Total Effective Dose Equivalent to Caregivers from Hospitalized Patients Treated with High Dose Radioiodine for Thyroid Carcinoma

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Thyroid cancer patients treated with high-dose radioactive iodine (3.7-7.4 GBq) are different from other people because after the administration, the radionuclide I-131 is excreted via urine, feces, saliva and breathing, and also via exposure to other patients. Caregivers of the patient may receive higher radiation doses than normal. The purposes of this study were to estimate the total effective dose equivalent from internal and external exposure to caregivers of patients treated with high dose I-131 admitted at Siriraj Hospital, and to compare the estimated dose with the dose constraint of 5 mSv per annum for caregivers. Thirteen caregivers of 13 patients who underwent radioiodine therapy for thyroid cancers following a standard protocol were given specific instructions with regard to radiation safety and were attached to an electronic personal dosimeter and a personal air sampler pump continuously to measure received radiation dose on a daily basis over three days in the hospital. On discharge day, caregivers were asked to perform an in vivo bioassay by the thyroid uptake instrument. The results from the thirteen caregivers were divided into 3 groups. The total effective dose equivalent to caregivers of patients administered 3.7 GBq (n = 1), 5.55 GBq (n = 9), and 7.4 GBq (n = 3) were 0.159 mSv, 0.123 to 0.629 mSv, and 0.631 to 0.718 mSv, respectively. There values were well below 5 mSv per episode as proposed in the IAEA Safety Reports Series No. 63 and the ICRP Publication 103.

Keywords: *Total effective dose equivalent, Caregivers, Thyroid carcinoma, Dose constraint*

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The use of radioiodine in the treatment of functioning distant metastases has been well accepted and continued as a mainstay of therapy for thyroid cancer today. I-131 is supplied as solution and/or capsules of a specific activity designed to be swallowed by patients. A dose range between 100 to 200 mCi (3,700-74,000 MBq) is commonly used[1]. I-131 is not occurring naturally, it is a reactor-produced radionuclide. With a half-life of 8.04 days, iodine I-131 decays to Xe-131 with beta and gamma emissions. The principle gamma ray energy is 364 keV. I-131 is classified in a group of high radiotoxicity by IAEA[2].

Thyroid cancer patient undergoing high-dose radioiodine treatment is required by the regulations to remain in the hospital if any individual member of the public is likely to exceed a radiation dose of 1 mSv per year or in some cases, 5 mSv per year from the patient[3-5]. According to IAEA Basic Safety Standards 1996[6], thyroid carcinoma patients treated with I-131 higher than 1,100 MBq (30 mCi) are performed with patient admitted to the hospital until the remaining activity is less than 1,100 MBq (30 mCi).

On average, after drug administration, the patient is not allowed to leave the ward for 3 days. In some cases, member of the public may referred to as a caregiver who directly involved in the care of a bed ridden patient containing I-131. The role of caregivers often involves close contact with the patient, sometimes for prolonged periods of time, with the result that the radiation doses received may be much higher than the dose limit that would normally apply to members of the public. Potential radiation exposures from I-131 therapy mainly focus on external exposure and internal contamination from ingestion or absorption of a spilled radioiodine-containing waste, and inhalation of airborne I-131 exhaled by a patient. Doses to caregivers from radioiodine treated patients are predominantly the result of external exposure[5]. Minimizing time spent

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with the patient, and remaining at a distance will minimized radiation dose to any individual in association with a patient. Optimization of protection is to provide appropriate radiation safety instructions to ensure that dose to caregivers, comforters and carers is ALARA and not likely to exceed 5 mSv.

The United States Nuclear Regulatory Commission (US NRC)[3] and International Commission on Radiological Protection (ICRP) Publication 103[7] recommends a dose constraint for comforters and carers of 5 mSv per procedure. European Commission, Radiation Protection 97 set a numerical dose constraint of 3 mSv per episode[8].

The measurements of airborne I-131 contamination by air sample collection are necessary to ensure that inhalation of I-131 exhaled by the patient has been within the safety limits. This study collected inhaled air samples to determine an intake estimates and the committed effective dose equivalent (CEDE) to caregivers.

The purposes of this study were to measure the effective dose and the CEDE to caregiver of a patient treated with high dose I-131 at Siriraj Hospital to ensure that the total effective dose equivalent (TEDE) to caregivers meets the ALARA requirement and not likely to exceed 5 mSv.

Material and Method

A. Instrumentation and materials

1) Electronic personal dosimeter, ALOKA PDM-112.

2) Gilian BDX II Air Sampling Pump powered by rechargeable NiCd battery. Sensidyne Industrial Health & Safety Instrument.

3) Mobile Thyroid uptake system, Microprocessor-controlled 1024 channel Multi-Channel Analyzer with 2x2” NaI (Tl) detector, flat field collimator IAEA standard and a personal computer interface, and an incorporated well counter 2x2” NaI (Tl) detector. Model Biodex Medical Systems, Atomlab 950 PC.

4) Automatic gamma counter: Wallac 1480 Wizard, 3x3” NaI (Tl) crystal, Perkinelmer Life Sciences, Boston, MA, USA.

5) Carbon impregnated cellulose filters with 2.5 cm diameter, thickness 0.914 mm. Hi Q Environmental Products Company, Inc. San Diego, CA.

6) Certified I-131 standard source obtained from the Office of Atom for peace.

B. I-131 isolation ward

Radioiodine-131 isolation ward for patient admission is on the 9th floor of the 72nd Year’s Anniversary Building.

C. Selection of study population

Thirteen caregivers of 13 patients were divided into 3 groups. They were caregivers of patients administered 3.7 GBq (n = 1), 5.55 GBq (n = 9) and 7.4 GBq (n = 3) of I-131.

D. Monitoring procedure

In this study, caregivers are instructed to wear electronic personal dosimeter clipped to a belt. A personal air sampler pump inserted in a belt pocket and tube sampling with carbon impregnated filter clipped to a collaras shown in Fig. 1. The system operates at a constant flow rate of 3 litres per minute. The sampler runs continuously on daily basis, during three days in the hospital.

This study was approved by the Institutional Review Board of the Faculty of Medicine Siriraj Hospital (2012). All the patients and caregivers signed a written informed consent.

Results

A. External exposure

Thirteen caregivers (3 males and 10 females), age ranged from 40 to 65 years, of thyroid cancer patient were participated in the study. I-131 treatment doses

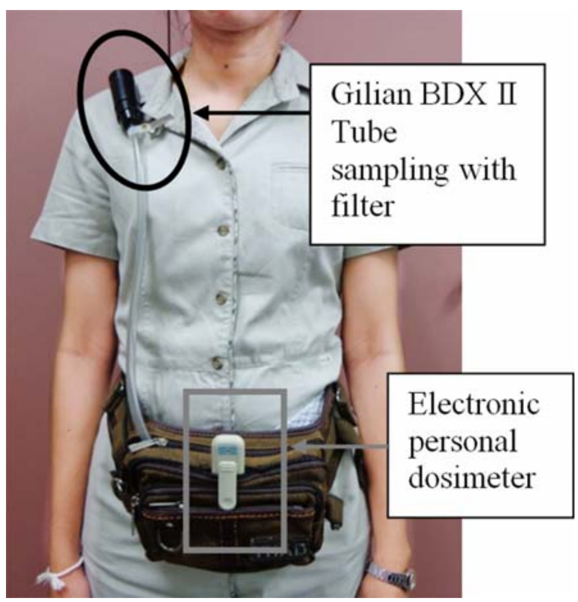

Fig. 1 Electronic digital dosimeter clipped to a belt, air sampler pump in a belt pocket and tube sampling clipped to a collar.

ranged from 3.7 to 7.4 GBq. All caregivers are provided with electronic personal dosimeter to continuously measure radiation dose received on the daily basis, during 3 days in the hospital.

Caregivers received an external dose ranged from 0.116 mSv to 0.696 mSv (n = 13) with a median of 0.247 mSv. A mean of 0.367±0.23 mSv accounted for approximately 7.3% of the 5 mSv numerical limit for caregivers, comforters or carers[5]. A 3-day accumulative dose from patients treated with 3.7 GBq (n = 1), 5.55 GBq (n = 9) and 7.4 GBq (n = 3) of I-131 were 0.123 mSv, 0.116 to 0.622 mSv and 0.623 to 0.696 mSv respectively (Table 1).

B. Committed effective dose equivalent (CEDE) from internal exposure

Committed effective dose equivalent (CEDE) from inhalation of airborne I-131 exhaled by a patient was shown in Table 2. The mean ± SD of the CEDE were 0.04 mSv, 0.03±0.02 mSv and 0.04±0.05 mSv for patient administered 3.7, 5.55 and 7.4 GBq of I-131 respectively.

C. Total effective dose equivalent (TEDE) to caregivers

Committed effective dose equivalent (CEDE) from internal exposure, external exposure and total effective dose equivalent (TEDE) to caregivers was summarized in Table 3. The TEDE of an individual caregiver is the combination of CEDE and the external dose.

Total effective dose equivalent (TEDE) to caregivers from patients administered 3.7 GBq (n = 1), 5.55 GBq (n = 9) and 7.4 GBq (n = 3) of I-131 ranged from 0.123 to 0.718 mSv.

Discussion

A. External exposure

On an out-patient basis of I-131 thyroid cancer treatment, there is a more space for caregivers to move around freely at home than in the hospital ward, Marriot et al[10] reported lower dose than our study. An average penetrating dose was as low as 98±64 m Svanda maximum dose of 0.283 mSv to family member of 26 patients administered 3.7 to 7.4 GBq of I-131. However, our result is in consistent with those reported by Grigsby et al[11], an average dose of 0.24 mSv with a range from 0.01 to 1.09 mSv.

Tonnonchiang S et al[12] reported a dose ranged by direct-reading dosimeter from 0.037 to 0.333 mSv and 0.176 to 1.920 mSv to caregivers of patients receiving 5.55 GBq (n = 11) and 7.4 GBq (n = 9). These are also in consistent with our result although the maximum dose was much higher (1.920 vs. 0.696 mSv) since most of the patients had received high dose of I-131 (5.55 to 7.4 GBq) and none received 3.7 GBq. Kiyoko K et al[13] reported a maximum effective dose of 0.43 mSv to caregivers after a treatment dose of 1,100 MBq.

Table 1. Radiation dose received from caring patient administered 3.7, 5.55 and 7.4 GBq therapeutic dose of I-131

Caregivers	Cumulative external dose to caregivers (mSv)		
	3.7 GBq	5.55 GBq	7.4 GBq
1	0.123	0.135	0.624
2		0.376	0.696
3		0.158	0.623
4		0.232	
5		0.116	
6		0.622	
7		0.238	
8		0.582	
9		0.247	
Mean	0.123	0.301	0.648
SD	-	0.188	0.042
Median	0.123	0.238	0.624
Min	0.123	0.116	0.623
Max	0.123	0.622	0.696
Overall mean	0.367±0.23		
Median	0.247		
Min-max	0.116-0.696		

Table 2. Committed effective dose equivalent (CEDE) from internal exposure by inhalation

	CEDE (mSv)		
	3.7 GBq	5.55 GBq	7.4 GBq
	0.04	0.04	0.01
		0.06	0.01
		0.02	0.09
		0.03	
		0.01	
		0.01	
		0.06	
		0.01	
		0.06	
Mean	0.04	0.03	0.04
SD	-	0.02	0.05
Min	0.04	0.01	0.01
Max	0.04	0.06	0.09

Table 3. Total effective dose equivalent (TEDE)

Case	Activity (GBq)	TEDE (mSv)		
		Internal dose, CEDE	External dose	TEDE
1	5.55	0.044	0.135	0.179
2	5.55	0.063	0.376	0.439
3	5.55	0.022	0.158	0.180
4	5.55	0.033	0.232	0.265
5	7.40	0.007	0.624	0.631
6	5.55	0.007	0.116	0.123
7	5.55	0.007	0.622	0.629
8	5.55	0.055	0.238	0.293
9	5.55	0.010	0.582	0.592
10	5.55	0.060	0.247	0.307
11	7.40	0.005	0.696	0.701
12	3.70	0.036	0.123	0.159
13	7.40	0.095	0.623	0.718
Mean		0.034	0.367	0.401
SD		0.028	0.227	0.225
Median		0.033	0.247	0.307
Min		0.005	0.116	0.123
Max		0.095	0.696	0.718

The external dose to caregivers depends mostly on supporting and caring required by the patients as well as time spent in association with the patients.

B. Committed effective dose equivalent (CEDE) from internal exposure

ICRP[4] has summarized from a number of studies that the risk of contamination with radioiodine is generally low but not negligible. For adult relatives, the internal dose due to contamination is usually less than 10% of the external dose. This is in agreeable with our results. The internal dose estimates from the intakes of inhaled I-131 (mean = 0.04 mSv) in this study was 10.9% of the external dose (mean = 0.367 mSv).

However, according to NRC Regulatory Guide 8.39[3], our result accounted for approximately 7.5%, 3.8% and 3.8% of the rough estimated maximum likely CEDE from internal exposure by ingestion. The calculation is based on an equation:

$$D_i = Q\,(10^{-5})\,(DCF)$$

Where

D_i = the maximum likely CEDE in rem from internal exposure by ingestion

Q = the activity administered to the patient in millicurie

10^{-5} = assumed fractional intake

DCF = dose conversion factor, 53 rem/mCi[14] to convert an intake in millicurie to CEDE

C. Total effective dose equivalent (TEDE) to caregivers

Total effective dose equivalent (TEDE) to all caregivers were well below the limit (5.0 mSv) recommended in the ICRP Publication 94 and the IAEA Safety Reports Series No. 63[4,5]. When radiation safety precautions and preventive measures to minimize radiation exposure to caregivers living with patients receiving outpatient I-131 therapy was effectively instructed, it was found that the highest radiation dose received by the caregiver was only 14.4% of the annual dose constraints. This data indicate that with appropriate radiation protection guidelines, caregivers of a patient treated with high dose I-131 can be reassured that their doses in these circumstances are very low.

Conclusion

Radiation doses to caregivers from comforting and caring of hospitalized in patients treated with I-131 for thyroid cancer increased with increasing administered dose to the patient. In this study, the external and internal radiation dose received by caregivers were found to be well within the prescribed safe limits of comforter dose of 5 mSv as per Basic Safety standards guidelines of the IAEA. An ALARA program has been applied to reduce the radiological exposure and for a best estimate of internal dose. All safety issues had been instructed to both patients and their caregivers.

What is already known on this topic?

Other related research are estimate external exposure. Their results are below the limit (5 mSv) recommended in the ICRP Publication 94 and the IAEA Safety Reports Series No. 63[4,5].

What this study adds?

This study are estimate the total effective dose equivalent from internal and external exposure to caregivers. The results were well below the limit (5 mSv).

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Potential conflicts of interest

None.

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ปริมาณรังสีทั้งหมดที่ผู้ให้การดูแลได้รับจากผู้ป่วยมะเร็งไทรอยด์ในโรงพยาบาลที่ได้รับการรักษาด้วยไอโอดีนรังสีระดับสูง

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การรักษาผู้ป่วยมะเร็งไทรอยด์ด้วยไอโอดีน-131 ปริมาณรังสีสูง (3.7-7.4 GBq) จำเป็นที่จะต้องแยกผู้ป่วยออกจากบุคคลอื่น เพราะหลังจากผู้ป่วยรับประทานยาไอโอดีน-131 จะขับออกมาทางปัสสาวะ, อุจจาระ, น้ำลาย ทางลมหายใจและจากการแผ่รังสีโดยตรงจากตัวผู้ป่วย ทำให้ผู้ที่อยู่ใกล้ชิดโดยเฉพาะ ผู้ให้การดูแลผู้ป่วย มีโอกาสที่จะได้รับรังสีจากผู้ป่วย วัตถุประสงค์ของงานวิจัยนี้เพื่อประเมินปริมาณรังสีสะสมทั้งหมดที่ผู้ให้การดูแลผู้ป่วยได้รับทั้งจากการได้รับรังสีเข้าสู่ร่างกายและการได้รับรังสีจากการแผ่รังสีจากผู้ป่วยโดยตรง ในขณะที่ผู้ป่วยพักรักษาตัวอยู่ภายในโรงพยาบาลศิริราชและเปรียบเทียบปริมาณรังสีที่ได้รับกับค่าขีดจำกัดปริมาณรังสีที่กำหนดไม่เกิน 5 mSv ต่อปี สำหรับผู้ดูแลใกล้ชิด โดยการติดเครื่องวัดรังสีชนิดอ่านค่าเป็นตัวเลขได้ทันทีและเครื่องตรวจวัดอากาศประจำบุคคล โดยติดไว้ตลอดเวลาที่ผู้ป่วยพักรักษาตัวอยู่ภายในโรงพยาบาล และในวันที่ผู้ป่วยกลับบ้านจะตรวจวัดการจับไอโอดีนที่ต่อมไทรอยด์โดยตรงด้วยเครื่องไทรอยด์อัพเทค ในการศึกษาผู้ดูแลผู้ป่วย 13 คน โดยแบ่งออกเป็น 3 กลุ่มคือ กลุ่มที่ 1 ผู้ป่วยที่รักษาด้วยไอโอดีน 131 ปริมาณรังสี 3.7 GBq ปริมาณรังสีทั้งหมดที่ผู้ดูแลได้รับคือ 0.159 mSv, กลุ่มที่ 2 รักษาด้วยปริมาณรังสี 5.55 GBq ได้รับ 0.123 ถึง 0.629 mSv และกลุ่มสุดท้ายรักษาด้วยไอโอดีนรังสีปริมาณ 7.4 GBq ปริมาณรังสีทั้งหมดที่ผู้ดูแลได้รับคือ 0.631 ถึง 0.718 mSv จากทุกกลุ่มปริมาณรังสีที่ผู้ดูแลได้รับต่ำกว่าขีดจำกัดปริมาณรังสีที่กำหนดคือ 5 mSv ต่อช่วงการรักษาที่ได้รับการรักษาในกรณีที่จำเป็นตามข้อกำหนดของ IAEA Safety Report Series No. 63 และ ICRP Publication 103