ASSESSMENT OF RADIATION SAFETY FROM VOLATILIZATION OF ^{131}I IN THE TREATMENT OF HYPERTHYROIDISM AND THYROID CANCER

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ABSTRACT

Oral administration of ^{131}I treatment doses to hyperthyroid and thyroid cancer patients is the most hazardous procedure in nuclear medicine due to possible volatilization of ^{131}Iodine. Internal radiation exposure to medical personnel and patients involving the use of ^{131}I were analysed and assessed at the Department of Radiology by air sampling method. The air sampling was performed on a daily basis in front of an iodine fume hood where treatment doses ranging from 18.5-740 MBq were openly given to 169 hyperthyroid patients during a period of 42 days. At Siriraj Hospital, two thyroid cancer patients are admitted together to the same room due to shortage of room. Room partition to control external radiation exposure is achieved by relocating two lead screens between the patients' beds. To assess internal radiation exposure to the patients, concentration of ^{131}I in air in the room was determined for two days during an isolation period in two pairs of treated patients. It was found that the daily concentration of ^{131}I in air in front of the fume hood ranged from 0.9 to 262.7 Bq/m^3, and the maximum concentration of ^{131}I in air in the thyroid cancer patients' room was 546.9 Bq/m^3. All values were well below the established Derived Air Concentration (DAC) for ^{131}I, 700 Bq/m^3. It could be demonstrated that an individual intake of ^{131}I in the thyroid gland would be less than the Annual Limit on Intake (ALI). It is concluded that where internal body burden of ^{131}I is concerned, it is safe for medical personnel to openly administer treatment doses to hyperthyroid patients, and it is practically safe for two thyroid cancer patients to share the admitting room provided that sufficient shielding is established between their beds to control external radiation exposure.

INTRODUCTION

Oral administration of sodium iodide ^{131}Iodine treatment doses to hyperthyroid and thyroid cancer patients is the most hazardous procedure in nuclear medicine practice due to possible volatilization of radioactive iodine. Iodide solution, particularly in acidic form, when exposed to air will be easily oxidised. The resulting iodine (see equation 1) which is poor water- soluble then become volatile.

$$4I^- + O_2 + 4H^+ \rightarrow 2I_2 + 2H_2O \quad \ldots (1)$$

The risk to medical personnel from airborne radioactivity depends upon the radionu-

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clide, its chemical form, its concentration in the air, and the duration of time that persons are exposed to it. Primary method in protecting personnel and the public from airborne radioactivity is to minimize the release of radioactivity to the atmosphere. As a good practice, vials of radioactive iodide solution should be kept tightly capped. The iodide content should be maintained at a basic pH. The volatile fraction can be further reduced by refrigerating the stored vials and keeping them in the dark. Also, when preparing and dispensing the treatment doses, it is advisable to minimize agitation of the vial, and to manipulate the doses in a fume hood.

At the Division of Nuclear Medicine, approximately 400 hyperthyroid and 150 thyroid cancer patients are treated in a year by an oral administration of the sodium iodide ^{131}Iodine. The objective of this study was to analyze and assess radiation safety from volatilization, if any, of radioactive iodine employing air sampling method. Concentration of ^{131}I in air was measured in two restricted areas as follows:

1. in front of the iodine fume hood where the treatment doses are openly given to the hyperthyroid patients to evaluate the safety for local medical workers, and
2. in an isolation room where two thyroid cancer patients are admitted together to evaluate the safety for the patients.

To assess the radiation safety from the volatilization of ^{131}I, measured air concentration of ^{131}I was then compared to its Derived Air Concentration (DAC)[#].

MATERIAL AND METHOD

AIR SAMPLING

A vacuum pump (General Electric A-C Motor) was used to sample the air at a flow rate of 0.025 m^3/min through a glass micro fibre filter (4.7 cm Whatman Grade GF/C) whose function is to filter out any particulate dusts. Volatile radioactive iodine which goes through the fibre filter will pass on to, and be trapped by an activated charcoal filter (4.7 cm TEDA impregnated charcoal). At the end of the daily sampling, both the fibre and charcoal filters were removed from the pump, and radioactivity on them was counted using a high purity germanium detector equipped with a multichannel analyzer and a PC computer. Figure 1 shows a diagram of the sequential processes.

MEASUREMENT OF THE CONCENTRATION OF ^{131}I IN AIR IN FRONT OF THE IODINE FUME HOOD

Approximately 4,440 MBq (120 mCi) of ^{131}I is prepared each week as a stock solution used for the treatment of hyperthyroidism having a fixed concentration of 37 MBq/ml on Monday. Processes of preparing and dispensing of the dose are manipulated remotely in a closed manner using a locally-built dispensing set[2] which is placed in the iodine fume hood. The only part which is open to the atmosphere is a bottle of prescribed amount of ^{131}I from which the patient will suck the dose through a straw (Fig. 2). To evaluate the volatilization of ^{131}I during the oral administration of the doses to the patients, air sampling was performed on a daily basis in front of the fume hood where the treatment doses ranging from 18.5-740 MBq (0.5-20 mCi) were openly given to 169 hyperthyroid patients during a period of 42 days (from July 1, 1997 to January 16, 1998). Durations of time that the workers were in contact with ^{131}I in each day were from 2-30 minutes.

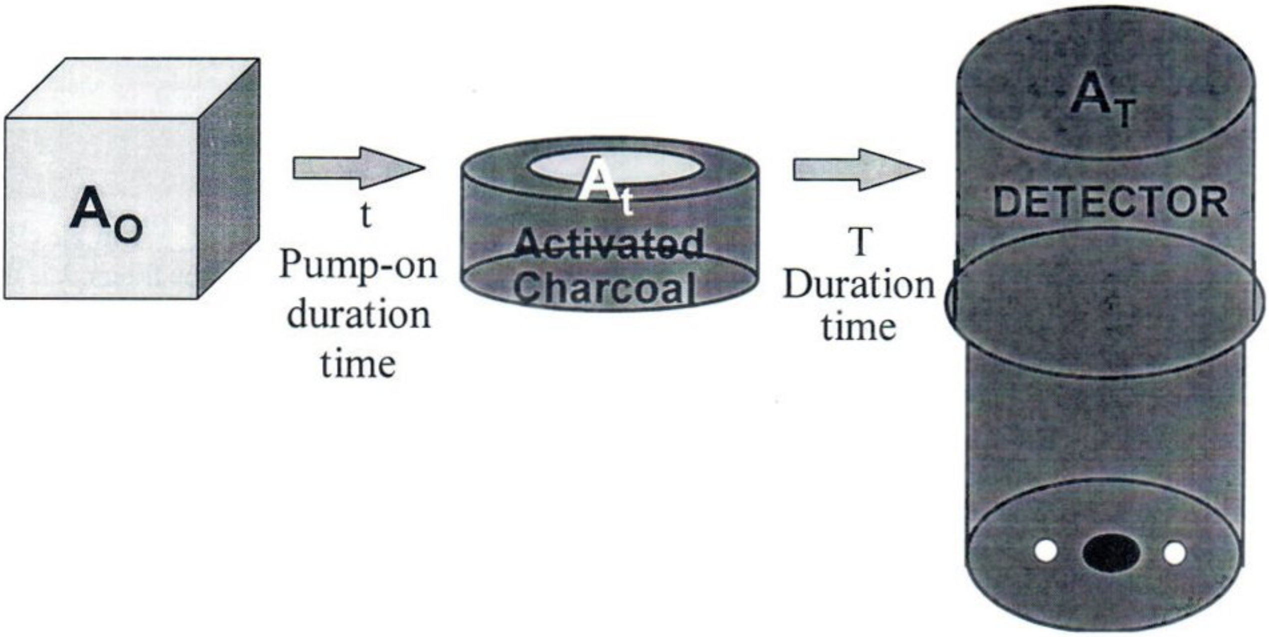

Fig. 1. Processes of air sampling and counting. A_0 is air to be sampled. ^{131}Iodine is trapped by the activated charcoal filter A_t during the pump-on duration time t. Radioactivity on the filter is counted by a germanium detector, and corrected for decay by the elapsed time between end of the sampling and the start of counting (duration time T).

Fig. 2. Air sampling in front of the fume hood during an oral administration of ^{131}I to a hyperthyroid patient.

MEASUREMENT OF THE CONCENTRATION OF ^{131}I IN AIR IN THE THYROID CANCER PATIENTS' ROOM

At Siriraj Hospital two thyroid cancer patients are admitted to the same room due to lack of room. Generally the patients receive 3,700 or 5,550 MBq of ^{131}I on Tuesday and will be discharged from the hospital on Friday. Room partition to control external radiation exposure to the patients is achieved by relocating two lead screens (height: length: thickness = 85: 120: 2 cm per screen) between the patients' beds. Two more lead screens are also placed at the end of each bed as shielding provision for visitors or passers-by. Figure 3 shows a diagram of the isolation room for admitting two thyroid cancer patients. However, as the two patients stay in the same room for 4 days after receiving the treatment doses, their inhale air might be the cause of internal radiation exposure to them. To assess the radiation safety for the patients, concentration of ^{131}I in air in the room was monitored for 2 days during an isolation period in two pairs of treated patients. Pump-on duration time on each day was not exactly 24 hours owing to technical inconvenience. As the isolation period, the most hazardous period, for patients being treated with upto 7,400 MBq (200 mCi) of ^{131}I is about 2 days,[3] no attempt was made to sample the air beyond this period.

CALCULATION OF THE CONCENTRATION OF ^{131}I IN AIR

The concentration of ^{131}I in air is calculated by equation (2).

$$C = R.\lambda.\ \exp(\lambda T) / V.E.F\ (1-\exp(-\lambda t)) \quad \text{.......... (2)}$$

where C is the concentration of ^{131}I in air (Bq/m^3), R is the count rate (cps) of the filters, λ is the decay constant of ^{131}I (5.9671 x 10^{-5} min^{-1}), T is the duration time or elapsed time between end of the sampling and the start of counting (min), t is the pump-on duration time or sampling time (min), V is the flow rate of the pump (0.025 m^3/min), E is the counting efficiency of the detecting system (0.013), and F is the photon yield of ^{131}I (0.82 for 365 keV).

RESULTS

The measurement of daily airborne ^{131}I in front of the iodine fume hood revealed that during the sampling period of 42 days the concentration of ^{131}I in air ranged from 0.9 to 262.7 Bq/m^3 (mean = 51.8) as shown in Fig. 4. Even the maximum concentration of ^{131}I was well below the DAC of ^{131}I (700 Bq/m^3). For the concentration of ^{131}I in air in the thyroid cancer patients' room as tabulated in Table 1, it was observed that among the two pairs of treated patients, the worst situation occurred in the first pair whereby one patient vomitted several times for 3 days due to radiation side effect. The patient informed that his vomitus was cautiously collected in a plastic garbage bag and was put into a lead-lining bin provided in the room. Nevertheless the maximum concentration of ^{131}I in air in the first day after the administration of the treatment doses was found to be 546.9 Bq/m^3, which was under the DAC limit.

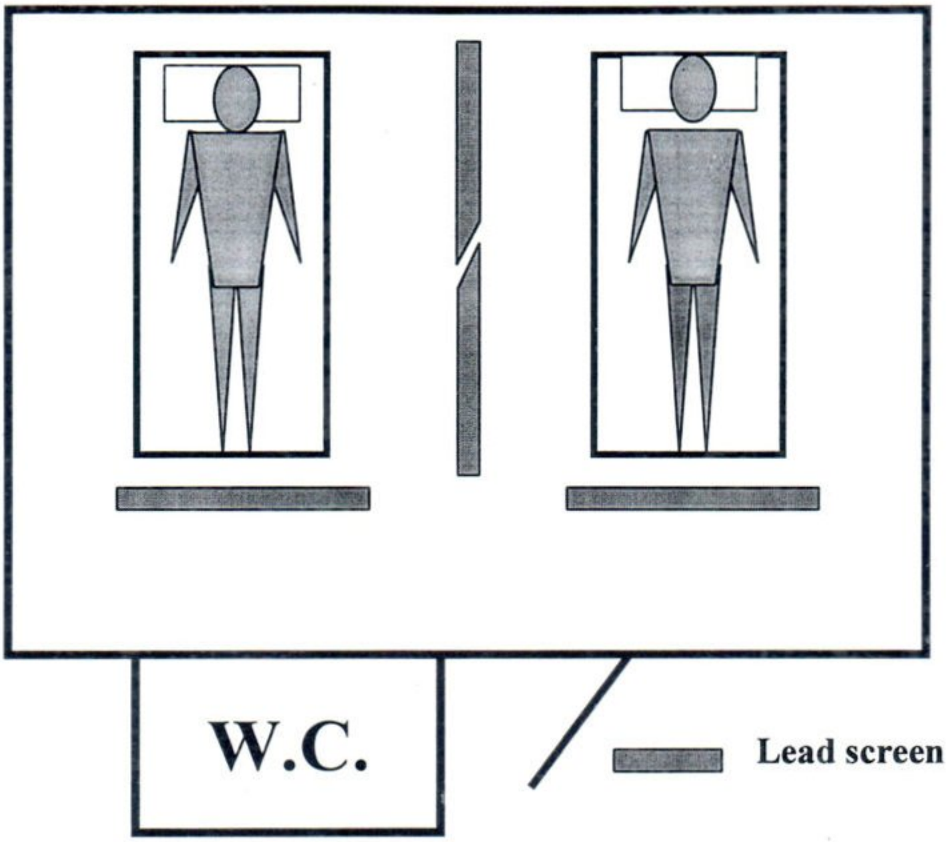

Fig. 3. Diagram of an isolation room for admitting two thyroid cancer patients.

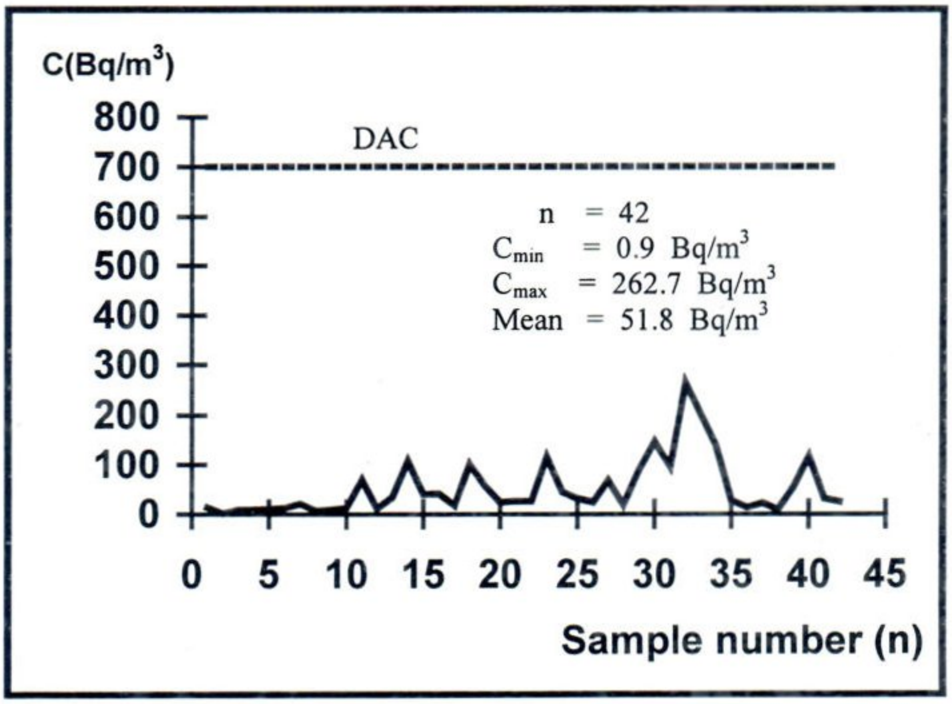

Fig. 4. Daily concentration of ^{131}I in air (C) in front of the iodine fume hood.

Table 1. Concentration of ^{131}I in air in the thyroid cancer patients' room.

Pair of patients	Administered doses in 2 patients (MBq)	Day	Pump-on duration	Concentration of ^{131}I in air in the room (Bq/m^3)
1	5,550 & 5,550	1	17 hr	546.9*
		2	23 hr 50 min	385.0*
2	3,700 & 5,550	1	19 hr 22 min	172.0
		2	23 hr 10 min	107.2

*There was patient's vomitus in the bin.

DISCUSSION

As the concentration of ^{131}I in air in front of the iodine fume hood where the treatment doses were openly administered to hyperthyroid patients, and in the room where two thyroid cancer patients shared it fell below the DAC, it could be concluded that there was little volatile ^{131}Iodine in the areas. This is so because present sodium iodide ^{131}Iodine solution, as commercially available, has been reformulated by changing the pH to basic form and adding buffers, antioxidants and stabilizers to the solution resulting in the reduction of volatilization of the iodine. Nevertheless it is a good practice to manipulate the iodide solution in the fume hood and to minimize the exposure of ^{131}I solution to air as much as possible. At Siriraj Hospital the process of preparing the stock solution of the treatment dose for the treatment of hyperthyroidism, and the dispensing of the prescribed amount of the dose are remotely and closely performed. Only the dispensed dose is open to the atmosphere to facilitate the administration of the dose to the patient.[2] In the case of the treatment of thyroid cancer, the dose is orally administered to the patient in a totally closed manner using a dispensing set locally designed.[5] Thus our concern is in the admittance of two radioactive patients to the same room. In doing so the two patients should be protected from the external radiation exposure by providing enough shielding or increasing the distance between their beds as much as possible. However this study revealed that the internal exposure to the patients themselves due to inhalation was not a problem.

From the measured concentration of ^{131}I in air in the restricted areas, body intake of ^{131}I for those who are in the areas can be calculated from the following equation:

$$\text{Body intake} = CI\tau \quad \dots\dots\dots (3)$$

where I is human inhalation rate ($2x10^{-2}$ m^3/min), and τ is the time in contact with ^{131}I (min). It can be seen that the body intake depends on the concentration of ^{131}I in air and the time a person spends in contact with the ^{131}I. ^{131}I intake in the thyroid, which is normally assumed to be 30% of the body intake, and the committed dose equivalent for the thyroid can thus be estimated. Table 2 demonstrates two most risky situations where the medical workers who gave the treatment doses to the hyperthyroid patients experienced in this study, i.e.

(1) the measured concentration of ^{131}I in air in one day was maximum at 262.7 Bq/m^3 where the time spent in contact with ^{131}I was 7 minutes, and

(2) the time in contact with ^{131}I on another day was as long as 30 minutes where the measured concentration of ^{131}I in air was found to be 89.0 Bq/m^3.

From these data, the thyroid intake of ^{131}I and committed dose equivalent for the thyroid of the workers could be estimated (Table 2), and found to be under the dose limits established by the International Commission on Radiological Protection (ICRP Publication 54),[4] as shown on the last row of Table 2.

Table 2. ^{131}I intake in thyroid and committed dose equivalent for thyroid in comparison to dose limits$: Two risky situations encountered in front of the fume hood.

Situation	Concentration of ^{131}I in air (Bq/m^3)	Time in contact with ^{131}I (min)	^{131}I intake in thyroid (Bq)	Committed dose equivalent for thyroid* (mSv)
1	262.7	7	11.0	0.0032
2	89.0	30	178.0	0.0046
Limit$	700 (DAC)	2,000 x 60	2×10^6 (ALI for inhalation)	400

* Committed dose equivalent per unit intake for thyroid = 2.9×10^{-4} mSv/Bq (ICRP Publication 54[4])

CONCLUSION

To evaluate the radiation safety for the medical workers and the patients, air samples were obtained from two restricted areas where the workers administered the ^{131}I treatment doses to hyperthyroid patients and in the room where two thyroid cancer patients were admitted together. Analyses of the air samples indicated that where internal body burden of ^{131}I was concerned, it was safe for medical workers to openly administer the treatment doses to the hyperthyroid patients, and it was practically safe for two thyroid cancer patients to share the room provided that enough shielding is established between the patients' beds to control the external radiation exposure.

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[#] The Derived Air Concentration (DAC) is the concentration of a radionuclide in air that, if breathed under conditions of light activity for 2,000 hours (working hours in one year), would result in the inhalation of an Annual Limit on Intake (ALI). The ALI is the activity of a radionuclide that, if inhaled or ingested, would produce a committed dose equivalent of 0.5 Sv (50 rem) in any individual organ or tissue or a committed effective dose equivalent of 0.05 Sv (5 rem). From inhalation of airborne ^{131}I pertained to restricted areas, the DAC is 700 Bq/m^3, and the ALI is 2×10^6 Bq.[1]