Review of the radiological protection discharge protocol used in the treatment of thyroid cancer in the Virgen del Rocío University Hospitals

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Abstract. The Radiophysical Service of the Virgen del Rocío University Hospitals, Seville, has established a protocol for the radioprotection of families and other members of the public after the treatment of cancer of the thyroid with I-131. The patient remains in hospital for 2 days in a room specially prepared for them, independent of the activity that has been administered, and on discharge is given written guidelines that must be followed for a period of a week, or 10 days, depending on the value of the dose rate at 1m on discharge. The objective of this paper is to carry out a review of this protocol, allowing the incorporation of new radiological discharge criteria and simplifying the rules for the patients to follow. It is intended to relate the period of hospitalisation to specific patient parameters, such as the activity received, his/her metabolism and his/her social, professional and family situation. It is, then, intended to personalise the time of the hospital stay, as well as follow-up advice, with the objective of improving health care, to have a better knowledge and control of the risks of exposure to third parties and to enable a possible increase in the number of patients treated.

1. Introduction.

The European Commission document entitled “Radiological Protection after therapy with I-131” (1) proposes dose limits for people voluntarily exposed to ionising radiation as a consequence of caring for a patient, as set out in Table I. For third parties who do not look after patients who could be exposed to radiation coming from them, the quoted dose restrictions or dose limits do not apply. This document establishes that the level reached must be less than an accumulated dose of 1mSv per year, because of other sources of exposure, and proposes a fractional value of 0.3 mSv.

Table I. Dose restrictions for relatives and people close-by

<table>
<thead>
<tr>
<th>Group</th>
<th>Dose Restriction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Children (including unborn)</td>
<td>1 mSv</td>
</tr>
<tr>
<td>Adults up to 60 years</td>
<td>3 mSv</td>
</tr>
<tr>
<td>Adults older than 60 years</td>
<td>15 mSv</td>
</tr>
</tbody>
</table>

In this study we intend to calculate, by measuring the dose rates at 1m at successive time intervals after radioisotope administration until the patient leaves the hospital, the accumulated doses up to the decay of the radioisotope. From this, it is hoped to establish the time when the patient can be discharged, taking into account that from the administration to total decay of the accumulated dose must be less than the established dose limit of 1 mSv. Also by calculating the accumulated dose at different times from the administration of the isotope and considering the family and professional circumstances we can pay attention to other particular aspects of the patient where possible, for example, the time that should pass before returning to work.

The possibility of less restrictive criteria for discharging a patient is supported by work done by Barrington et al (2) who established that patients receiving radioiodine to ablate the thyroid after surgery could travel in a private car for 8 hours on the day of treatment and 20.5 hours the following day, should remain off work for 3 days, sleep apart for 16 days and contact with children according to their age, ranging from 16 days for younger children and 10 days for older children (for an administered activity of 1850 MBq) and patients receiving treatments for recurrent disease could travel in a private car for 8 hours on the day of treatment and 20.5 hours the following day, should remain off work for 1 day, sleep apart for 3 days and contact with children according to their age, ranging from 4 days for younger children and 3 days for older children (for an administered activity of 1850 MBq); or Grigsby et al (3) who measured the dose received by families of patients treated with I-131 for 10 days after the administration of the
isotope and the immediate discharge of the patient, finding that the doses received varied between 0.02 mSv and 1.11 mSv; or Bererhi et al (4) who carried out the same study for 7 days on 70 patients, finding that only one of them was over the dose limit of 1 mSv or Venencia y cols (5) who studied 14 patients treated postoperatively with I-131, found that the maximum restriction time was just 1.22 days when occupancy factor was 1 and the dose limit adopted was 1 mSv.


Measurements of the dose rate were taken at distances of 1m in 10 hospitalised patients who received I-131 with activities is ranging between 2960 and 6216 MBq.

The dose rate was measured with a previously calibrated VICTOREEN pressurised ionisation chamber, model 450-P.

Before admitting the patient, the background of the ward room was measured. After the patient received the radio isotope, measurements of the dose rate were made at successive hours during the time the patient was in hospital, the first of which was approximately 3 h after the iodine was administrates to the patient. The geometry used was, the patient standing, with marks on the floor to make the measurements and marks on the wall for placing the chamber, located opposite the abdominal region, which is where the hottest point was located. A few days after discharge, we made the last patient measurement, coinciding with the appointment for the medical check-up.

3. Results

We modelled the progression of the dose rate using a decreasing exponential proportional to the activity. The proportionality constant was the dose factor, DF, which relates the spatial distribution of the activity with the dose rate at a certain distance from it. For the dose rate we have:

\[ D'(t) \propto \exp \left( -0.693 \frac{t}{T_{\text{effect}}} \right) \]

which we adjust to:

\[ D'(t) = B \cdot \exp \left( -0.693 \frac{t}{T_{\text{effect}}} \right) \]

where B is the product factor of the dose and the initial activity at the distance considered and T_{\text{effect}} is the period of effective elimination.

We distinguish the dose rate decay for patients receive radioiodine to ablative the thyroid after surgery (group 1) and dose rate for patients receiving subsequent treatments for recurrent disease (group 2). FIG.1. and FIG.2. show an example of both groups.

**FIG.1. The dose rate decay for group 1.**

**FIG.2. The dose rate decay for group 2.**
If dose rate decay is monoexponential for group 2, with the last measurements dose rate has decayed, but we obtained a small dose rate greater than background.

For group 2, if we adjust the data obtained for the first measurements and the last measurements obtained separately and we represent jointly, we are left with FIG. 3, where it is seen that the isotope is eliminated in two periods, one rapid, in the first hours and another slower, in the following hours until decay. The rapid period is for kidney and the slow period is for metabolic products from thyroid origin. The superimposition of both is shown in FIG.4:

![FIG.3. Decay of the dose rate at 1 m in patient 3 (6216 MBq)](image1)

![FIG.4. Result of superposition of both graphs.](image2)

In summary, we made the adjustment as two curves, and for calculating the dose we added the integral until the cut off point of the first curve with the integral of the second from that point until the isotope is decayed. We also calculated the dose accumulated between 24 and 48 hours, between 48 and 72 hours and between 72 hours and the decay, with the limits set out in Table 1, allowing us to define certain rules of behaviour in relation to the radiological protection of third parties.

For group 1, the process is similar but we adjust as three curves, the rapid period is for kidney, intermediate period is for thyroid (rest) and the slow period is for metabolic products from thyroid origin. FIG.5. shows graph for group 1.

![FIG.5. Graph for group 1.](image3)

The results we obtained, using point-source approximation, are in keeping with the conclusion of Sparks, Siegel and Wahl (6). These authors used the Monte Carlo method to find the relationship between the
dose equivalent per unit of activity measured, to take into account a point source and that of an anthropomorphic whole body model, assuming that the activity was localised in the abdominal region, and determined that the concept of point-source overestimates the dose rate by 61% at 1m in respect to that obtained by whole body calculation.

Analysing FIG. 6, we see that for patient 3 (6216 MBq), group 2, the elimination period changes between 28 and 30 hours. During this time interval the dose rate hardly changes, which is in total agreement with iodine metabolism, which in general consists of the elimination of iodine by the stomach (where almost all the administered dose is placed), from where some is excreted within a short period and some passes into the circulation, which after passing through the bloodstream arrives once more at the thyroid where it is eliminated slowly.

At approximately 246 hours, the isotope at 1m distance has decayed. The dose accumulated from the first measurement, at 3 hours 57 min, until 24 hours is 2.325 mSv and from 24 hours until decay is 1.86 mSv. The results fully concur with the metabolism of iodine in the treatment of cancer of the thyroid in which the major part of the activity is excreted in the first 24 hours. At approximately 42 hours from the administration of the isotope, the accumulated dose until decay is less than 1 mSv. The accumulated dose is 0.937 mSv between 24 hours and 48 hours, 0.455m Sv, between 48 hours and 72 hours and 0.468 mSv between 72 hours until decay.

With the last measurement taken on patient 3 at 141.67 hours after the administration of the radioiodine, we show that although the dose rate at 1 m, although small, it is greater than background. It coincides with results we have obtained. FIG.7. shows that the last measurement adjusts so well to graphic representation which is obtained with the last measurements before hospital discharge of patients.
For patient 8 (3700 MBq), group 1, the first period changes between 13 hours and 14 hours after administration of the radioisotope, the second period changes between 23 hours and 24 hours decaying at 1m at around 141 hours. The accumulated dose at 1m from the first measurement, 3 hours and 22 minutes after administration, until 24 hours is 1.367 mSv and from 24 hours until it decays it is 0.768 mSv. The time from administration until the accumulated dose is less than 1 mSv is around 19 hours. Therefore this patient may be discharged 24 hours after administration and could even limit his stay to several hours taking in to account the discharge regulations to ensure the radiological protection of third parties, since all these measurements are calculated for an occupation factor of 1. In this patient the last measurement was made at 117 hours and 02 minutes, giving a small dose rate but no background, which agreed with our predictions since the necessary time had not passed for the decay of the dose rate at 1m.

The data for the remaining patients are shown in Table II for 1m. In all cases, the time of calculated decay was checked by measurements days after discharge, at the first medical check-up of the patient.

<table>
<thead>
<tr>
<th>Patient</th>
<th>Activity (MBq)</th>
<th>Time of administration-1st measurement</th>
<th>Dose 1st measurement-24 h (mSv)</th>
<th>Dose 24h-48 h (mSv)</th>
<th>Dose 48h-72 h (mSv)</th>
<th>Dose 72 h-decay (mSv)</th>
<th>Decay Time (h)</th>
<th>Time dose&lt;1 mSv (h)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Patient 1</td>
<td>3700</td>
<td>3 h 22 min</td>
<td>1.285</td>
<td>0.460</td>
<td>0.239</td>
<td>0.288</td>
<td>245</td>
<td>24</td>
</tr>
<tr>
<td>Patient 2</td>
<td>5920</td>
<td>3 h 07 min</td>
<td>2.730</td>
<td>1.247</td>
<td>0.668</td>
<td>0.710</td>
<td>276</td>
<td>60</td>
</tr>
<tr>
<td>Patient 3</td>
<td>6216</td>
<td>3 h 57 min</td>
<td>2.335</td>
<td>0.937</td>
<td>0.455</td>
<td>0.468</td>
<td>246</td>
<td>42</td>
</tr>
<tr>
<td>Patient 4</td>
<td>3700</td>
<td>3 h 57 min</td>
<td>1.350</td>
<td>0.461</td>
<td>0.176</td>
<td>0.106</td>
<td>166</td>
<td>18</td>
</tr>
<tr>
<td>Patient 5</td>
<td>3700</td>
<td>3 h 27 min</td>
<td>0.936</td>
<td>0.321</td>
<td>0.101</td>
<td>0.043</td>
<td>136</td>
<td>9</td>
</tr>
<tr>
<td>Patient 6</td>
<td>5180</td>
<td>3 h 24 min</td>
<td>2.215</td>
<td>0.779</td>
<td>0.240</td>
<td>0.068</td>
<td>108</td>
<td>26</td>
</tr>
<tr>
<td>Patient 7</td>
<td>2960</td>
<td>3 h 06 min</td>
<td>1.399</td>
<td>0.442</td>
<td>0.218</td>
<td>0.217</td>
<td>199</td>
<td>21</td>
</tr>
<tr>
<td>Patient 8</td>
<td>3700</td>
<td>3h 22 min</td>
<td>1.367</td>
<td>0.551</td>
<td>0.154</td>
<td>0.063</td>
<td>141</td>
<td>19</td>
</tr>
<tr>
<td>Patient 9</td>
<td>4440</td>
<td>2h 59 min</td>
<td>1.149</td>
<td>0.416</td>
<td>0.125</td>
<td>0.053</td>
<td>140</td>
<td>15</td>
</tr>
<tr>
<td>Patient 10</td>
<td>3700</td>
<td>3h 17 min</td>
<td>1.177</td>
<td>0.547</td>
<td>0.251</td>
<td>0.207</td>
<td>201</td>
<td>24</td>
</tr>
</tbody>
</table>

Conclusions.

The first results of a review initiated at the University Hospital Virgen del Rocio are presented. Although the number of patients treated in the hospital is more than 2000, we have only used 10 in our study, since to obtain confidence in what we have proposed it has been necessary to establish a strict measurement protocol, whose rigorous requirements do not exceed the measurements stored in our data base. Therefore, these first conclusions have not been considered as definitive. However, it seems clear that an estimation of the dose from a sufficient number of measurements carried out in the first hours after the dose allows us to calculate the accumulated dose in the first 24 hours and that in all cases it is more than 50 % of that accumulated from this time until decay. Also it points out that hospitalisation for 48 hours is obligatory for patients with higher activities, whilst those who were administrated activities of 3700 MBq could be discharged after one night in hospital or even on the same day following the appropriate rules.
References.

1. European Guide “Radiation Protection following iodine-131 therapy (exposures due to outpatient or discharge in patients)”. Radiation Protection 97.