been carried out concerning patients' EDRs, and these studies have provided results regarding the decrease in radiation in the patient's body (10-13). However, most of these studies are based on measurements taken at the end of the treatment up until the patient is discharged (13-17). Furthermore, the approach in long-term studies has involved taking measurements from 1-2 m away from the patient (13, 18). Both the individuals who are exposed as well as health authorities must possess a basic understanding of the exposure risks associated with close contact with a patient who has undergone $^{131}$I treatment.

This study aims to assess patients' short-range dose rates and calculate the cumulative doses to which family members or those in close contact are exposed.

## MATERIALS and METHOD

### Patient population

This study includes a total of 44 patients (6 males, 38 females) who received $^{131}$I treatment at the Istanbul University Faculty of Medicine Department of Nuclear Medicine between 2005-2006 are included in this study. The average age of these patients is 42±13.8 years. This study was approved by the Istanbul Faculty of Medicine Clinical Research Ethics Committee (Date: 15.12.2023, No: 25).

**Treatment procedure**

All patients had previously undergone total thyroidectomy, and $^{131}$I therapy was administered after a minimum waiting period of 6 weeks following surgery. Additionally, all patients adhered to a low-iodine diet for at least two weeks before therapy, with LT4 therapy being discontinued for 4–6 weeks prior to receiving $^{131}$I therapy in order to prevent iodine contamination and to ensure maximum iodine retention. Before treatment, a $^{131}$I uptake test was performed to ensure that the TSH levels of the patients admitted to the clinic for treatment were >30 mIU/L. Furthermore, female patients underwent hCG testing to rule out pregnancy. To optimize $^{131}$I absorption in patients, they were required to fast for 3 hours before treatment. The dose of the $^{131}$I capsule to be administered to the patient was measured using a dose calibrator and then administered with 200 ml of water.

**The measurements**

The measurements were performed using a Ludlum Model 3 survey meter (measurement range 0-2 R/h; Ludlum Measurements, Inc., Sweetwater, TX, USA), calibrated by the national Secondary Standard Dosimetry Laboratories (SSDL). To reduce the margin of error in the measurements following the administration of $^{131}$I, readings were taken using a specially designed setup at distances of 30 cm and 1 meter from the abdominal region at 0, 4, 24, 48, 72, 144, and 240 h post-treatment. Upon considering the localization of $^{131}$I uptake in the thyroid region, additional measurements were also recorded from the neck area at distances of 0 meters and 30 cm over the 240 h period with the survey meter.

**Scenarios**

The radiation exposure experienced by individuals who were in close contact with the patient as companions after receiving treatment was calculated for the total periods between 48 hours and 240 hours in accordance with the following three different scenarios:

Scenario 1 (S1): At 48 h post-discharge, a scenario was devised assuming that the patient sleeps in the same bed as the companion at a distance of 30 cm for eight hours in a day.

Scenario 2 (S2): At 48 h post-discharge, a second scenario was devised assuming that the patient sleeps in a different bed than the companion in an adjacent room and separated by a 10 cm concrete wall (at 30 cm distance from the patient) for eight hours in a day. In accordance with radiation protection rules, the reduction effect of the concrete wall was calculated mathematically. It was calculated that a 10 cm concrete wall absorbed 20% of $^{131}$I radiation (19).

Scenario 3 (S3): At 48 h post-discharge, a third scenario was devised assuming that the patient slept in separate beds in the same room, with a 50 cm distance between them (1 m distance between patient and companion), for eight hours in a day (Figure 1).

For these three scenarios, calculations were made to determine the radiation exposure dose for the companion of the treated patient. A decay graph of the EDR values measured from the patients was plotted based on these calculations. The cumulative dose value was determined by calculating the area under this graph. After 240 hours, the activity regarding the dose calculations was assumed to only decrease physically within the patient's body.

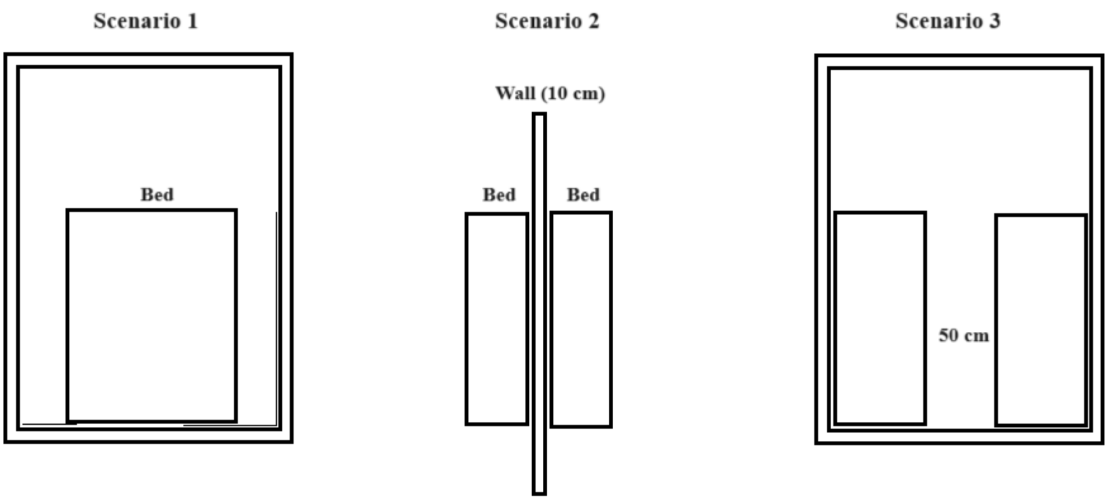


**Figure 1:** Positions of rooms and beds for the three scenarios used in the study.

**Statistical analysis**

IBM SPSS Statistics for Windows (Ver. 28.0; IBM Corp., Armonk, NY, USA) was used for the statistical analyses. The Pearson correlation test was used to analyze the relationship between TSH and EDR, uptake at 24 h and EDR, and dose and EDR, with a $p<0.05$ being considered statistically significant.

## RESULTS

Table 1 presents the TSH, uptake value at 24 h, and EDR measurements for all patients. When considering these values, the median TSH value for the 44 patients was calculated as 81.74±41.98 mIU/L, and their median uptake value at 24 h was calculated as 6.39±8.42%.

The mean administered treatment dose was 5.28 GBq (±1.3). Treatment dosages were distributed as follows: 14 patients received 3.7 GBq, 23 received 5.55 GBq, six received 7.4 GBq, and one received 8.51 GBq. Of these patients, five were undergoing repeated treatment.

The 30 cm EDR values at 0 h, 4 h, 24 h, 48 h, 72 h, 144 h, and 240 h were measured and found respectively as 67.2±15.02 mR/h, 66.59±14.95 mR/h, 19.76±8.74 mR/h, 7.92±4.87 mR/h, 4.14±4.35 mR/h, 1.23±1.40 mR/h, and 0.45±0.74 mR/h (Figure 2).

The 1 m EDR values at 0, 4, 24, 48, 72, 144, and 240 h were measured and found respectively as 16.26±3.80 mR/h, 16.01±3.88 mR/h, 4.94±1.99 mR/h, 2.02±1.32 mR/h, 1.08±1.18 mR/h, 0.40±0.76 mR/h, and 0.07±0.21 mR/h.

Pearson correlation tests were performed for the EDR measurements with TSH, uptake at 24 h, and the applied treatment dose. No significant relationship was found between the patients' pre-treatment TSH values and EDR measurements ($p>0.05$). While no significant relationship was found between uptake result at 24 h and the EDR measurements at 0, 4, and 24 h ($p>0.05$), significant relationships were found for subsequent EDR measurements at 48, 72, 144, and 240 h ($p<0.05$).

A significant relationship was observed to exist between the $^{131}$I dose that was applied to the patients and EDR measurements at 0, 4, and 24 h ($p<0.05$). However, the subsequent measurements showed no significant relationship ($p>0.05$). Dose calculations were made using the EDR results based on the three different scenarios. The radiation exposure dose for the patients' companions was calculated as 1.62 mSv for scenario 1, 1.29 mSv for scenario 2, and 0.4 mSv for scenario 3 (Figures 3 and 4).

Scenario 1: Calculations were made based on the average EDR measured at a distance of 30 cm from patients undergoing treatment. According to these calculations, a person who spends eight hours in the same bed at 30 cm from the patient would be exposed to approximately

**Table 1:** Patients' thyroid stimulating hormone (TSH), uptake values at 24 h, external dose rates (EDR) mR/h taken from distances of 30 cm and 1 m

| Patient | TSH (mIU/L) | Iodine Uptake at 24 h (%) | 30 cm EDR (mR/h) | | | | | | | 1 m EDR (mR/h) | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 0 h | 4 h | 24 h | 48 h | 72 h | 144 h | 240 h | 0 h | 4 h | 24 h | 48 h | 72 h | 144 h | 240 h |
| 1 | 97.3 | 1.00 | 50 | 49 | 16.0 | 9.0 | 4.2 | 0.9 | 0.40 | 12.0 | 12.0 | 3.4 | 1.6 | 1.0 | 0.2 | 0.0 |
| 2 | 70.9 | 2.97 | 44 | 44 | 20.0 | 9.0 | 4.6 | 1.1 | 0.22 | 11.0 | 11.0 | 4.2 | 2.7 | 1.0 | 0.3 | 0.0 |
| 3 | 65.0 | 1.10 | 49 | 50 | 9.0 | 3.5 | 1.0 | 0.4 | 0.20 | 12.0 | 12.0 | 3.3 | 1.3 | 0.4 | 0.1 | 0.0 |
| 4 | 75.0 | 6.41 | 45 | 45 | 8.0 | 3.1 | 0.9 | 0.5 | 1.00 | 10.5 | 10.5 | 2.6 | 0.9 | 0.3 | 0.2 | 0.1 |
| 5 | 74.0 | 9.35 | 48 | 48 | 11.0 | 4.0 | 2.1 | 1.1 | 0.20 | 12.0 | 12.0 | 2.8 | 1.1 | 0.5 | 0.1 | 0.0 |
| 6 | 69.0 | 4.07 | 50 | 48 | 12.0 | 4.8 | 2.9 | 1.0 | 0.08 | 12.0 | 10.0 | 2.7 | 1.2 | 0.9 | 0.1 | 0.0 |
| 7 | 130.5 | 0.75 | 46 | 46 | 12.0 | 2.6 | 1.2 | 0.4 | 0.12 | 12.0 | 12.0 | 3.2 | 0.9 | 0.3 | 0.0 | 0.1 |
| 8 | 65.9 | 26.79 | 41 | 41 | 15.0 | 8.0 | 4.3 | 1.7 | 0.54 | 11.0 | 11.0 | 3.3 | 1.8 | 1.1 | 0.4 | 0.2 |
| 9 | 71.9 | 8.60 | 45 | 45 | 14.0 | 8.0 | 4.8 | 1.0 | 0.20 | 12.0 | 12.0 | 3.1 | 2.0 | 1.1 | 0.3 | 0.0 |
| 10 | 13.2 | 4.19 | 49 | 48 | 22.0 | 12.0 | 4.0 | 0.9 | 0.15 | 13.0 | 13.0 | 4.8 | 2.0 | 1.2 | 0.2 | 0.0 |
| 11 | 154.0 | 0.26 | 48 | 48 | 10.0 | 1.6 | 0.9 | 0.3 | 0.19 | 12.0 | 12.0 | 2.8 | 0.5 | 0.3 | 0.0 | 0.0 |
| 12 | 19.9 | 33.22 | 49 | 49 | 22.0 | 11.0 | 5.6 | 2.1 | 0.40 | 11.0 | 11.0 | 4.3 | 2.3 | 1.3 | 0.4 | 0.0 |
| 13 | 63.0 | 6.20 | 72 | 72 | 46.0 | 11.0 | 6.0 | 2.1 | 0.70 | 12.0 | 12.0 | 8.0 | 2.6 | 1.5 | 0.6 | 0.2 |

| | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 14 | 36.8 | 6.54 | 72 | 72 | 24.0 | 9.0 | 4.8 | 1.1 | 0.47 | 16.0 | 16.0 | 4.5 | 2.2 | 1.2 | 0.5 | 0.0 |
| 15 | 46.5 | 1.56 | 76 | 76 | 26.0 | 13.0 | 5.8 | 1.3 | 0.35 | 17.0 | 17.0 | 7.0 | 2.5 | 1.3 | 0.5 | 0.2 |
| 16 | 225.4 | 11.35 | 75 | 75 | 27.0 | 9.0 | 4.9 | 1.6 | 0.34 | 19.0 | 19.0 | 8.0 | 2.1 | 1.2 | 0.6 | 0.1 |
| 17 | 136.8 | 11.20 | 74 | 74 | 20.0 | 10.0 | 5.0 | 1.5 | 0.23 | 17.0 | 17.0 | 4.2 | 2.2 | 1.0 | 0.5 | 0.1 |
| 18 | 38.6 | 9.10 | 70 | 70 | 18.0 | 9.0 | 4.5 | 1.6 | 0.80 | 16.0 | 16.0 | 4.8 | 2.2 | 1.0 | 0.4 | 0.0 |
| 19 | 97.5 | 2.16 | 68 | 68 | 13.0 | 3.7 | 1.3 | 0.6 | 0.12 | 17.0 | 17.0 | 4.2 | 0.8 | 0.35 | 0.1 | 0.0 |
| 20 | 76.1 | 3.78 | 75 | 75 | 18.5 | 6.0 | 3.6 | 0.8 | 0.40 | 20.0 | 19.0 | 4.5 | 1.6 | 0.9 | 0.3 | 0.0 |
| 21 | 92.4 | 2.45 | 72 | 72 | 14.0 | 3.8 | 1.6 | 0.6 | 0.15 | 17.0 | 17.0 | 3.3 | 1.2 | 0.41 | 0.1 | 0.0 |
| 22 | 79.0 | 4.20 | 74 | 74 | 19.0 | 6.0 | 3.4 | 0.9 | 0.46 | 18.0 | 18.0 | 4.5 | 1.5 | 0.9 | 0.2 | 0.1 |
| 23 | 64.8 | 1.05 | 73 | 73 | 23.0 | 7.5 | 3.0 | 1.2 | 0.80 | 18.0 | 18.0 | 6.0 | 1.7 | 0.6 | 0.3 | 0.2 |
| 24 | 89.0 | 1.49 | 78 | 78 | 15.0 | 7.5 | 3.9 | 1.6 | 0.90 | 18.0 | 16.0 | 3.3 | 1.8 | 0.7 | 0.3 | 0.1 |
| 25 | 145.0 | 0.95 | 72 | 72 | 21.0 | 13.0 | 4.6 | 0.5 | 0.22 | 24.0 | 24.0 | 4.6 | 2.7 | 1.1 | 0.4 | 0.0 |
| 26 | 72.5 | 0.66 | 75 | 75 | 11.0 | 3.3 | 1.2 | 0.4 | 0.24 | 18.0 | 18.0 | 3.7 | 1.2 | 0.3 | 0.1 | 0.0 |
| 27 | 33.0 | 14.30 | 72 | 72 | 28.0 | 18.0 | 9.0 | 2.8 | 0.40 | 16.0 | 16.0 | 8.0 | 3.8 | 2.0 | 0.4 | 0.2 |
| 28 | 117.0 | 0.39 | 78 | 78 | 24.0 | 7.0 | 4.1 | 0.3 | 0.12 | 16.0 | 16.0 | 6.0 | 1.6 | 1.2 | 0.3 | 0.0 |
| 29 | 48.7 | 3.76 | 78 | 78 | 17.0 | 6.0 | 3.2 | 0.8 | 0.20 | 21.0 | 21.0 | 5.0 | 1.7 | 0.8 | 0.3 | 0.0 |
| 30 | 54.7 | 6.00 | 72 | 72 | 20.0 | 6.5 | 3.2 | 1.3 | 0.38 | 16.0 | 16.0 | 4.2 | 1.6 | 0.7 | 0.2 | 0.0 |
| 31 | 16.0 | 37.77 | 75 | 74 | 40.0 | 30.0 | 30.0 | 9.5 | 5.00 | 19.0 | 18.0 | 10.0 | 8.0 | 8.0 | 5.2 | 1.4 |
| 32 | 129.0 | 4.20 | 72 | 71 | 17.0 | 6.0 | 3.1 | 0.9 | 0.40 | 15.0 | 15.0 | 3.6 | 1.1 | 0.7 | 0.2 | 0.0 |
| 33 | 72.7 | 7.60 | 72 | 72 | 19.0 | 10.0 | 5.2 | 1.9 | 0.90 | 19.0 | 18.0 | 4.1 | 2.3 | 1.2 | 0.5 | 0.2 |
| 34 | 42.0 | 14.19 | 76 | 75 | 23.0 | 9.0 | 3.3 | 1.4 | 0.45 | 18.0 | 18.0 | 6.0 | 1.8 | 1.2 | 0.4 | 0.2 |
| 35 | 162.0 | 10.07 | 89 | 89 | 30.0 | 9.0 | 4.4 | 1.6 | 0.35 | 20.0 | 19.0 | 7.0 | 2.1 | 1.2 | 0.2 | 0.1 |
| 36 | 94.4 | 1.40 | 88 | 87 | 29.0 | 8.5 | 4.3 | 1.1 | 0.30 | 19.0 | 19.0 | 7.0 | 2.4 | 1.0 | 0.4 | 0.0 |
| 37 | 44.6 | 15.79 | 83 | 76 | 29.0 | 13 | 5.9 | 1.8 | 0.30 | 22.0 | 22.0 | 7.0 | 3.5 | 1.4 | 0.5 | 0.0 |
| 38 | 96.8 | 1.57 | 80 | 76 | 32.0 | 6.0 | 2.9 | 0.6 | 0.30 | 21.0 | 21.0 | 9.0 | 1.9 | 0.9 | 0.3 | 0.0 |
| 39 | 72.9 | 1.00 | 85 | 82 | 15.0 | 6.0 | 2.7 | 0.9 | 0.20 | 21.0 | 21.0 | 4.5 | 2.2 | 0.8 | 0.2 | 0.0 |
| 40 | 64.9 | 0.24 | 49 | 43 | 10.5 | 4.1 | 1.5 | 0.4 | 0.20 | 12.0 | 11.0 | 3.4 | 1.4 | 0.5 | 0.1 | 0.0 |
| 41 | 70.0 | 0.19 | 86 | 86 | 38.0 | 6.0 | 2.1 | 0.5 | 0.16 | 20.0 | 20.0 | 9.0 | 1.5 | 0.6 | 0.2 | 0.0 |
| 42 | 85.8 | 0.20 | 45 | 45 | 6.5 | 1.6 | 1.0 | 0.3 | 0.06 | 11.0 | 9.0 | 2.0 | 0.4 | 0.2 | 0.1 | 0.0 |
| 43 | 124.0 | 1.08 | 96 | 96 | 13.0 | 3.2 | 1.1 | 0.4 | 0.05 | 23.0 | 23.0 | 3.6 | 1.1 | 0.3 | 0.0 | 0.0 |
| 44 | 98.6 | 0.38 | 71 | 71 | 12.0 | 10 | 5.0 | 0.4 | 0.10 | 19.0 | 19.0 | 7.0 | 6.0 | 3.0 | 0.9 | 0.0 |
| Median ±SD | 81.74 ±41.98 | 6.39 ±8.42 | 67.2 ±15.02 | 66.59 ±14.95 | 19.76 ±8.74 | 7.92 ±4.87 | 4.14 ±4.35 | 1.23 ±1.40 | 0.45 ±0.74 | 16.26 ±3.80 | 16.01 ±3.88 | 4.94 ±1.99 | 2.02 ±1.32 | 1.08 ±1.18 | 0.40 ±0.76 | 0.07 ±0.21 |

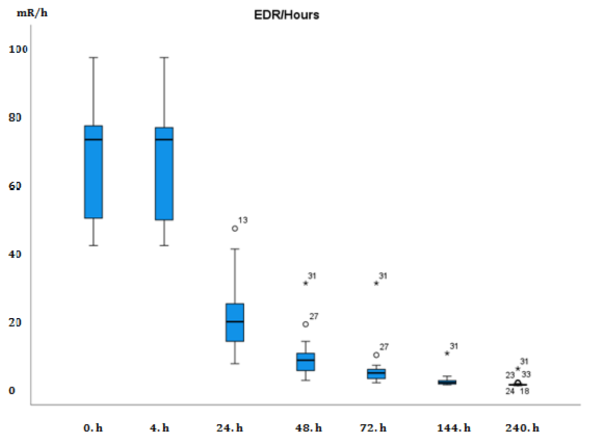


**Figure 2:** Distribution of patients' decrease in external dose rates (EDR) in milliroentgen per hour (mR/h) at 30 cm.

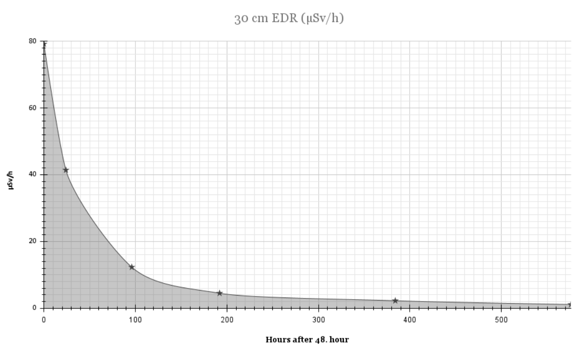


**Figure 3:** Cumulative companion dose measured using the external dose rates (EDR) for the period of 48-240 h post-treatment at a distance of 30 cm from the patient in microsieverts per hour (μSv/h).

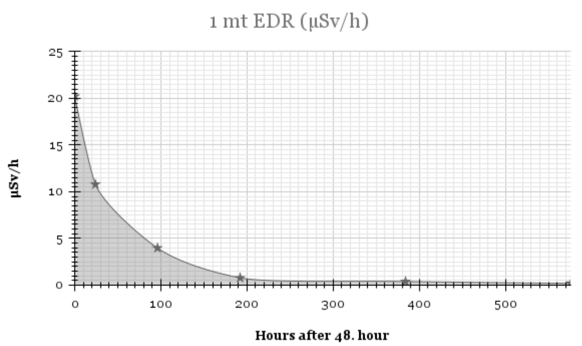


**Figure 4:** Cumulative companion dose measured using the external dose rates (EDR) for the period of 48-240 h post-treatment at a distance of one m from the patient in microsieverts per hour (μSv/h).

1.62 mSv of radiation. This dose exceeded the permissible exposure limit for the public (an average of 1 mSv over 5 consecutive years) (20).

Scenario 2: The calculations were performed using the average EDR measured 30 cm away from patients receiving treatment. According to these calculations, a person who spends all eight hours a day in a bed 30 cm away next to the same 10 cm concrete wall will be exposed to approximately 1.29 mSv of radiation. The exposure dose may vary depending on the construction material of the wall separating the beds. If the wall is made of brick, the exposure dose will be higher than 1.29 mSv.

Scenario 3: According to Scenario 3, even if the two beds in the same room are assumed to have 50 cm between them, the distance between the patient and the person being exposed is approximately one meter due to their position in the center of the bed. Therefore, calculations were made based on the average EDR measured at a distance of one meter from patients undergoing treatment. According to the calculations, a person who spends a total of eight hours in a separate bed in the same room as the patient would be exposed to approximately 0.4 mSv of radiation.

## DISCUSSION

$^{131}$I ablation therapy is a proven and commonly administered treatment for thyroid cancers. Due to the high gamma energy of $^{131}$I, patients who receive this treatment can be a significant source of radiation exposure to people nearby. Patients are typically kept in the hospital until the radioactivity in their body falls to a safe threshold as defined by national guidelines. However, even after discharge, external radiation emissions continue until the radioactive substance is fully depleted from the body, thus presenting a risk to individuals close to the patient.

This study found 91% (n=41) of the patients who'd received treatment to have reduced their radiation levels to below the discharge threshold (30 μSv/h or 3 mR/h) by the 48$^{th}$ hour. For those patients whose measurements were above 3 mR/h at the 48-hour mark, three were noted to have had high iodine uptake values at 24 hours because of remnant thyroid tissue and the third patient to have distant metastasis.

A notable correlation emerged between the treatment dose administered to a patient and the measurements recorded at 0, 4, and 24 h ($p<0.05$). However, no correlation was detected regarding the measurements taken at 48, 72, 144, or 240 h. The median EDR values obtained following the administration of 3.7 GBq, 5.55 GBq, and 7.4 GBq of $^{131}$I at a distance of 30 cm were respectively 6.38 mR/h (±3.51), 10.96 mR/h (±5.75), and 8.5 mR/h (±2.87).

Notably, the association between the administered dose and the subsequent measurements deteriorated with time, particularly at 48 h and beyond. These findings suggest the physiological excretion of $^{131}$I to occur within the initial 48 h post-administration, with any remaining activity likely sequestered within residual tissue or metastatic sites.

When looking at the EDR measurements regarding the activity of patients who've received ablation therapy, the following observations are made: at 72 h post-treatment, the average EDR measurements at 30 cm was 3.04 mR/h for patients who received 3.7 GBq, 5.21 mR/h for those who'd received 5.55 GBq, and 4.04 mR/h for those who'd received 7.4 GBq. At 240 h (10 d) post-treatment, the average EDR measurements at 30 cm for these same groups were found to be 0.3 mR/h, 0.631 mR/h, and 0.29 mR/h, respectively. Based on these results, no direct relationship has been concluded to exist between the dose administered to the patient and the EDR measurements after 48 h. This suggests that factors other than just the administered dose may influence the radiation exposure levels measured from patients different times post-treatment.

When looking at the iodine uptake values at 24 h compared to the EDR measurements, no correlation was observed to be present in the measurements taken at 0, 4, and 24 h, while correlations with EDR measurements were found for uptake values at 48, 72, 144, and 240 h ($p<0.05$). After the physiological excretion had completed, the activity is thought to remain solely in remnant tissue. When considering these findings, companions of patients with higher 24-hour uptake values were observed to have increased radiation exposure post-discharge. In light of these results, patients with high 24-hour iodine uptake values should pay more attention to isolation rules after discharge.

Because of high $^{131}$I uptake value of 31th patient (24-hour $^{131}$I uptake value of 37.77%), patient number 31 had a 144 h post-treatment EDR measurement of 9.5 mR/h at a distance of 30 cm and a 240 h post-treatment EDR measurement of 5 mR/h at a distance of 0.3 meters.

Bhatia et al.'s study with 32 patients conducted EDR measurements following the administration of radioiodine therapy for ablating remnant tissue after a total thyroidectomy (16). The average EDR measurements taken 1 m away from the patients were 0.16 mR/h/mCi at 0 h, 0.13 mR/h/mCi at 1 h, and 0.11 mR/h/mCi at 2 h. These findings are consistent with the 0-hour EDR measurements in the current study. Moreover, Bhatia et al. also simultaneously measured EDRs at 5 cm away from the skin at the neck and stomach levels. They observed the stomach level EDRs to be higher during the first hour, with neck-level EDRs increasing and stomach EDRs decreasing in the second hour. This indicates the residual tissues in the patients to have quickly absorbed the radioactivity and the physiological excretion to also occur rapidly. Although this study provided important information about the physiology in the early post-treatment period, it did not provide any long-term EDR details.

Zhang et al.'s study with 70 patients took EDR measurements while patients were seated at distances of 1, 1.5, 2, and 2.5 m over 72 h (18). The study found a majority of the physiological excretion to finish within the first 48 h and also noted excretion rates to occur faster in subsequent treatments. This aspect aligns with the initial hour EDR measurements in the current study. However, Zhang et al.'s study did not include close-range measurements or assess the radiation exposure risks associated with close physical contact.

The outcomes of the scenarios indicated radiation exposure levels to exceed the permissible public dose limit in Scenarios 1 and 2 while falling below this threshold in Scenario 3. $^{131}$I has high gamma energy, and although the building material of the wall between patient and companion in S2 reduces the dose from 1.62 mSv to 1.29 mSv, this value is higher than the annual maximum allowable dose limit for the public (1 mSv/year). As can be understood from the descending graph, radioactivity in a patient's body fully diminishes by 240 h post-treatment. Hence, ensuring patients' compliance with isolation protocols for a minimum of 10 days is imperative. $^{131}$I is also known to be excreted through the respiratory system. Even if the exposure to external radiation is below the permissible dose when sharing the same room with a patient, the risk of internal radiation exposure through inhalation is still present. Internal radiation is a significant concern for individuals. Numerous studies have demonstrated the internal exposure following $^{131}$I treatment due to the exhalation of patients treated with $^{131}$I to result in the presence of $^{131}$I in the environment. When considering both external and internal exposure, adherence to radiation safety guidelines becomes even more crucial for patients who undergo $^{131}$I treatment. Therefore, patients receiving $^{131}$I treatment should be thoroughly educated about the importance of post-treatment radiation protection and the specific conditions to be observed during isolation.

## CONCLUSION

The companions of patients who receive $^{131}$I treatment may be exposed to an external dose of over 1 mSv if the patients do not comply with isolation rules. Even in cases where the patient and companion sleep in separate rooms, maintaining a safe distance between the beds remains imperative. Consequently, giving these patients comprehensive information about the importance of protection from radiation after treatment and about the precautions to be taken during isolation is crucial.

**Ethics Committee Approval:** The study has ethical approval from the İstanbul University, İstanbul Faculty of Medicine Clinical Research Ethics Committee (Date: 15.12.2023, No: 25).

**Informed Consent:** Written informed consent was obtained from patients who participated in this study.

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