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Internal Dosimetry of Human Brain for ^{99m}tc and ^{131}I Using Nuclear Imaging in Bangladesh

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ABSTRACT

Internal dosimetry deals with the measurement of the radiation dose absorbed internally by an organ after the application of isotopes for diagnosis and treatment. In the present study radiation absorbed dose has been calculated for ^{99m}Tc-pertechnetate, ^{99m}Tc-DTPA, ^{99m}Tc–hepatate and ^{131}I (NaI) which are used frequently for functioning test of disordered organs and therapeutic treatment of thyroid in Bangladesh. In these cases a small amount of isotopes are accumulated in other soft tissues like brain, gonads etc. Brain tissues are soft and cannot be regenerated if it is damaged. So, to ensure the safety of brain, the internal radiation absorbed dose has been calculated from direct measurement by using planer image of gamma cameras. International Commission for Radiological Protection (ICRP) and National Commission for Radiation Protection (NCRP) have laid emphasis on direct measurement because it provides more accurate result than that of other methods which are based on few mathematical assumption, bio-kinetic modeling and extrapolation of animal data to human etc. Finally these results have been compared with the data of ICRP publication 71.

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1. INTRODUCTION

Radioisotopes are being used frequently for diagnosis and treatment of various diseases. But there is always a risk factor involved in case of using ionizing radiation. In order to know the risk and ensure the safety of human organs it is necessary to know the amount of radiation dose absorbed by an organ[1]. Some human tissues like brain, gonads etc. are soft and a small amount of dose is sufficient to cause damage. Brain tissues are that type of soft tissues, which cannot be regenerated if it is damaged. So it is essential to reduce unwanted dose to the brain[2]. Normally ^{99m}Tc-pertechnetate, ^{99m}Tc-DTPA and ^{99m}Tc-hepatate are used frequently for functioning test of thyroid, kidney and liver respectively and ^{131}I (NaI) is used for therapeutic purposes of thyroid. In these cases sufficient amount of radioactivity accumulated to the brain[3]. So, in order to ensure the safety of brain, the internal radiation absorbed dose calculation is necessary. This study is aimed to calculate absorbed dose for brain from direct measurement. International Commission for Radiological Protection (ICRP) has also emphasized on direct measurement as it provides more accurate result than that of other methods, which are based on a few mathematical assumption and animal data[4]. In ICRP publication there are few dosimetric data for this purpose, which are based on European and American standard people. We know that the entire environment of Indian subcontinent and physical fitness, behavior, biological excretion, food habit etc. of the people of this region is different from European and American people[5]. So there may be a variation in the result. In that cases, it may be assumed that the output of this research will ensure the safe use of those radiopharmaceuticals and will generate base line data for the human brain so that further recommendation about the application for diagnosis and treatment may be formulated.

2. MATERIALS AND METHODS

To establish a calibrated data a special counting model was arranged with the help of a NaI detector and a survey meter. At first the background count per minutes and the background exposure of the laboratory were measured by using NaI detector and survey meter respectively. The water phantoms of various length, height and width were filled with pure water. Then a suitable amount of technetium-99m source of known activity (500 MBq) was kept just in front of the detector and the survey meter. To get a suitable peak of counts the detector voltage was adjusted at 750 volt. The amount of count per minutes of the NaI detector and the exposure of the survey meter reading was recorded simultaneously. The back ground readings were subtracted from each reading that gave the amount of count per minute by the detector and the amount of exposure in milli Roentgen per hour at about nearest distance (d=0) from the source. The amount of the count per minute and the amount of exposure at various distances from the source in water medium were measured by keeping the source at one end of water phantoms of various lengths and the detector and the survey meter at the other end respectively. The amount of count per minute and the amount of exposure were calculated by subtracting the background reading in similar way for various distances from the source. As a result a calibrated data of counts per minute and exposure for technetium-99m was obtained at different distances from the source. Similar procedure was followed to get a calibrated data for radio iodine but the detector voltage was adjusted at 705 volt in this case to get a suitable peak of counts[6].

Clinical histories of the patients who came to select nuclear medicine centers (NMC, Dhaka and NMC, Khulna) for diagnosis and therapeutic treatment were recorded. In case of thyroid, liver and kidney imaging normally ^{99m}Tc-pertechnetate, ^{99m}Tc-hepatate and ^{99m}Tc-DTPA are used respectively and image is taken after a certain period of time when maximum amount of activities accumulate to the target organ. ^{131}I is normally used for therapeutic purpose of disordered thyroid. In order to get 'Region of Interest (ROI)' option these images were reconstructed with the help of Advanced Center for Imaging Research (ACIR) software[7]. This software shows the corresponding counts of any region of interest drawn in the image. Sample of these images are shown in Figure 1 for brain and thyroid due to ^{99m}Tc-pertechnetate. Free hand ROI (Region of Interest) for the visualizing organs like brain and the source organ thyroid for each case was drawn and corresponding counts were noted. Average values of the counts were converted as counts per second per MBq by using patient's clinical background information[8]. Similarly, images were taken at various interval of time from the time of activity applied and counts per minute were calculated in same way.

Table 1: Calibration data of Tc-99m at various distances from source (activity 3 mCi) in water phantom

Distance (cm)	Exposure (mR/hr)	Count per minute (CPM)
0	0.1000	106282
18	0.0200	25415
30	0.0076	20144
45	0.0043	16548
60	0.0036	14725

Table 2: Calibration data of I-131 at various distances from source (activity 300 μCi) in water phantom

Distance (cm)	Exposure (mR/hr)	Count per minute (CPM)
0	3.400	160826
18	0.038	29108
30	0.026	24291
45	0.022	19205
60	0.016	13537

These counts were converted into exposure rate by using the calibrated data of Table 1 and Table 2 and then converted into dose rate with the help of dose versus exposure relation[9]. Total dose absorbed by an organ was calculated by using the formula given below and with the help of time versus exposure curves of various organs for various isotopes fitted by using Khaleda Graph software[10]. A few samples of these curves are shown in Figure 2. These total absorbed doses were converted into absorbed doses per MBq by using patient's background data[11]. Finally the results obtained from this study were compared with that of ICRP publication 71[12].

$$D = \int_{0}^{t_{\max}} dD\, dt + \int_{t_{\max}}^{\infty} dD\, dt \qquad (2.1)$$

where, D is the total absorbed dose, 0 is the initial time, t_{max} is the time when the dose rate is maximum[11].

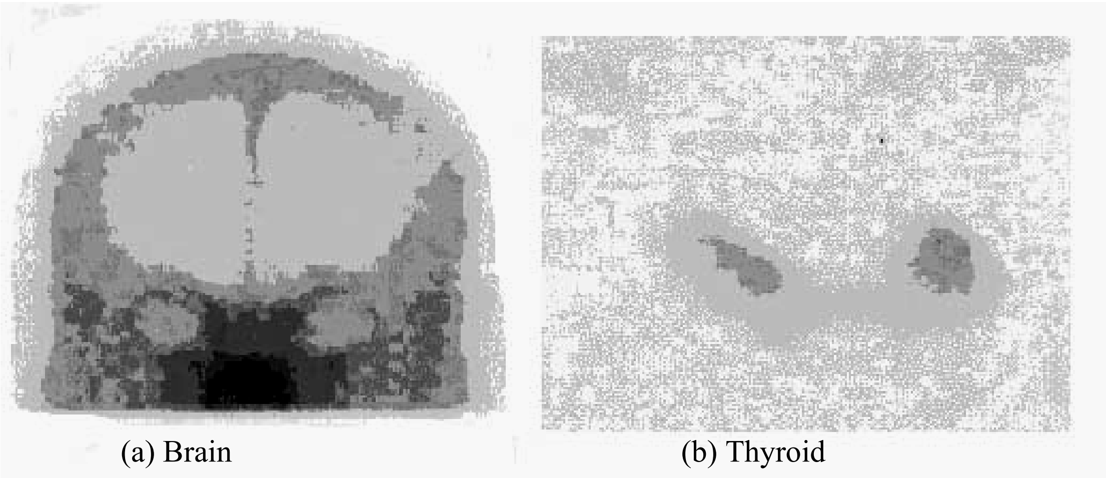

Figure 1: Planner images of human (a) Brain (injected dose 12 mCi of ^{99m}Tc-pertechnitate) and (b) Thyroid (injected dose 300 μCi of NaI)

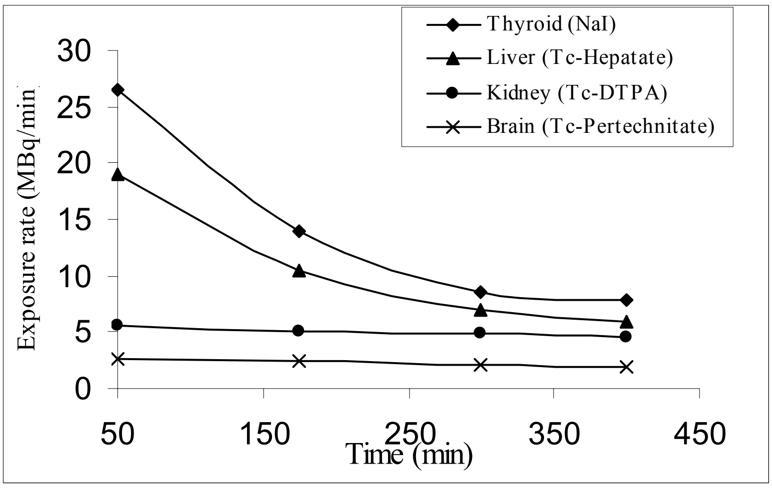

Figure 2: Time versus exposure curves of various organs for various isotopes

3. RESULTS AND DISCUSSION

The absorbed doses for human brain as well as the target organs have been estimated. Data were obtained from the studies using the pharmaceuticals ^{99m}Tc-pertechnitate, ^{99m}Tc-DTPA, ^{99m}Tc-hepatate and ^{131}I (NaI). To obtain biokinetic data planner images gamma camera were used.

Internal radiation absorbed dose for brain and thyroid of thirty-seven Bangladeshi patients were calculated in case of ^{99m}Tc-pertechnetate. Radiation absorbed dose for thyroid has been calculated because thyroid is considered as a target organ and major part of the isotopes are accumulated in the thyroid. The average measured values of absorbed doses in thyroid and brain are 55.10 x 10^{-5} mGy/MBq and 19.08 x 10^{-5} mGy/MBq respectively, where as ICRP-71 recommended values for thyroid and brain are 33.8 x 10^{-5} mGy/MBq and 12.5 x 10^{-5} mGy/MBq. The data depicts that the average values are relatively higher, because of high thyroid uptake due to iodide deficiency of the people in this region. Brain dose is also high because brain itself receive dose as a secondary target from thyroid as well as a primary source.

For ^{99m}Tc-DTPA, internal radiation absorbed dose for brain and kidney of twelve patients were calculated. Radiation absorbed dose in kidney has been calculated because it was considered as a target organ. The average values of absorbed doses in kidney and brain are 79.70 x 10^{-5} mGy/MBq and 11.90 x 10^{-5} mGy/MBq respectively, where as ICRP-71 recommended values for thyroid and brain are 92.0 x 10^{-5} mGy/MBq and 9.2 x 10^{-5} mGy/MBq. Comparison of the data from this study depicts that the average values are almost same as ICRP-71. So, in case of diagnosis with ^{99m}Tc-DTPA, conventional doses may be used.

For ^{99m}Tc-hepatate, radiation absorbed dose in brain and liver of eleven patients were calculated. In this case, radiation absorbed dose in liver has been calculated because ^{99m}Tc-hepatate is used to diagnosis and functioning test of liver. The average values of absorbed doses in liver and brain are 113.50 x 10^{-5} mGy/MBq and 4.80 x 10^{-5} mGy/MBq respectively, where as ICRP-71 recommended values for liver and brain are 140 x 10^{-5} mGy/MBq and 5.3 x 10^{-5} mGy/MBq. respectively. Comparison of the data from this study depicts that the average values are also almost same as ICRP-71. So, in case of diagnosis with ^{99m}Tc-Hepatate, conventional doses may be used also.

Due to therapeutic use of ^{131}I, internal radiation dose absorbed in brain and thyroid of ten patients were calculated. As thyroid considered as a target organ, radiation absorbed dose in thyroid has been calculated. The average values of absorbed doses in thyroid and brain are calculated to be about 52.60 x 10^{-5} mGy/MBq and 5.80 x 10^{-5} mGy/MBq respectively, where as ICRP-71 recommended values for thyroid and brain are 15.0 x 10^{-5} mGy/MBq and 5.0 x 10^{-5} mGy/MBq. It can be seen that the average value of absorbed dose in thyroid is very high compared to ICRP-71. The observed higher accumulated isotopes absorbed may be due to iodine deficiency of the people studies in the present case. But, brain dose is almost similar with ICRP-71 because in this case brain does not receive dose as a primary target. Another cause may be owing to the low dose rate of ^{131}I because the biological half-life of ^{131}I is higher than that of ^{99m}Tc. As a result, most of the dose accumulated in blood-brain barrier in this case.

Table 3: Comparison of absorbed dose by brain due to various isotopes with ICRP-71[12]

Radioisotopes	Injected dose (MBq)	Organ	Absorbed dose in mGy per MBq ($\times 10^{-5}$)		% Difference
			Present study	ICRP-71	
^{99m}Tc-pertechnitate	444	Thyroid	55.10	33.80	63.02
		Brain	19.08	12.30	55.12
^{99m}Tc-Hepatate	185	Liver	113.50	140.00	-18.93
		Brain	4.80	5.30	-9.43
^{99m}Tc-DTPA	185	Kidney	79.70	92.00	-13.37
		Brain	11.90	9.20	29.35
NaI	11.1	Thyroid	52.60	15.00	250.67
		Brain	5.80	5.40	7.41

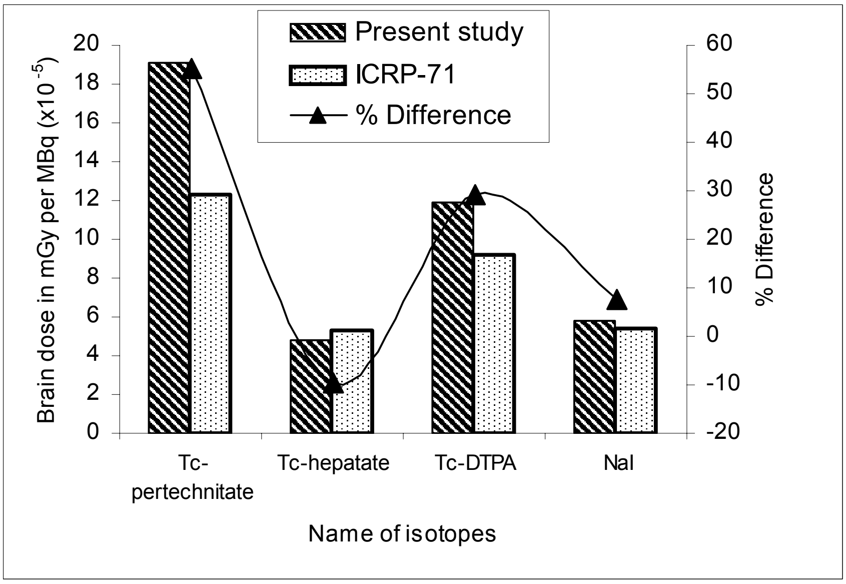

Figure 3: Comparison graph of brain dose per MBq for various isotopes

4. CONCLUSIONS

Radiation absorbed doses were estimated from experimental data after intravenous injection of ^{99m}Tc-pertechnetate, ^{99m}Tc-DTPA, ^{99m}Tc-hepatate and ^{131}I (Na^{131}I) and also were compared with the recommended data of ICRP publication 71. Our experimental data were in good agreement with the data of ICRP publication 71 in case of ^{99m}Tc-DTPA and ^{99m}Tc-hepatate. But, in case of ^{99m}Tc-pertechnetate and Na^{131}I, experimental data were much higher than that of ICRP publication 71 because of high accumulation due to iodide deficiency of the patients studied. Quantity of radio isotope use in nuclear medicine is based on detector efficiency, optimum imaging time and radiation safety. Optimization depends on several factors such as patient's weight, age time available for imaging, isotope available etc. The results in this work can be useful to estimate the amount of activity that can be administered to the patient and also serve as a way of comparing the risk to the benefit value of these nuclear medical procedures with other modalities of diagnostic procedures. It may be concluded that except free ^{99m}Tc-pertechnetate and ^{131}I (Na^{131}I) conventional doses may be used for diagnosis purposes. For thyroid imaging use of ^{99m}Tc-pertechnetate and ^{131}I (Na^{131}I), care should be taken to reduce the doses.

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