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## Pediatric Radiation Exposure from Diagnostic Nuclear Medicine Examinations in Tehran

**Background/Objectives:** As a part of a nationwide survey to estimate population exposure to radiation from diagnostic nuclear medicine in Iran, this paper presents the pediatric population radiation exposure due to nuclear medicine examinations in Tehran.

**Patients and Methods:** The effective dose equivalent,  $H_E$ , was used to calculate the collective effective dose in pediatric patients undergoing nuclear medicine procedures, and the corresponding data were obtained from thirty out of thirty seven active nuclear medicine departments in Tehran.

**Results:** Annually about 5.26% of nuclear medicine examinations were performed on patients under 15 years of age in Tehran. The most frequent was renal examinations (38.2%), followed by thyroid (27.4%) and bone (26.7%). The annual collective  $H_E$  for patients under 15 was 19.03 human-Sv, which contributed 3.96% to the collective  $H_E$  for all patients. The contribution of renal, bone and thyroid examinations to the pediatric collective  $H_E$  were 24.6%, 48.8% and 13.5% respectively. The mean effective dose equivalent per pediatric patient was 3.75 mSv.

**Conclusion:** Among the three most frequent examinations, the bone with a relative frequency of 27.4% constituted 48.8% of the collective  $H_E$ , which was the highest absorbed dose per examination. The mean effective dose per examination for patients younger than 15 years was 67.9% of the adults.

**Keywords:** pediatrics, diagnostic nuclear medicine, radiation exposure

### Introduction

Life on earth is constantly exposed to various forms of ionizing radiation from natural sources such as cosmic rays and natural radioactivity, as well as the ionizing radiation used in medicine. Ionizing radiation has valuable clinical usage in diagnostic radiology, nuclear medicine and radiotherapy. Diagnostic x-ray examinations constitute the largest source of man-made radiation exposure,<sup>1-8</sup> however, the rapid expansion of diagnostic nuclear medicine procedures that involve the use of unsealed radiopharmaceuticals also requires assessment of the population exposures to this type of radiation.<sup>9-27</sup>

Given the significant benefits of properly conducted nuclear medicine procedures to pediatric patients, the main concern in radiation protection is reducing the exposures of children as far as possible. Therefore, the main purpose of this study was to identify the amount of pediatric population exposure during diagnostic nuclear medicine examinations.

The concept of "total body dose" or "whole body dose" has been employed by many investigators in evaluation of the risks of different nuclear medicine procedures. Although this concept may be useful for comparing the doses received from different procedures, it does not give an indication for the non-uniform distribution of radiopharmaceuticals throughout the body. ICRP (International Commission on Radiation Protection) has issued quantitative recommendations on patient exposure to nuclear medicine examinations which have been applied

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and evaluated in several studies.<sup>9-29</sup> The “effective dose equivalent”,  $H_E$ , was introduced by ICRP originally to protect workers occupationally exposed to radiation.<sup>28</sup> At first,  $H_E$  was not meant for patients undergoing x-ray examinations or nuclear medicine procedures involving administration of radiopharmaceuticals. However, many investigators used  $H_E$  for comparing patient exposure from different diagnostic procedures subsequently.<sup>9-27</sup>

## Patients and Methods

Comprehensive data including annual frequencies of nuclear medicine procedures, the type and amount of administered radiopharmaceuticals, and the age distribution of the examined patients were obtained from 33 of the 37 active nuclear medicine departments in Tehran, from April 2001 to March 2002. The effective dose equivalents ( $H_E$ ) of different radiopharmaceuticals are calculated based on absorbed doses per unit administered activities for different organs given in the ICRP publication 53, and tissue weighting factors given in the ICRP publication 26.<sup>28,30</sup> The effective dose per examination (mSv) for different radiopharmaceuticals are calculated by multiplying mean administered activity (MBq) and effective dose equivalent (mSv/MBq) for each examination in five age groups (<1, 1-5, 6-10 and <15 years). The collective effective dose equivalents (man-Sv) were calculated by multiplying the frequency of each examination in each age group by the corresponding effective dose per examination.

## Results

The mean administered activity (MBq), effective dose equivalent (mSv/MBq), and effective dose per examination for 12 nuclear medicine procedures are given in Table 1. Some miscellaneous procedures using <sup>99m</sup>Tc-pertechnetate such as RBC scan, WBC scan, and parathyroid scan are summarized in one group as ‘other’ in the last row of Table 1. The mean value of effective dose equivalent per examination among all radiopharmaceuticals and age groups was 6.256 mSv with a range of 0.05-28.26 mSv.

Lung ventilation scan with <sup>81m</sup>Kr had the lowest value for effective dose equivalent per examination (0.05-0.07 mSv), while tumor scan with <sup>67</sup>Ga-citrate showed the highest value (16.4-28.2 mSv). The

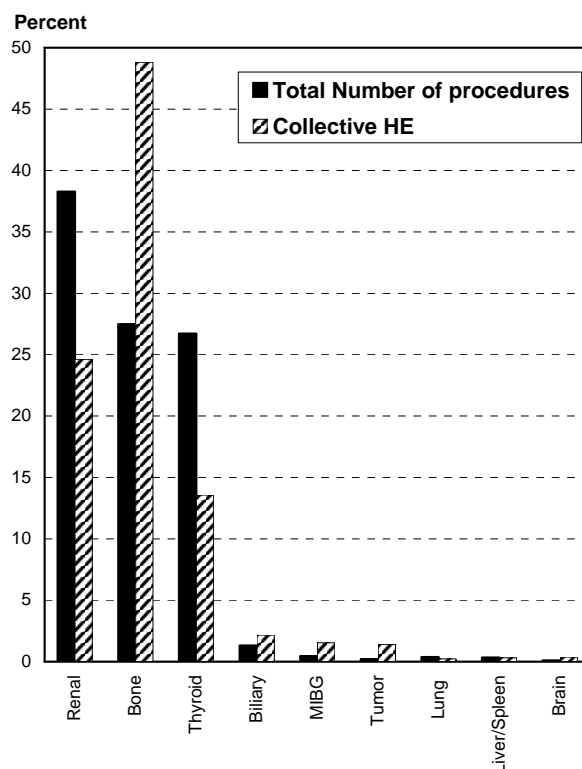


Fig 1. The contribution of each age groups to the total number of procedures and collective  $H_E$

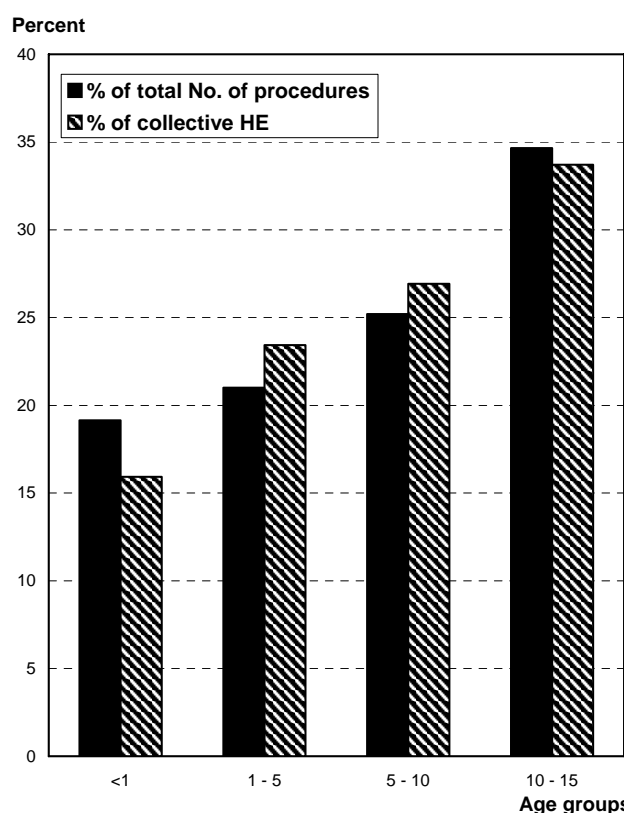


Fig 2. The contribution of each procedure to the total number of procedures and collective  $H_E$ .

**Table 1.** Mean administered activities (MBq), effective dose equivalents (mSv/MBq) and effective dose per examination (mSv) for different radiopharmaceuticals used for pediatric imaging in nuclear medicine departments

Procedure	Radio-pharmaceutical	Mean Administered Activity (MBq)					Effective Dose Equivalent H <sub>e</sub> (mSv / MBq)					Effective Dose / Exam (mSv)				
		<1	1-5	6-10	11-15	1.32	<1	1-5	6-10	11-15	10.00000	<1	1-5	6-10	11-15	
Thyroid	<sup>131</sup> I INa	<1	1-5	6-10	11-15	1.32	<1	1-5	6-10	11-15	10.00000	<1	1-5	6-10	11-15	
	<sup>99m</sup> Tc TcO <sub>4</sub>	22.90	45.80	59.27	66.59	0.07300	0.04000	0.02500	0.01600	0.01600	1.67	1.83	1.48	1.07	13.16	
Bone	<sup>99m</sup> Tc MDP, PYP	157.00	314.00	406.32	456.56	0.05000	0.02500	0.01500	0.01000	0.01000	7.85	7.85	6.09	4.57	236.88	
Liver/Spleen	<sup>99m</sup> Tc SC	41.00	82.00	106.11	119.23	0.07600	0.04300	0.02900	0.01900	0.01900	3.12	3.53	3.08	2.27	555.33	
Biliary	<sup>99m</sup> Tc IDA	40.38	80.75	104.49	117.41	0.15000	0.07000	0.04400	0.02900	0.02900	6.06	5.65	4.60	3.40	20.43	
Renal	<sup>99m</sup> Tc DTPA	88.08	176.15	227.94	256.12	0.03000	0.01700	0.01100	0.00780	0.00780	2.64	2.99	2.51	2.00	64.60	
	<sup>99m</sup> Tc DMSA	27.15	54.30	70.26	78.95	0.06900	0.04000	0.02700	0.01900	0.01900	1.87	2.17	1.90	1.50	460.00	
Lung perfusion	<sup>99m</sup> Tc MAA	36.33	72.65	94.01	105.63	0.06900	0.03800	0.02500	0.01800	0.01800	2.51	2.76	2.35	1.90	412.50	
Lung Ventilation	<sup>81m</sup> Kr - Gas	437.50	875.00	1132.2	1272.25	0.00017	0.00009	0.00006	0.00004	0.00004	0.07	0.08	0.06	0.06	11.40	
Brain	<sup>99m</sup> Tc TcO <sub>4</sub>	185.00	370.00	478.78	537.98	0.07300	0.04000	0.02500	0.01600	0.01600	13.51	14.80	11.97	8.61	20.43	
MIBG	<sup>131</sup> I INa	9.25	18.50	23.94	26.90	1.10000	0.61000	0.40000	0.26000	0.26000	10.18	11.29	9.58	6.99	20.43	
Tumor	<sup>67</sup> Ga Citrate	35.33	70.65	91.42	102.73	0.79000	0.40000	0.25000	0.16000	0.16000	27.91	28.26	22.86	16.44	555.33	
Other	<sup>99m</sup> Tc TcO <sub>4</sub>	74.00	148.00	191.51	215.19	0.07300	0.04000	0.02500	0.01600	0.01600	5.40	5.92	4.79	3.44	20.43	

**Table 2.** Frequency of examination, radiopharmaceuticals and the corresponding collective effective dose for each diagnostic nuclear medicine procedure on pediatric patients.

Procedure	Radiopharmaceutical	Frequency of examinations					Effective dose per examination (m Sv)					Collective effective dose (Man-mSv)				
		<1	1-5	6-10	11-15	<1	1-5	6-10	11-15	<1	1-5	6-10	11-15			
Thyroid	<sup>131</sup> I INa	0	0	0	18	-	-	-	-	13.16	0.00	0.00	0.00	236.88		
	<sup>99m</sup> Tc TcO <sub>4</sub>	335	359	388	519	1.67	1.83	1.48	1.07	559.45	656.97	574.24	555.33			
Bone	<sup>99m</sup> Tc MDP, PYP	101	212	434	917	7.85	7.85	6.09	4.57	792.85	1664.20	2643.06	4190.69			
Liver/Spleen	<sup>99m</sup> Tc SC	0	5	7	9	3.12	3.53	3.08	2.27	0.00	17.65	21.56	20.43			
Biliary	<sup>99m</sup> Tc IDA	34	15	12	19	6.06	5.65	4.66	3.40	206.04	84.75	55.92	64.60			
Renal	<sup>99m</sup> Tc DTPA	85	121	110	230	2.64	2.99	2.51	2.00	224.40	361.79	276.10	460.00			
	<sup>99m</sup> Tc DMSA	570	470	457	275	1.87	2.17	1.90	1.50	1065.90	1019.90	868.30	412.50			
Lung perfusion	<sup>99m</sup> Tc MAA	0	7	6	6	2.51	2.76	2.35	1.90	0.00	19.32	14.10	11.40			
Lung Ventilation	<sup>81m</sup> Kr - Gas	0	0	2	2	0.07	0.08	0.06	0.05	0.00	0.00	0.12	0.10			
Brain	<sup>99m</sup> Tc TcO <sub>4</sub>	0	1	2	4	13.51	14.80	11.97	8.61	0.00	14.80	23.94	34.44			
MIBG	<sup>131</sup> I INa	0	18	8	2	10.18	11.29	9.58	6.99	0.00	203.22	76.64	13.98			
Tumor	<sup>67</sup> Ga Citrate	0	2	5	6	27.91	28.26	22.86	16.44	0.00	56.52	114.30	98.64			
Other	<sup>99m</sup> Tc TcO <sub>4</sub>	34	61	95	92	5.40	5.92	4.79	3.44	183.60	361.12	455.05	316.48			
Total		1159	1271	1526	2099					3032.24	4460.24	5123.33	6415.47			

frequency of procedures using each radiopharmaceutical and their corresponding collective effective dose for all age groups are given in Table 2. The total number of examinations and the collective effective dose for each age group are also presented in the last row of Table 2.

A total of 6055 diagnostic nuclear medicine examinations were performed on pediatric patients in Tehran with a collective effective dose of 19.03 man-Sv, between April 2001 to March 2002. The mean effective dose equivalent per pediatric patient was estimated 3.75 mSv. During the study period, 5.26% of the annual nuclear medicine examinations were performed on patients under 15 years of age in Tehran, which constituted 3.96% of the collective  $H_E$  for all patients. The relative frequency and collective effective dose for each procedure are given in Figure 1. The relative frequency of renal nuclear examinations was 38.2% followed by bone (27.4%) and thyroid (26.7%). Renal, bone, and thyroid examinations contributed 24.6% , 48.8% and 13.5% to the pediatric collective  $H_E$ , respectively.

The total number of procedures and their corresponding collective effective dose for each age group are given in Figure 1. The <1 age group had the lowest number of procedures and collective  $H_E$  (19.1% and 15.9% respectively), whereas the 10-15 age group had the highest values (34.6% and 33.7%, respectively).

## Discussion

Because nuclear medicine is highly useful in urologic problems in pediatric patients, this paper clearly shows (Figure 2) the highest relative frequency for renal scans. Since the prevalence of urinary infections is a relatively common pediatric disease and regarding the values of DMSA renal scan in evaluation of renal parenchyma, the incidence of this scan is highest among the scintigraphic renal studies. The contribution of renal, bone and thyroid examinations to the total number of examinations are calculated to be 38.2%, 27.4% and 26.7% respectively. However, among the three most frequent examinations, bone with a relative frequency of 27.4% contributes 48.8% to the collective  $H_E$  which reflects the higher absorbed dose per examination for this procedure.

procedure.

The mean effective dose per examination for patients younger than 15 years of age was 67.9% of the adults, which is in agreement with the requirements of radiation burden in children as compared to adults.<sup>18</sup>

Our data regarding the total diagnostic nuclear medicine procedures (5.26%), collective  $H_E$  (3.96%) and mean effective dose per patient (3.75 mSv) in the pediatric patients of Tehran resemble the findings of a study performed on Czech pediatric population in 1995.<sup>18</sup>

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