Regarding Care Giving Family Members Stray Radiation Exposures from Discharged Patients after Administration of Large Dose Therapeutic Radioactive Iodine in Differentiated Carcinoma Thyroid

Introduction

An interesting article is published[1] on the measured radiation exposures by the care givers to discharged cancer thyroid-treated patients after administration of high doses of Iodine-131. In the Paper introduction, 5 mSv (500 mRem) is wrongly printed as 5 mSv/h (500 mRem/h), 0.05 mSv/h (50 mRem/h) misleading the readers. The authors estimated whole body doses to care givers of 22 discharged cancer thyroid patients who received radioactive I-131 3.79 ± 1.07 GBq (range 1.85–5.55 [50–150 mCi]).

The authors[1] gave lockets containing calibrated lithium fluoride (LiF: Mg, Ti). Mean doses received by caregivers from the discharged patients was 14.60 ± 3.43 mSv (range [9.73–24.25 mSv (973 mR to 2425 mR)]). The 1 m exposure rates at the time of discharge from isolation wards were 28 ± 15 µSv/h (2.8 ± 1.5 mR/h). Calibration details with gamma radiations of what energy were not mentioned in their methods. As I-131 has beta component and gammas, the energy sensitivity without proper filters needs confirmation. Authors highlight that most critical factors may be long duration of the journey when caregiver is in close contact, stay in single rooms, toilets/washing areas.

With a logic that even if 5 mRem/h exposure rate prevails with discharged patients, and no decrease in exposure rate occurs with the patient, for 7 days (168 h), the 1 m cumulated stray radiation dose to caregiver with 100% occupancy at 1 m cannot come >840 mRem (8.4 mSv). If decay of exposure rate for the discharged patient occurs, then it cannot exceed >500 mRem (5 mSv) even proximity distance is reduced. Therefore, we attempted to explain the reality of encountered situation with exposure to stray radiations for caregivers, based on international/national stipulations and our own data.

In this published script,[1] the American Thyroid Association 2011 recommendations was cited,[2] which is based on patient specific calculation of 0.17 mRem/h/mCi, yielding patient discharge with activities administered as high as 1110 MBq (50 mCi) for hyperthyroidism and 7400 MBq (200 mCi) for thyroid cancer. Another stipulation stated that patient could be released when the total dose effective equivalent (TEDE) in mRem of mSv does not exceed 500 mRem (5 mSv). Furthermore, if the TEDE to any person exceeds >100 mRem (1 mSv), then written and verbal instructions to caregivers to be provided. These stipulations are based on the living conditions of residents in countries like USA.

IAEA Recommendations 2009[3] mentions with proper explanation that, public dose limit in special circumstances, a higher value of effective dose could be allowed in a single year, provided that the average over 5 years does not exceed 1 mSv/annum. Further, the Basic Safety Standards on medical exposures explains that a “Comforter or Visitor of patients shall be constrained so that it is unlikely that his or her dose will exceed 5 mSv during the patient’s treatment. With the available data in literature and in the light of existing international guidelines a brief review of work practices for many years in many institutions in India and abroad, a brief communication is presented.[1]

In Oman, most of the thyroid cancer patients have living conditions in houses in much similar to our Indian Villages in the periphery to metropolitan cities. Thyroid cancer treatments were started in Oman in the Royal Hospital at 2006, as thyroid cancers form second leading cancer in female population following the breast cancer. As a conservative approach, from 2006 to 2019 in Oman, we followed a stipulation of 10 µSv/h (1 mR/h) for patient’s discharge for thyroid cancer high-dose radioactive treatments. From the year 2020, this protocol is modified to 25 µSv/h (2.5 mR/h) as discharge limits. We increased discharge limit due to long waiting list and now we treat 4 patients/week on Mondays and Thursdays scheduling. All thyro-Toxicosis/Grave’s disease patients received treatments with 555 MBq (15 mCi) as outpatients for long time. However, they also received I-131 administration if they are from poor socioeconomic conditions or illiterate. 50 µSv/h (5 mR/h) is widely practiced as discharge limits for well-differentiated thyroid cancer treatments as per recommendations by many national regulatory authorities, including India. We are in the process of establishing radio-isotope therapy facilities in the remote northeastern part of India at Silchar, Assam; where the living conditions in families may be similar to Oman. Hence, there is a need to re-look at past values of patient’s release conditions, for discharge stipulations in the light of American Thyroid Association Recommendations.[2] Clear understanding of health physics aspects based on the therapeutic use of I-131 over 8 decades will answer the question objectively to corroborate the experience to present problem.[1] This also will substantiate the existing international/national recommendations about statutory stipulations on hospitalization, monitoring, discharge of patients, and prevailing public dose at large, which covers relatives/caregivers of discharged patients at home.
Retention of Radioactive Body Burden during Hospitalization and Time of Discharge

The authors’ experience in the past four decades,[5-8] and a few references[9,10] are brought into highlight the background on which “safe release of patients” depended on. During first 72 h postadministration, a tri-exponential pattern was confirmed in 23 patients,[2] with administered activities of 1-131 ranging from 1.67 to 7.96 GBq (45-215 mCi). The effective half-lives of clearance were 11.20 h, 11.89 h, and 15.4 h, respectively, during these patients’ stay in isolation. These values agreed well with Barrington et al[8] highlighted later[6]

Another large series of Omani patients in the treatments (years 2006–2009) clearly brought out[7] two clearance patterns, with hyperthyroid and cancer thyroid patients. Thyrotoxicosis administered doses ranged from 479 to 627 MBq (574 ± 27.3 n = 50) and measured exposure rates at 1 m from 0 to 72 h were highlighted. For cancer thyroid, the administered doses ranged from 2.04 to 9.3GBq (4.363 ± 1.170 GBq), with measured exposure rates 0 h to 120 h. These patients were only from hypothyroid state with hormone support withdrawal, before high-dose administration. During period 2010–2012, after introduction of application of recombinant thyroid-simulating hormone (rhTSH), there was a documentation of comparison of clearance of body burden in rhTSH group vis-à-vis thyroid hormone withdrawal group (THW).[9] 44 treatments were from rhTSH group, and 162 treatments were from THW group (in n = 22 rhTSH and n = 81 for stop thyroxine). Administered activities of I-131 were 5.11 ± 1.40GBq (rhTSH, n = 22) and 4.24 ± 0.95GBq (THW n = 81) and the activities uses were in the range of 2.6–7.9GBq.

In addition to radioactive body burden, for estimation of blood and bone-marrow doses in the treated patients, we felt the need for documenting residual activities in whole body at the time of discharge.

We standardized External “opposed conjugate counting method using a calibrated thyroid uptake probe” for whole-body estimates of residual radioactivity in large number of treated patients. This revealed different “retention factors estimates” in the whole body by “exposure rate method” and “whole body counting method.” By exposure rate method, retention factors in the rhTSH group were 0.089 ± 0.06 (n = 24) and 0.05 ± 0.05 (n = 19) at 48 h and 72 h, respectively. These values for THW group were 0.148 ± 0.12 (n = 211) and 0.07 ± 0.08 (n = 68) at 48 h and 72 h, respectively. By “probe counting method,” the respective values At 48h were 0.045±0.04 for rhTSH and 0.081 ± 0.013 for THW. At 72h, 0.06±0.05 for rhTSH and 0.038±0.024 for THW respectively.

The quantified actual residual I-131 body burden in whole body was only 44–286 MBq (1.2–7.7 mCi) for rhTSH group (Euthyroid) and 290–315MBq (7.8–8.5 mCi) for THW group (hypothyroid), respectively.

The whole-body clearance pattern is clearly established with T_{eff} 14.4 h, 22 h, and 41.3 h for THW large series in 2006–2009 in cancer thyroid patients population.[7] Delayed clearance, due to healthy toxic thyroid patients, showed T_{eff} 111.4 h, which was in the same magnitude of T_{eff} = 5.5 days (132 h) in normal thyroid subjects. Another study[8] in comparing THW and rhTSH patients[9] showed striking results of initial clearance T_{eff} = 12 h and 16.5 h in rhTSH patients and THW patients, respectively. When we compare late clearance, the T_{eff} was 47 h and 27 h, respectively, for rhTSH patients and THW patients. Our own studies using blood dose estimates from whole-body counting[9] clearly brought out another important behavior of humans that body retention does not have correlation to the “administered dose GBq of I-131,” showing that discharging patients on the 2nd day and 3rd day had no relation to administered radioactivity strength. It was also concluded that mean residual activity <150MBq (4.05 mCi) for rhTSH group vis-à-vis about 200 MBq (5.5 mCi) for TSH patients. This fits well with 0.17 mRem/mCi thumb rule,[8,9] 200 MBq coinciding with about 0.9 mR/h, our discharge limits (1 mR/h at 1 m).

Exposure Rates Encountered from Treated cancer thyroid Patients

As there is a need to document the actual exposure rate, pattern encountered in large group of cancer thyroid patients (n = 69) treated in THW condition, with administered activities 2.04–9.3 GBq (4.363 ± 1.170 GBq) and hospitalized hyperthyroid patients (n = 50), with administered I-131 activities 479–627 MBq (574 ± 27.3 MBq). Initial 1 m exposure rates in cancer thyroid patients was 88.0 ± 37.6 µSv/h (range: 34–184 µSv/h; 3.4–18.4 mR/h), which decreased to 30.1 ± 21.6 µSv/h (at 24 h); 11.6 ±7.4µSv/h (at 48h); 6.3 ± 6.4 µSv/h (at 72 h); 4.2 ± 4.6 µSv/h (at 96 h); 2.6 ± 2.9 µSv/h (at 120 h).

This will clearly show that, at 24 h itself, an exposure rate at 1 m (30.1 ± 21.6 µSv/h) <50 µSv/h is achieved. From discussions of earlier paragraphs, if we assume an effective half-life of whole-body clearance T_{eff} = 24 h we do not make any error in generalizing the exposure rates arrived at, to the caregivers. Vide reference[2] recommendations, it was cited that an occupancy factor (OF) for caregivers at home, could be OF = 0.25 (day time restriction at 1 m as 1/4) and OF = 0.33 (night time restriction at 0.3 m as 1/3) as realistic.

The dose integrated with an initial activity at discharge with residual activity 200MBq (5.5 mCi) for 7 days for our criterion 10 µSv/h at discharge time (prevailing Oman situation) can be calculated using I-131 emission constant \( \Gamma = 7.467 \times 10^{-5} \text{mSv.m}^{-2} \text{MBq.h}^{-1} \) and total emitted dose relation using

\[
T_{\text{mean eff}} = T_{\text{eff}} / 0.693 = 1.44 T_{\text{eff}} \quad \text{and equation[1]}
\]

Total cumulated dose = \( \text{Activity} \times \Gamma \times (1.44 T_{\text{eff}}) \times \text{OF} \) (1)
By substituting a notional ‘Activity’ retention at discharge as 200 MBq (5.5 mCi)

Total Exposure Dose equivalent for caregiver = 200 MBq $\times 0.07467$ $\mu$Sv/h $\times 24$ h $\times$ OF (day + night).

$= 200 \times 0.07467 \times 24 \times (0.25 + 0.33) \\
= 200 \times 0.07467 \times 24 \times 0.58 = 207.9 \mu$Sv.

If we take $50 \mu$Sv/h as department protocol for discharge, then we could assume 5 times body burden residual activity which could be extrapolated as $5 \times 207.9 = 1040 \mu$Sv (1.04 mSv).

**Verified Kinetic Model in Local Circumstances**

There were two earlier publications$^{[10,11]}$ on the outpatient administrations of hyperthyroid treatments. In Oman, the caregiver doses were measured by TLD$^{[10]}$ (spouses and other relatives $n = 86$). There were 57 adults and 29 children. Quantity of administered I-131 activities as outpatients ranged from 520 to 862 MBq (610 ± 79 MBq); measured radiation levels were in the range of 13–42 $\mu$Sv/h (23.4 ± 6.3 $\mu$Sv). They reported 10 days estimated dose equivalents in the range of 7–425 $\mu$Sv (mean 105 ± 152 $\mu$Sv) for spouses and 0–2921 $\mu$Sv (mean 206 ± 440 $\mu$Sv). Because hyperthyroid patients are normal subjects, an assumption was earlier made$^{[12]}$ to take 2 m reference distance (applying restrictions) and applying use factors $1/4$ for 6 h/day, 1/12 for 2 h/day, and 1/24 for 1 h/day and explained a mean total cumulative dose equivalent of 685 $\mu$Sv. We could therefore justify, the Indian context in Delhi.$^{[11]}$ Pant et al.$^{[11]}$ reported slightly higher doses to family 0.4–2.4 mSv (mean: 1.10 mSv) for thyrotoxicosis patients’ study and 0–1.9 mSv (mean: 0.6 mSv) for thyroid cancer patients. Our present calculated kinetic model agreed well with earlier reported values from another premier institution in India.$^{[11]}$

**Expressed Conflict in the Recommendations on Present Script**

From the objective detailed discussions and kinetic models taking into effect of clearance of radioactive Iodine in human subjects, for an exposure rate of discharged patients at 1 m 28 ± 15 $\mu$Sv/h, the cumulated caregiver dose may correspond to only in the range of 312 $\mu$Sv to 894 $\mu$Sv only. However, the mean doses reported for caregivers in the recent work$^{[1]}$ are 14.60 ± 3.43 mSv (range [9.73–24.25 mSv (973 mR to 2425 mR)]). Therefore, there may be some systematic errors, either in detector response, or any possible beta contamination by caregivers by any of the patients’ sweat/urine etc., or these lockets could have been left in close proximity of patients. The authors’ highlighting critical factors may be of long duration of the journey when caregiver is in close contact, stay in single rooms, toilets/washing areas, do not explain the high doses estimated for care givers. The results need scientific scrutiny.

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**Conflicts of interest**

There are no conflicts of interest.

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