

**POPULATION EXPOSURE FROM DIAGNOSTIC NUCLEAR
MEDICINE PRACTICE: 2000 UPDATE**

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Abstract. This survey represents a update of the Romanian population exposure from *in vivo* diagnostic nuclear medicine procedures, focused on the year 2000. The new estimates are: 3.2 for the average annual number of diagnostic nuclear medicine procedures per 1000 population, 12.7 mSv a⁻¹ for the average effective dose per patient undergoing diagnostic nuclear medicine procedures, 910 man Sv for the annual collective effective dose and 40 µSv for the annual effective dose per capita. As in previous surveys conducted during 1990 and 1995, the most important examination both, by frequency and contribution to annual collective dose, was the thyroid investigation. Although the frequency of the ^{99m}Tc use has increased since the last survey (1995) by 44 per cent, ¹³¹I is still the radionuclide of choice for more than 50% of thyroid investigations, imparting continuously high doses to patients.

Key words: diagnostic nuclear medicine, radiopharmaceuticals, effective dose.

Rezumat. Prezentul studiu reevaluează expunerea populației României ca urmare a utilizării în scop diagnostic a radiofarmaceuticelor. În anul 2000, în România, s-au efectuat în medie 3,2 proceduri de medicină nucleară diagnostică *in vivo* la 1000 de locuitori, doza efectivă anuală pentru pacientul mediu s-a estimat la 12,7 mSv, doza efectivă colectivă anuală la 910 om Sv, iar doza efectivă *per capita* la 40 µSv. Ca și în ultimele două studii naționale, efectuate în cursul anilor 1990 și 1995, în prezentul studiu, examenul dominant de medicină nucleară diagnostică, ca frecvență și contribuție la doza colectivă, îl reprezintă investigația tiroidiană. Deși frecvența de utilizare a ^{99m}Tc a crescut în anul 2000 cu 44% față de cea raportată în 1995, totuși, ¹³¹I continuă să fie radionuclidul de elecție pentru mai mult de 50% din procedurile de medicină nucleară diagnostică adresate tiroidei, furnizând pacienților doze ridicate de radiații ionizante.

Cuvinte cheie: medicină nucleară diagnostică, radiofarmaceutice, doză efectivă.

INTRODUCTION

According to our last national study on population exposures from natural and artificial sources of ionizing radiation, 16% of overall annual collective effective dose represent the contribution of diagnostic medical exposures (1). 92 per cent from these medical exposures is due to diagnostic X-ray examinations and only 8 per cent arise from diagnostic nuclear medicine procedures. This small contribution to

collective dose is mainly the result of their lower frequency compared to that of the X-ray examinations, doses delivered to patients being, on average, ten times higher (2).

The purpose of this paper was to reassess the population exposure from *in vivo* diagnostic nuclear medicine procedures and to evaluate the temporal trends of diagnostic usage of radiopharmaceuticals in Romania.

The current survey is the third one conducted in the last decade. As in the previous ones (1990 and 1995), the basic information have been collected by the Radiation Hygiene Laboratories Network of the Ministry of Health and Family (2,3).

METHODS

The methods used to estimate the population exposure from in vivo diagnostic nuclear medicine procedures performed annually in Romania were described previously (2,3).

Information on the age and sex distribution of patients, frequency of procedures and typical activities of radiopharmaceuticals administered to patients were provided by a survey conducted in a four weeks time period at nuclear medicine units deserving more than one third of the Romanian population. The resulted data were extrapolated to the overall diagnostic nuclear medicine practice reported to

Ministry of Health and Family by hospitals with nuclear medicine departments.

Effective doses per procedure, for each type of administered radiopharmaceutical, were derived by multiplying the average activities of administered radionuclides by the appropriate dose conversion factors (4). Annual collective doses were calculated from individual effective dose per procedure and total number of procedures of each type. By dividing the total annual collective dose to entire population of Romania in 2000, annual effective dose per capita was calculated (5).

RESULTS AND DISCUSSION

Annual numbers of diagnostic administrations of radiopharmaceuticals in 2000, the distribution by age and sex of patients are summarized in Table 1 by type of procedures and for all diagnostic nuclear medicine practice.

Table 1. Distribution by age and sex of patients undergoing diagnostic nuclear medicine procedures

Examination	Patients examined in 2000 No %		Age and sex distribution of patients (%)				
			0-15 years	16-40 years	>40 years	M	F
Brain scan	876	1.2	-	14.8	85.2	58.1	41.9
Thyroid scan	29476	41.1	0.9	30.2	68.9	7.6	92.4
Thyroid uptake	14305	20.0	-	33.6	66.4	5.9	94.1
Lung scan (perfusion)	347	0.5	-	8.7	91.3	55.6	44.4
Cardiovascular	1555	2.2	-	9.7	90.3	49.3	50.7
Liver / spleen scan	7344	10.2	1.2	12.0	86.8	54.5	45.5
Renal scan	6740	9.4	3.5	22.5	74.0	36.3	63.7
Bone scan	10607	14.8	2.1	17.7	80.2	47.1	52.9
Gastroenterology	266	0.4	-	43.2	56.8	56.4	43.6
Other	114	0.2	-	37.7	62.3	30.4	69.7
All examinations	71640	100	1.2	25.8	73.0	23.0	77.0

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The annual total administrations was 71,640, what corresponds to a frequency of approximately 3.2 of *in vivo* nuclear medicine procedures per thousand of population. It is generally less than figures reported for most other developed countries, classified by the UNSCEAR 2000 Report in health care level one, on average 18.8 mSv procedures per 1000 population (6). Thyroid investigations are the most important type of procedure accounting for more than 60 per cent of all diagnostic nuclear medicine examinations performed in 2000. Approximately three quarters of procedures are performed on patients of over 40 years old and only 1.2 per cent on children.

Some differences in age distribution of patients are evident for each type of examination. More than 90 % of lung

and cardiovascular investigations performed on older patients while, particularly renal and bone scans conducted on children.

Regarding the distributions of diagnostic nuclear medicine examinations between sexes, 77% of procedures performed on women, the most investigated organs being thyroid (92%), kidneys (64%) and bones (53%). Only 23 % of procedures performed on men, particularly brain (58%), gastrointestinal tract (GIT) (56.4%) and lung (55.6%) scans.

Annual number of administrations, average administered activities and dose conversion factors per radionuclide and radiopharmaceutical used are presented in Table 2, for each type of diagnostic nuclear medicine procedure.

Table 2. Total annual administrations and the average administered activity per diagnostic nuclear medicine examination

Examination	Radio nuclide	Pharmaceutical	No of administrations	Average administered activity (MBq)	Effective dose factor (mSv/MBq)
Brain scan	^{99m} Tc	DTPA	530	500 ± 130	5.2 10 ⁻³
		Pertechnetate	346	700 ± 60	1.2 10 ⁻²
Thyroid scan	^{99m} Tc	Pertechnetate	21,350	195 ± 120	1.2 10 ⁻²
	¹³¹ I	Nal	8,126	1.35 ± 1.0	24
Thyroid uptake	¹³¹ I	Nal	14,305	1.35 ± 1.0	24
Lung scan (perfusion)	^{99m} Tc	MAA	208	100 ± 20	1.1 10 ⁻²
		Pertechnetate	139	285 ± 120	1.2 10 ⁻²
Cardiovascular	^{99m} Tc	Pertechnetate	1275	800 ± 360	1.2 10 ⁻²
		RBC	116	740 ± 60	6.6 10 ⁻³
		MIBI	164	740 ± 80	8.5 10 ⁻³
Liver/spleen scan	^{99m} Tc	Pertechnetate	5,497	160 ± 70	1.2 10 ⁻²
		Colloid	1,847	160 ± 35	9.7 10 ⁻³
Renal scan	^{99m} Tc	Pertechnetate	1,542	265 ± 140	1.2 10 ⁻²
		DTPA	4,691	800 ± 650	5.3 10 ⁻³
		Glucoheptonate	517	185 ± 50	5.8 10 ⁻³
Bone scan	^{99m} Tc	Pertechnetate	8,745	665 ± 150	1.2 10 ⁻²
		MDP	1,862	610 ± 170	5.8 10 ⁻³
Gastroenterology (GIT)	^{99m} Tc	Pertechnetate	266	185 ± 85	1.4 10 ⁻²
Other	^{99m} Tc	Pertechnetate	114	170 ± 100	1.2 10 ⁻²
All examinations			71,650		

As can be seen, ^{99m}Tc is now the radionuclide of choice and the pertechnetate is used in all type of imaging nuclear procedures. That is because, since 1997, the ^{99m}Tc -ROMTEC generator made in Romania is available (7). At the present time, most of nuclear medicine departments are provided with such equipment. The total activity of ^{99m}Tc used in 2000 for diagnostic purposes was estimated at 18,450 GBq. ^{131}I is still used in thyroid investigations and its

total activity in diagnostic administrations was estimated at 35 GBq. The average values of typical administered activities reported for diagnostic tests (Table 2) corresponded reasonably well with “maximum usual activity per test” recommended as guidance levels by the IAEA in Basic Safety Standards (8). Both resulting effective doses, individual and collective, associated with diagnostic nuclear medicine procedures are given in Table 3.

Table 3. Average annual exposures from diagnostic nuclear medicine procedures

Examination	Radio nuclide	Pharmaceutical	Individual effective dose (mSv)		Annual collective effective dose (man Sv) (%)	
			arithmetic	weighted averages		
Brain scan	^{99m}Tc	DTPA Pertechnetate	2.6 ± 0.2 8.4 ± 2.2	4.9	1.38 2.91	0.5
Thyroid scan	^{99m}Tc ^{131}I	Pertechnetate NaI	2.4 ± 1.5 32.4 ± 24	10.6	50 263	34.4
Thyroid uptake	^{131}I	NaI	32.4 ± 24	32.4	463	50.9
Lung scan (perfusion)	^{99m}Tc	MAA Pertechnetate	3.4 ± 0.7 1.1 ± 0.5	1.8	0.47 0.16	0.07
Cardiovascular	^{99m}Tc	Pertechnetate RBC MIBI	9.6 ± 4.3 4.9 ± 0.4 6.3 ± 0.7	8.9	14.5 0.57 1.03	1.5
Liver/spleen scan	^{99m}Tc	Pertechnetate Colloid	1.9 ± 0.8 1.6 ± 0.4	1.7	10.4 1.79	1.3
Renal scan	^{99m}Tc	Pertechnetate DTPA Glucoheptonate	3.2 ± 1.7 4.3 ± 3.5 1.1 ± 0.3	3.8	4.93 20.2 0.57	2.8
Bone scan	^{99m}Tc	Pertechnetate MDP	8.0 ± 1.8 3.5 ± 1.0	7.2	70 6.52	8.4
Gastroenterology	^{99m}Tc	Pertechnetate	2.6 ± 1.2	2.6	0.69	0.08
Other	^{99m}Tc	Pertechnetate	2.0 ± 1.2	2.0	0.29	0.03
All examinations Per capita				12.7 0.04	910	100

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The choice of radionuclide (dependent on the availability of radionuclides with short half-life) has a very important influence on the radiation burden of patient. For example, a thyroid examination performed with ^{99m}Tc causes a mean effective dose of 2.4 mSv, while, performed with ¹³¹I (NaI), is over ten fold higher (32.4 mSv). The choice of radiopharmaceutical is very important, too. As can be seen in Table 3, effective dose received by patients during lung scan conducted with ^{99m}Tc MAA (3.4 mSv), is three times higher than that performed with ^{99m}Tc pertechnetate (1.1mSv).

Fig 1 illustrates the weighted average effective dose by the common types

of diagnostic nuclear medicine procedures. Thyroid uptake is associated with highest effective dose. It could be an overestimation because a thyroid uptake value of 35% was assumed in dose calculation. On the second place as dimension of dose received by patients is thyroid scan. The weighted average effective dose for thyroid scan is three times lower (10.6 mSv) than that received during thyroid uptake due to the fact that, in 2000, 72% of the total annual thyroid scans were performed with ^{99m}Tc. Cardiovascular investigations (8.9 mSv) and bone scans (7.2 mSv) are the following procedures imparting high enough doses to patients.

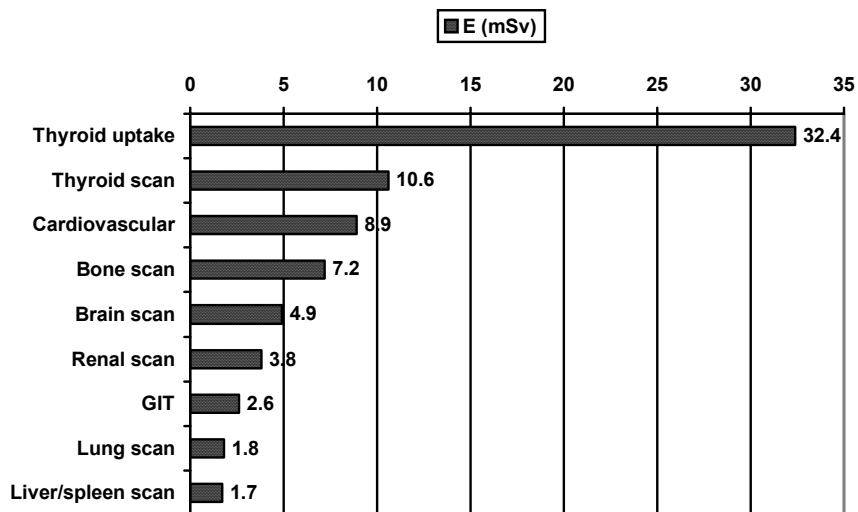


Fig. 1 Patient –weighted average effective doses resulted from various types of diagnostic nuclear medicine procedures

The annual average effective dose per patient (Table 3) from all in vivo diagnostic nuclear medicine practice was 12.7 mSv, that is approximately

three times higher than the average value reported by countries in health care level one (6).

The corresponding annual collective effective dose was estimated at 910 manSv, and the resulted annual effective dose per capita at 0,040 mSv.

The contribution to the annual collective dose of various types of diagnostic nuclear medicine procedures and their annual frequencies is illustrated in Fig.2.

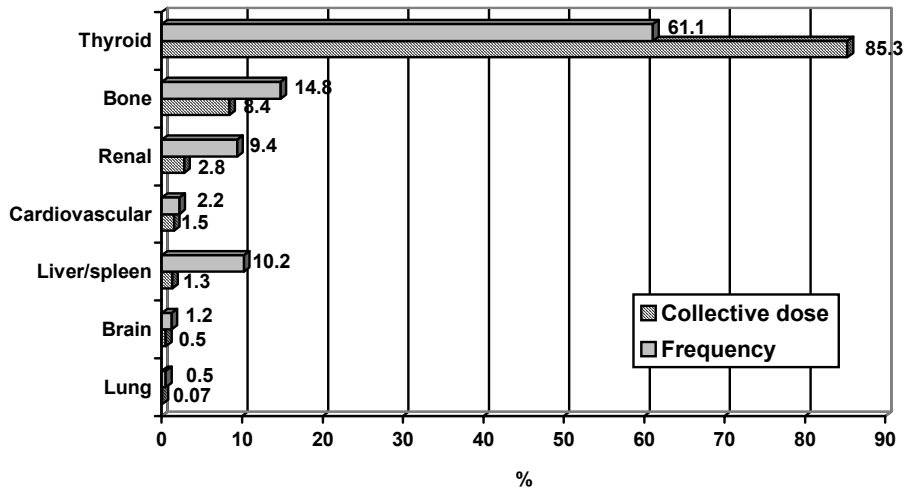


Fig. 2 Contributions to frequency and annual collective dose from the various types of diagnostic nuclear medicine procedures

As Fig 2 shows, 96.5 per cent of the annual collective dose come from three types of investigations, the most frequently carried out in 2000: thyroid studies (85.4%), bone scans (8.4%) and renal scans (2.8%), the contributions of cardiovascular, liver

and brain investigations being less important, 1.5%, 1.3% and 0.5%, respectively.

The relative contribution of administered radionuclides to the annual collective dose is illustrated in Fig 3.

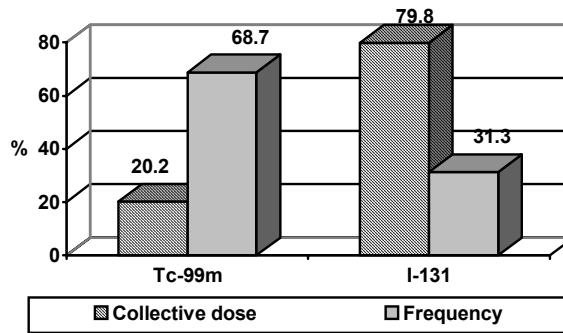


Fig. 3 Contributions of administered radionuclides to annual collective dose and their frequency of use

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Approximately 80% of overall collective dose is due to ^{131}I (NaI), although its frequency of use is about 31%. The contribution of $^{99\text{m}}\text{Tc}$ labeled compounds is four times smaller, although the current survey found that about 69% of total diagnostic nuclear medicine procedures were performed with $^{99\text{m}}\text{Tc}$.

Based both on previously published data (2,3) and the present ones, the trends of diagnostic nuclear medicine practice are analyzed in Table 4.

In the last decade, the Romanian population decreased by 3 per cent while the number of diagnostic nuclear medicine procedures per 1000 inhabitants increased in 2000 by 19% since 1990 and only by 7% since 1995.

The age and sex distributions of patients shown that, in 2000, the diagnostic nuclear medicine procedures were carried-out on older age groups in a larger proportion than in 1990 (23%) and 1995 (15%). At the same time, the annual number of investigations performed on children decreased continuously, as a result of the new imaging techniques available in Romania. The number of investigations performed on females over 40 y increased significantly, by 45% since 1990 and 21% since 1995.

Regarding to the annual frequencies of examinations, thyroid continues to be the most frequently investigated organ, particularly on females. The number of bone scans performed in 2000 increased by 22 % since 1995, while the number of renal scans remained quite constant. Numbers of

liver, brain and lung scans performed in 2000 decreased as compared with those in 1995 by 61%, 66% and 50% respectively. This was mainly the result of their replacement by other imaging modalities such as CT or MRI. On the other hand, the number of cardiovascular investigations increased by a factor of about 3, since 1995.

The annual collective dose resulted from diagnostic nuclear medicine practice in 2000 was of 910 manSv, that means that it dropped by about 20% as compared with the value associated to year 1995. At the same time, the average effective dose received by an average patient from overall diagnostic nuclear medicine practice of the year 2000, 12.7 mSv, decreased by 22% since 1995.

As shown in Table 4, in diagnostic nuclear medicine practice in 2000, the two most important radionuclides were: $^{99\text{m}}\text{Tc}$, the use of which increased by 44 per cent since 1995 and ^{131}I , the use of which decreased by 38 per cent but which still contributes much to the collective dose (about by 80%). The contribution of $^{99\text{m}}\text{Tc}$ to the annual collective dose increased since 1995 by three times and, in comparison with 1990, by six times. Liver scans performed with ^{198}Au , virtually disappeared in 2000. The increase of $^{99\text{m}}\text{Tc}$ usage, the decrease of the ^{131}I usage and the disappearance of ^{198}Au from diagnostic nuclear medicine practice in 2000 explains the decrease of the present annual collective dose by about 20%, although the frequency

Table 4. Temporal trends in diagnostic nuclear medicine in Romania

		2000	1995	1990	Ratios 2000/ 1995 2000/1990		
Population (thousands)		22,458	22,681	23,152	0.99	0.97	
Number of examinations		71,640	68,584	61,420	1.04	1.17	
Number of examinations/1000 inhabitants		3.2	3.0	2.7	1.07	1.19	
Age distribution of patients (%)	0-15	1.2	3.2	4.3	0.38	0.29	
	16-40	25.8	33.4	36.2	0.77	0.71	
	>40	73.0	63.4	59.5	1.15	1.23	
Sex distribution of patients (%)	Male	23	36	47	0.63	0.49	
	Female	77	64	53	1.21	1.45	
Frequency of examinations (%)	Thyroid	61.1	47.2	45.3	1.29	1.36	
	Bone	14.8	12.1	2.4	1.22	6.17	
	Liver/Spleen	10.2	26.0	40.8	0.39	0.25	
	Kidney	9.4	9.4	2.9	1.0	3.24	
	Cardiovascular	2.2	0.7	0.6	3.14	3.70	
	Brain	1.2	3.4	7.4	0.34	0.16	
	Lung	0.5	1.0	0.6	0.50	0.83	
Effective doses	Collective (man Sv)	910	1124	1330	0.81	0.68	
	Average patient (mSv)	12.7	16.2	22.0	0.78	0.58	
	Per capita (μ Sv)	40	49	58	0.82	0.68	
Frequency of radionuclide use (%)	^{131}I	31.3	50.2	44.2	0.62	0.71	
	$^{99\text{m}}\text{Tc}$	68.7	47.7	40.2	1.44	1.71	
	^{198}Au	-	2.1	15.6	-	-	
Contribution to collective dose (%)	Radionuclide	^{131}I	79.8	92.2	89.6	0.86	0.89
		$^{99\text{m}}\text{Tc}$	20.2	6.5	3.5	3.11	5.77
		^{198}Au	-	1.3	6.9	-	-
	Procedure	Thyroid	85.3	93.4	81.4	0.91	1.05
		Bone	8.4	2.5	0.3	3.36	28
		Renal	2.8	0.3	0.2	9.33	14
		Cardiovascular	1.5	0.3	0.2	5.0	7.5
		Liver	1.3	3.3	7.9	0.39	0.16
Brain	0.5	0.4	1.8	1.25	0.28		

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of examinations (in terms of annual number per 1000 inhabitants) increased by 7% since 1995.

The analysis of contributions of various types of diagnostic nuclear medicine procedures to collective dose indicated that thyroid investigation is still the largest contributor, but, since 1995, its contribution to collective dose decreased by 9 percent.

Comparisons of data regarding to bone, cardiovascular and renal examinations performed in 2000 and 1995 indicated a significant increase of their contributions to collective dose by factors of about 3, 5, and 9, respectively.

According to information summarized in Table 4, the situation of diagnostic nuclear medicine practice in 2000 appear to be better than in 1995 and 1990, but it must be improved continuously.

CONCLUSIONS

The analyses of presented data supports the following conclusions.

1. In 2000, the number of in vivo diagnostic nuclear medicine procedures per 1000 population was estimated at 3.2, that is higher than in 1995 by 7%.
2. The resulted annual collective effective dose was estimated at 910 manSv and the corresponding annual effective dose per capita, at 40 μ Sv. These values are by about 20 per cent lower than similar values estimated for 1995.
3. Thyroid investigations and ^{131}I (NaI) is still the most important contributor to the annual collective effective dose.
4. The effective dose per average patient from overall diagnostic nuclear medicine practice in Romania in 2000 was estimated at 12.7 mSv, that is three times higher than the average value for countries in health care level one.
5. In 2000, the frequency of usage of $^{99\text{m}}\text{Tc}$ labeled compounds increased to about 70%, contributing by 20% to the annual collective dose.
6. The usage of ^{198}Au colloid in liver scan, continuously decreased since 1990, being replaced in 2000 by $^{99\text{m}}\text{Tc}$ or other imaging technique.

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