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RADIATION RISK TO PATIENTS FROM NUCLEAR MEDICINE PROCEDURES IN CUBA.

Brígido, O.[1], Barreras, A.[2], Montalván, A.[1], Hernández, J.[2]

[1] Centro de Ingeniería Ambiental de Camagüey (CIAC)
[2] Oncological Hospital " Marie Curie

ABSTRACT

Man-made radiation exposure to the Cuban population predominantly results from the medical use of ionizing radiation. It was therefore the aim of the present study, to provide public health information concerning diagnostic nuclear medicine procedures carried out in Camagüey and Ciego de Ávila provinces between 2000 and 2005. Population radiation dose estimation due to administration of radiopharmaceuticals in Camagüey and Ciego de Ávila provinces was carried out using Medical Internal Radiation Dose scheme (MIRD). Data were gathered on the type of radiopharmaceuticals used, the administered activity, the numbers of each kind of examination, and the age and sex of the patients involved during the period 2000 – 2005. The average annual frequency of examinations was estimated to be 3.34 per 1000 population. The results show that imaging nuclear medicine techniques of thyroid and bone explorations with 13.3 and 12.9%, respectively and iodide uptake with 50% are the main techniques implicated in the relative contribution to the total annual effective collective dose which averaged 95 man·Sv for the studied period. Radiation risks for the Camagüey-Ciego de Avila population caused by nuclear medicine examinations in the period studied were calculated: the total number of fatal and non-fatal cancers was 34.2 and the number of serious hereditary disturbance was 7.4 as a result of 24139 nuclear medicine procedures, corresponding a total detriment of 1.72 per 1000 examination.

1. INTRODUCTION

The use of radionuclides in medical practice, either for diagnosis or for treatment, has grown steadily in recent years due to the introduction of new radiopharmaceuticals and equipment and its use contributes significantly to the radiation exposure of individuals and populations. The annual population doses from medical exposure have been reported in developed and in some developing countries [1,2,3]. According to the UNSCEAR Reports 2000 and 2008 [2,3], diagnostic exposures are characterized by relatively low doses to individual patients (effective doses are typically in the range 0.1-10 mSv) that in principle are sufficient to provide the required clinical information, although the resulting collective doses to populations are significant. It has become common to quantify the patient's exposures in terms of the effective dose [4], but in nuclear medicine this dose can only be assessed indirectly via known amount and types of administered radiopharmaceuticals. Overall, diagnostic practices with radiopharmaceuticals remain small in comparison with the use of x rays; the annual numbers of nuclear medicine procedures and their collective dose are only 2% and 6%, respectively, of the corresponding values for medical x rays. How ever, the mean dose per procedure is larger for nuclear medicine (4.6 mSv) than for medical x rays (1.2 mSv) [2,3]. On the other hand, collective dose from medical exposures is an important quantitative

[1] E-Mail del autor. O.Brigido@ciac.cu

feature of the radiation effect on a population. Information about this collective dose allows determining of the contribution of diagnostic examinations to the mean population dose caused by natural and technological sources as well as an evaluation of the additional radiation risk of oncological diseases and hereditary effects in their descendants.

Surveys of population doses derived from medical procedures have been conducted in several countries [2,3], but in Cuba this information has been scarce or non-existent. We thus decided to undertake a survey of nuclear medicine procedures in the Provinces of Camagüey and Ciego de Avila, in order to help establish reference levels for nuclear medicine patients in this region. In order to determine an average annual effective dose and collective effective dose, and subsequently the resulting radiation detriment in terms of the expected additional number of cancer cases and hereditary abnormalities, data were gathered on the type of radiopharmaceuticals used, the administered activity, the numbers of each kind of examination, and the number of the patients involved during the period 2000 – 2005, from above mentioned provinces.

2. MATERIALS AND METHODS

The studies were conducted on the basis of statistics from nuclear medicine examinations carried out by nuclear medicine service of Camagüey from 2000 to 20005 to 1.2 million population of Camagüey and Ciego de Avila provinces, taking into account type, frequency and radiopharmaceutical used. In order to estimate the effective dose and effective collective dose use was made of the values of effective dose per unit administered activity, which were published by Stabin, Stubbs & Toohey [5,6] and Stabin [7] and of average activity per type of examination. On the basis of above-mentioned data estimations were made of the frequency of examinations and the relative contribution (%) of each procedure to the total effective collective dose. In the paper are also estimated the total effective collective dose (man·Sv), per caput effective dose (mSv), and finally, the detriment caused to patients undergoing these examinations, for which use was made of the values of nominal probability coefficients for stochastic effects which were published in the ICRP-60 [8].

3. RESULTS AND DISCUSSION

The annual average frecuency per type of examinations performed by nuclear medicine service of Camagüey in the period studied is illustrated in Figure 1 and Table 1 shows the frequency per type of examinations.

The studies indicate an increase in the use of such examinations a value 4.6 times as high as that reported for Cuba in 1970’s [1,3]. These results show annual values of frequency similar for all period, except for the year 2005, in which it was 1.89 examinations per 1000 population. The annual average frequency for whole period has been estimated to be 3.34 examinations per 1000 population.

The percentage of each type of diagnostic nuclear medicine procedure differs substantially not only from country to country but intra-country. Table 1 shows that procedures done with

^{131}I constitute the 79% of procedures performed in Camagüey while 21% of the rest of the scans were done using ^{99m}Tc. Marcos [9] reported statistic concerning nuclear medicine examinations in Pinar del Río, Cuba, for the years 1991 through 1995, values that are similar to those reported in this paper. However, ^{131}I imaging constitutes a small percentage of procedures in the United States and many developed countries [1,2,3].

Table 1:Frequency of nuclear medicine procedures in Camagüey and Ciego de Avila Territory (2000-2005).

Examination	Frequency per 1000 population						
	2000	2001	2002	2003	2004	2005	Annual average
Imaging							
Brain	0.12 (3.0)[a]	0.14 (4.0)	0.15 (3.9)	0.11 (3.3)	0.10 (2.7)	0.07 (3.9)	0.12 (3.4)
Bone	0.53 (13.3)	0.45 (13.1)	0.52 (14.0)	0.41 (12.3)	0.49 (13.4)	0.27 (14.2)	0.45 (13.3)
Thyroid [(b)]	0.49 (12.4)	0.39 (11.2)	0.50 (13.4)	0.50 (14.8)	0.45 (12.4)	0.25 (13.1)	0.43 (12.9)
Thyroid metastases (after ablation) [(b)]	0.21 (0.5)	0.19 (5.6)	0.17 (4.5)	0.16 (4.7)	0.17 (4.5)	0.09 (4.7)	0.16 (4.9)
Liver	0.019 (2.2)	0.015 (0.43)	0.012 (0.3)	0.016 (0.5)	0.027 (0.7)	0.007 (0.4)	0.016 (0.5)
Kidney	0.12 (3.0)	0.13 (3.9)	0.10 (2.8)	0.09 (2.7)	0.09 (2.5)	0.05 (2.4)	0.10 (2.9)
Salival glands	0.01 (0.25)	0.006 (0.17)	0.004 (0.11)	0.007 (0.22)	0.009 (0.25	0.002 (0.13)	0.007 (0.19)
Biliary system	0.009 (0.23)	0.006 (0.17)	0.003 (0.09)	0.005 (0.15)	0.002 (0.05)	0.001 (0.04)	0.004 (0.13)
Lymphatics node	0.002 (0.04)	0.001 (0.02)	0.002 (0.07)	0.001 (0.02)	0 (0)	0 (0)	0.001 (0.03)
Whole body	0.005 (0.13)	0.003 (0.10)	0.002 (0.07)	0.004 (0.12)	0.002 (0.05)	0.001 (0.04)	0.003 (0.09)
Oesophageal reflux	0.001 (0.02)	0 (0)	0.001 (0.02)	0 (0)	0 (0)	0 (0)	0.0003 (0.01)
Breast	0.008 (0.19)	0.006 (0.17)	0.010 (0.27)	0.005 (0.15)	0.008 (0.23)	0.002 (0.13)	0.007 (0.19)
Non_imaging							
Renal function [2]	0.38 (9.6)	0.25 (7.2)	0.52 (13.9)	0.41 (12.1)	0.35 (9.6)	0.43 (22.8)	0.39 (11.6)
Thyroid uptake [2]	2.07 (52.1)	1.86 (53.9)	1.73 (46.6)	1.65 (49.1)	1.97 (53.6)	0.72 (38.2)	1.67 (49.9)
Total	3.98 (100)	3.45 (100)	3.72 (100)	3.36 (100)	3.67 (100)	1.89 (100)	3.34 (100)

[(a)] Relative contribution in percent.
[(b)] Procedures performed using pharmaceuticals labeled with ^{131}I.

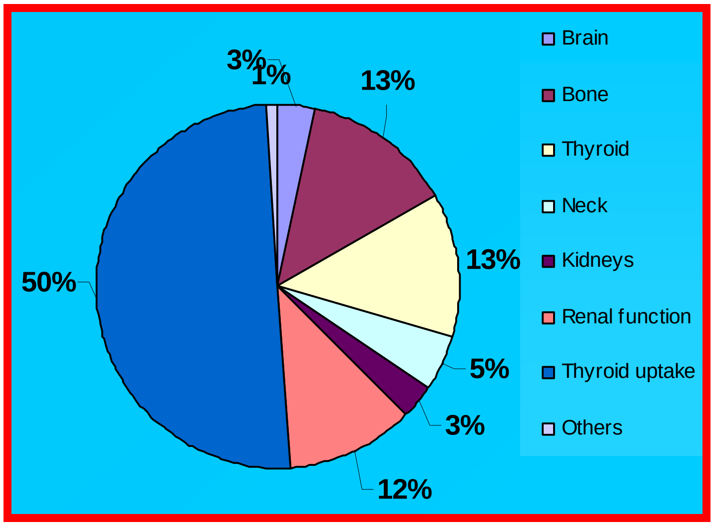

Figure 1: Annual frecuency of nuclear medicine examinations (Camagüey-Ciego de Ávila, 2000-2005).

A comparison between the nuclear medicine examinations in Camagüey and those in some other countries is shown in Table 2. Similar trends have been reported in countries with levels of health care equal to our own [10-13], but it has been found that there are some differences between various nuclear medicine services in Cuba as to the number of patients examined, the type of examinations, and also the administered activity of radiopharmaceuticals for the same examination. The reasons for such variation are not known, but they may include training of the staff and, possibly, sensitivity of equipment.

Table 2.: Comparison of total annual number of nuclear medicine examinations per 1000 population in Camagüey-Ciego de Avila, Cuba and some other countries with different health care levels [2,3,10].

Country	Number of examinations per year per 1000 population	Country	Number of examinations per year per 1000 population
Taiwan (1991-1996)	6.6	United Kingdom (1991-1996)	8.2
Germany (1991-1996)	34.1	Australia (1991-1996)	12.0
Belgium (1985-1990)	36.8	Cyprus (1991-1996)	6.6
USA (1991-1996)	31.5	USSR (1980-1985)	3.9
Czechoslovakia (1985-1990)	22.9	Ethiopia (1991-1996)	0.014
Japan (1991-1996)	11.7	Turkey (1991-1996)	2.1
Canada (1991-1996)	64.6	Brazil (1991-1996)	1.1
Argentina (1991-1996)	11.1	China (1985-1990)	0.6
France (1985-1990)	6.9	India (1985-1990)	0.2
Finland (1991-1996)	10.0	Camagüey, CUBA (2000-2005)	3.3

Administered activity for a given examination is also shown in Table 3 and there are some differences between nuclear medicine services in the average activity used for certain examination. The values shown in Table 3 are compared with those reported in other countries and in other services in Cuba [9,14].

Table 3: Radionuclide, radiopharmaceutical and mean administered activity per examination used in Camagüey, Cuba.

Examination	Radionuclide	Radiopharmaceutical	Mean activity, MBq	Other issues, MBq
Imaging				
Brain	^{99m}Tc	DTPA	740	500 [1,4] 740 [9] (370-516) [15]
Bone	^{99m}Tc	MDP	740	600 [1,4] 740 [9] (182-740) [15]
Thyroid	^{131}I	Iodide	3.7	3.7 [9] (1.7-11.1) [15]
Thyroid metastases (after ablation)	^{131}I	Iodide	74	400 [1,4] 74 [9]
Liver	^{99m}Tc	Colloid	222	80 [1,4] 111 [9] (37-296) [15]
Kidney	^{99m}Tc	DMSA	222	(160-350) [1,4] 74 [9] (74-740) [15]
Salival glands	^{99m}Tc	Pertechnetate	222	40 [1,4]
Biliary system	^{99m}Tc	DISIDA	222	150 [1,4] 140 [2]
Lymphatics node	^{99m}Tc	Pertechnetate	222	80 [1,4] 185 [9]
Whole body	^{99m}Tc	DMSA	555	-
Oesophageal reflux	^{99m}Tc	Pertechnetate	37	40 [1,4]
Breast	^{99m}Tc	MIBI	700	-
Non_imaging				
Renal function	^{131}I	Hippuran	0.6÷1.1	1.5[9] (1.1-1.5) [15]
Thyroid uptake	^{131}I	Iodide	0.93	0.8 [2] 0.93 [9] (0.11-10) [15]

Table 4: Annual and total effective collective dose for 2000-2005 (man·Sv).

Examination	Radionuclide (Radiopharmaceutical)	Effective dose per examination, (mSv)	Annual effective collective dose (man·Sv)						
			2000	2001	2002	2003	2004	2005	Average
Imaging									
Brain	^{99m}Tc (DTPA)	3.63	0.52	0.61	0.64	0.48	0.43	0.32	0.50
Bone	^{99m}Tc (MDP)	4.22	2.67	2.31	2.65	2.10	2.48	1.36	2.26
Thyroid	^{131}I (Iodide)	88.8	52.48	41.56	53.46	53.19	48.31	26.46	45.91
Thyroid metastases (after ablation)	^{131}I (Iodide)	5.92	1.51	1.37	1.19	1.12	1.18	0.63	1.17
Liver	^{99m}Tc (Colloid)	2.09	0.05	0.04	0.03	0.04	0.07	0.02	0.04
Kidney	^{99m}Tc (DMSA)	1.95	0.28	0.32	0.24	0.21	0.22	0.11	0.23
Salival glands	^{99m}Tc (Pertechnetate)	2.89	0.03	0.02	0.01	0.03	0.03	0.01	0.02
Biliary system	^{99m}Tc (DISIDA)	3.77	0.04	0.03	0.02	0.02	0.01	0.00	0.02
Lymphatics node	^{99m}Tc (Pertechnetate)	2.89	0.01	0.00	0.01	0.00	0.00	0.00	0.00
Whole body	^{99m}Tc (DMSA)	4.88	0.03	0.02	0.01	0.02	0.01	0.00	0.02
Gastroesephageal reflux	^{99m}Tc (Pertechnetate)	0.48	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Breast	^{99m}Tc (MIBI)	6.30	0.06	0.04	0.08	0.04	0.06	0.02	0.05
Non_imaging									
Renal function	^{131}I (Hippuran)	0.06	0.03	0.02	0.04	0.03	0.02	0.03	0.03
Thyroid uptake	^{131}I (Iodide)	22.32	55.33	50.11	46.67	44.39	52.65	19.37	44.76
Total (man·Sv)			113.03	96.44	105.04	101.68	105.47	48.34	95.00
Per capita (μSv)			94.37	79.97	87.01	84.22	87.89	40.05	78.92

Values of effective dose per examination, effective collective dose and effective dose per caput are shown in Table 4. Those values are some different to those reported in previous surveys carried out in this nuclear medicine service [15-17], due to the use of effective dose instead of effective dose equivalent. These quantities may generally differ for the same type of examination under the same irradiation conditions as much as 50% in some cases [5-7].

The relative contribution to the total average annual collective dose of different procedures is illustrated in Table 4. This table shows that the average collective effective dose for all diagnostic nuclear medicine procedures in Camagüey-Ciego de Avila territory has been estimated at 95 man·Sv per year (78.9 μSv per year per caput); 48.3% of which concerned thyroid explorations (45.9 man·Sv per year); 47% iodide uptake (44.7 man·Sv per year); 2,4% bone explorations (2.3 man·Sv per year) and the rest 2.3% concerned remaining procedures. The percentages of collective effective dose attributable to different radionuclides in Cienfuegos and Pinar del Río territories, Cuba, have been reported by Usugaua & Santander [14] and Marcos [9], respectively. First authors [14] indicate that thyroid explorations and iodide uptake constitute the largest percentages of the total effective collective dose, while Marcos [9] report neck examinations and thyroid explorations as the largest ones. The effective collective dose decrease for year 2005. Such trend is due to the decrease of number of examinations from 4763 in 2000 to 1885 in 2005. As mentioned before the value for the collective effective dose for all the period has been estimated at 95 man·Sv per year which represents an annual per caput dose of 78.9 μSv. This latest dose is obtained from the total doses from all examinations and is similar to that reported by Usugaua & Santander [14] and Marcos [9]. A comparison between the effective dose per caput in Camagüey and those in some other countries is shown in Table 5.

Table 5: Comparison between effective dose per capita in Camagüey-Ciego de Avila Territory (Cuba) and those reported in other countries [2].

Country	Year	Effective dose per capita (μSv a^{-1})	Country	Year	Effective dose per capita (μSv a^{-1})
China	1981	5	Manitoba, Canada	1981-1985	130
USSR	1981	34	Netherlands	1984-1985	37
Poland	1981	57	United Kingdom	1988	20
Finland	1982	90	Australia	1991	64
United States	1982	140	Taiwan	1992-1993	29
United Kingdom	1982	17	Cyprus	1990-1992	18
Sweden	1983	60	Camagüey, Cuba	1995-1999	79

Procedures which more contribute to the effective collective dose imparted to patients are shown in Table 7 and are compared with those reported in other countries. The average per caput dose to patients reported for our territory is 3-5 times higher than that reported for most developed countries [1-3] and similar to that reported for developing ones due to the more expanded use in our country of longer-lived radionuclides. For example, ^{99m}Tc has a short physical half-life, making the dose of the pharmaceutical lower than that of a similar pharmaceutical labeled with ^{131}I. But only 21% of all procedures were performed using pharmaceuticals labeled with technetium in the period studied. Therefore, it is necessary to increase the use of pharmaceutical labeled with ^{99m}Tc in order to reduce the doses administered to the patient.

Table 6: Effective dose to patients due to diagnostic nuclear medicine examinations in Camagüey-Ciego de Avila territory, (mSv) and those reported in other countries [2].

Examination	Level I of health care			Level II of health care	
	Czechoslovakia, 1987	Denmark, 1990	Italy, 1989	China, 1985	Camagüey, Cuba (2000-2005)
Brain Scan	3.5 - 6.0	0.6 - 11.3	3.7	1.8	3.6
Bone Scan	4.5	1.1 - 6.8	0.5	-	4.2
Liver Scan	1.4 - 3.5	0.9 - 2.6	1.9	1.2 (^{99m}Tc) 22 (^{198}Au)	2.1
Kidney Scan	0.04 - 2.1	0.01 - 1.3	1.7	<0.1	1.95
Thyroid Scan	1.0 - 36.3	2.1 - 13.7	2.1	94 (^{131}I) 0.3 (^{99m}Tc)	88.8 (^{131}I)
Thyroid uptake	3.1	3	-	1.5	22.3
Average	2-4	3	4.5	15-30	18

Total detriment to patients for all diagnostic nuclear medicine procedures in Camagüey-Ciego de Avila territory between 2000 and 2005 is shown in Table 7. It shows that total detriment caused to patients has been estimated at 42 as a result of 24139 examinations; 28 of which concerned additional cases of cancer. These results indicate that risk in association with diagnostic techniques in the nuclear medicine service studied is globally low and similar to that reported by others authors [11-12]. In Table 7 are also shown the values estimated for both fatal and no-fatal cancers and for severe hereditary effects for which use was made of values of nominal probability coefficients for stochastic effects which were published in ICRP-60 [8].

4. CONCLUSIONS

The annual collective effective dose for all diagnostic nuclear medicine procedures performed in period studied has been estimated at 95.0 man·Sv with progressive decrease in its value for years 2001 through 2005 and increase in 2000 and 2004 due to the growth in explorations with ^{131}I. The annual per caput effective dose was estimated to be 79 μSv.

The thyroid explorations, iodide uptake and neck examinations constitute the largest percentages of the total effective collective dose.

The 75% of explorations were done using pharmaceuticals labeled with ^{131}I and only 25% with pharmaceuticals labeled with ^{99m}Tc. That trend is similar to that reported for countries with levels of health care equal to our own and substantially different to that reported for developed ones.

Risk estimation in association with diagnostic techniques in the nuclear medicine service studied is globally low and was estimated to be 42 as a result of 24139 examinations; examinations using ^{131}I being the largest contributing ones.

Table 7: Detriment caused to patients undergoing nuclear medicine examinations between 2000 and 2005.

Whole population (ICRP 60)	Nominal probability Coefficients for stochastic effects, Sv^{-1}			
	Fatal cancer	Non-fatal cancer	Severe hereditary effects	Total detriment
	0.050	0.01	0.013	0.073
Year	Nuclear Medicine examination			
	Fatal cancer	Non-fatal cancer	Severe hereditary effects	Total detriment
2000	5.65	1.13	1.47	8.25
2001	4.82	0.96	1.25	7.04
2002	5.25	1.05	1.37	7.67
2003	5.08	1.02	1.32	7.42
2004	5.27	1.05	1.37	7.70
2005	2.42	0.48	0.63	3.53
Detriment caused to patients	28.50	5.70	7.41	41.61
Detriment caused per 1000 examination	1.18	0.24	0.31	1.72

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