OCCUPATIONAL DOSIMETRY IN A PET CENTER DUE TO RADIONUCLIDE PRODUCTION AND MEDICAL USE

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1. INTRODUCTION

The occupational exposure due to Positron Emission Tomography (PET) procedures will be analyzed in our Center since we started in 1996 until 2001. Collective effective dose and finger dosimetry, evaluated with TLD dosimeters, for cyclotron and laboratory technicians and for nurses will be related to their working procedures and workload: activity produced and used in our center, ^{18}FDG activity distributed to other PET centers (since 1998) and PET studies performed.

2. METHODS

The thermoluminescent dosimeters used in this study, Panasonic UD-802 AR, provided the dose to the personnel at the deep depth (1000 mg/cm2) that has been used as effective dose. Ring dosimeters, with a lithium-7 borate element, were used to evaluate "finger" doses.

In 1996 there were working in our institution 3 technicians and 2 nurses that increased up to 5 and 4, respectively. The technicians tasks consist in dose drawing and preparation, hot PET laboratory management and basic cyclotron maintenance; nurses take care of the patient, inject the dose and, for a few procedures, perform the blood pressure monitoring and blood sampling. From mean 1998, our PET center started ^{18}F-FDG distribution to other institutions, with a maximum of 22.2 GBq per package [1], that have been being also prepared by the laboratory technicians.

3. RESULTS

In the period 1996-2001 a total of 7032 PET studies were performed. Table 1 shows its distribution and the activity used each year, as well as the mean activity per study, that was 414 MBq in the year 2001. Radiopharmaceuticals used were ^{18}F-FDG, ^{11}C-bicarbonate, ^{15}O-water, ^{13}N-ammonia, ^{11}C-methionine and ^{18}F-FDOPA. Figure 1 shows the mean activity per study used for each radiopharmaceutical. The amount of ^{18}F-FDG prepared for distribution is illustrated in table 1.

Table 1. Activity administered to the patients and amount of ^{18}F-FDG distributed to other centers

Year	Activity used in our PET center			^{18}F-FDG distributed		
	Activity (GBq)	Patients Studied	Mean activity per study (MBq/study)	Activity (GBq)	Number of Deliveries	Mean activity per package (GBq)
1996	155	370	419	0	0	0
1997	387	800	485	0	0	0
1998	498	1191	420	98	24	4.1
1999	610	1422	429	1743	168	10.4
2000	713	1652	432	2901	242	12.0
2001	662	1597	414	2102	201	10.5

Tables 2 and 3 summarize the collective effective and finger doses received by nurses and technicians, as well as the normalization to the amount of activity managed by each group. In the year 2001, mean effective and finger doses were 0.032 and 0.087 μSv/MBq for nurses and 0.002 and 0.155 μSv/MBq for technicians, respectively. Nurses received a mean effective dose per study of 13.3 μSv, while the finger dose was 35.9 μSv. Figures 2 and 3 illustrate the evolution across the years of received doses by each nurse and technician. Less differences in dosimetry were found between nurses than between technicians.

The relation between the activity managed for the two groups studied and the dose received is shown in Figure 4. For nurses, the determination coefficient of the linear regression between injected activity and doses was 0.94, with $p<0.002$. Technicians showed positive correlation ($p<0.01$) between the total activity (injected to patients plus distributed) and received doses, with a quadratic dependence. Regression analysis between effective dose and finger dose showed a determination coefficient of 0.997 ($p<0.001$) and 0.926 ($p<0.002$) for technicians and nurses respectively.

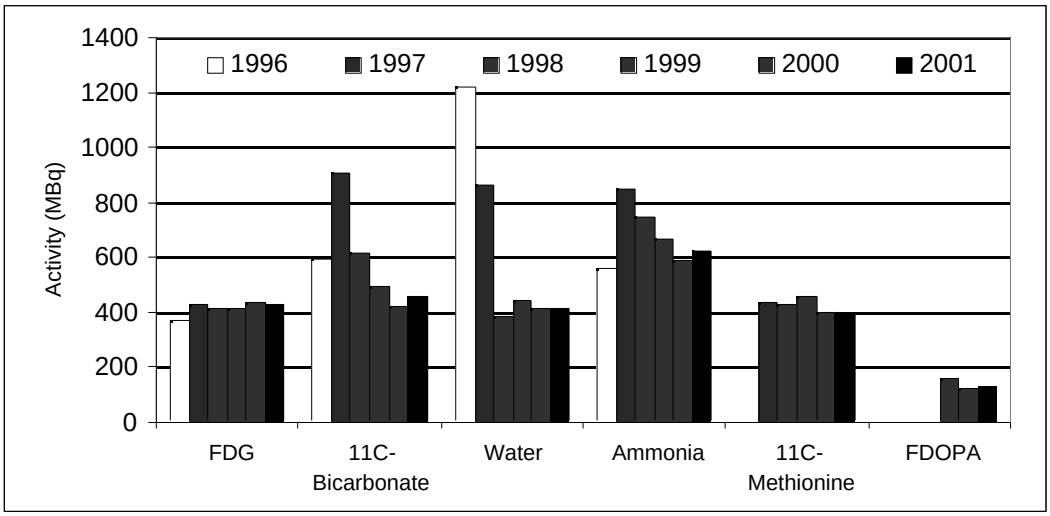

Figure 1. Mean activity used per study for each radiopharmaceutical

Table 2. Collective effective and finger doses received by nurses

Year	Collective effective dose (mSv *man)	Finger collective dose (mSv*man)	Effective dose per study (μSv/study)	Finger dose per study (μSv/study)	Effective dose per injected activity (μSv/MBq)	Finger dose per injected activity (μSv/MBq)
1996	2.5	13.8	6.8	37.3	0.0163	0.0889
1997	11.0	40.4	13.8	50.5	0.0285	0.1044
1998	15.8	39.4	13.2	33.1	0.0316	0.0790
1999	14.8	48.1	10.4	33.8	0.0242	0.0787
2000	22.1	66.6	13.4	40.3	0.0310	0.0933
2001	21.2	57.4	13.3	35.9	0.0321	0.0867

Table 3. Collective effective and finger doses received by technicians

Year	Collective effective dose (mSv *man)	Finger collective dose (mSv*man)	Effective dose per total activity (μSv/MBq)	Finger dose per total activity (μSv/MBq)
1996	1.13	83.7	0.0073	0.539
1997	1.36	98.3	0.0035	0.254
1998	1.52	105.9	0.0025	0.177
1999	5.49	384.8	0.0023	0.163
2000	12.81	845.6	0.0035	0.234
2001	6.88	428.5	0.0025	0.155

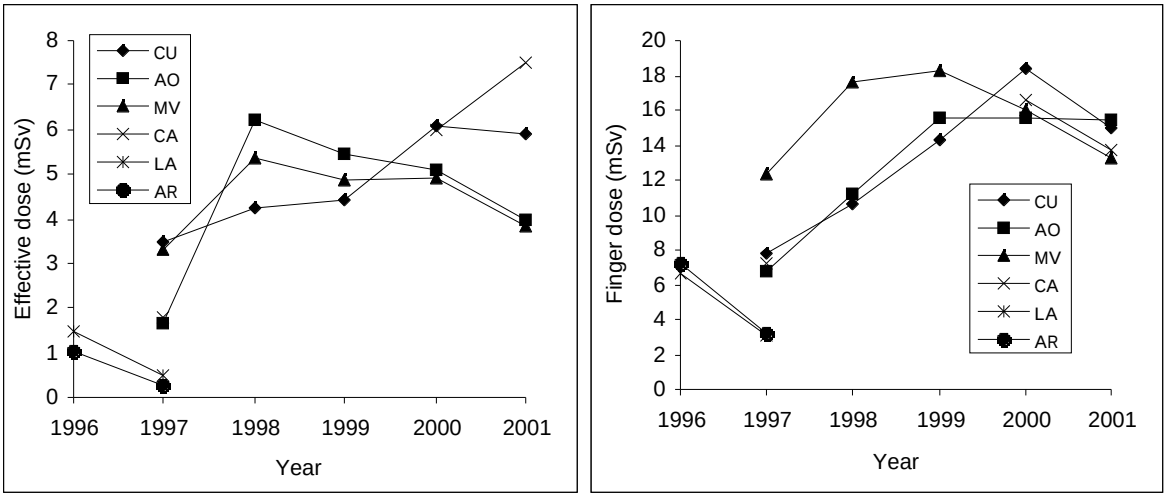

Figure 2. Nurses dosimetry evolution: effective (left) and finger (right) doses

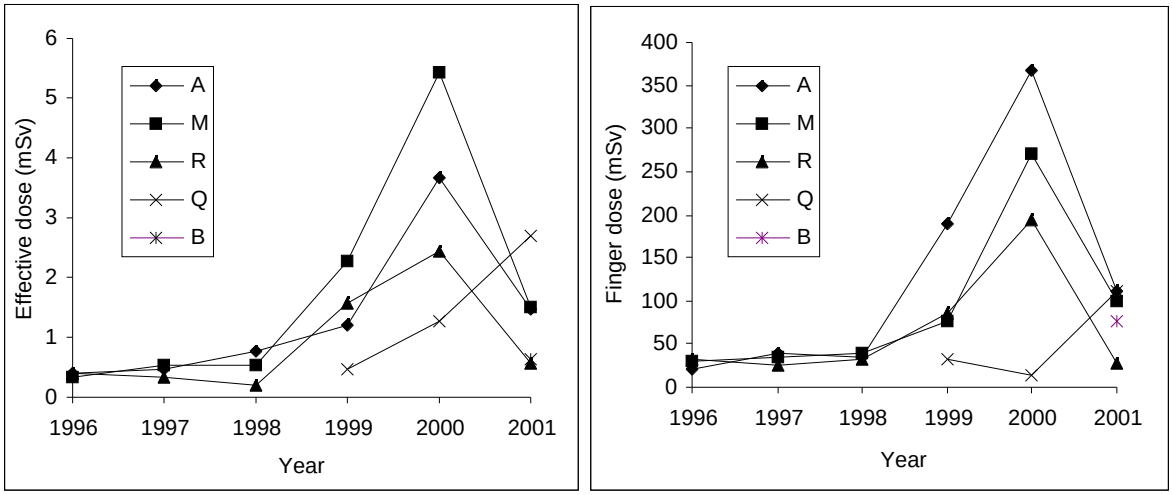

Figure 3. Technicians dosimetry evolution: whole body (left) and finger (right) doses

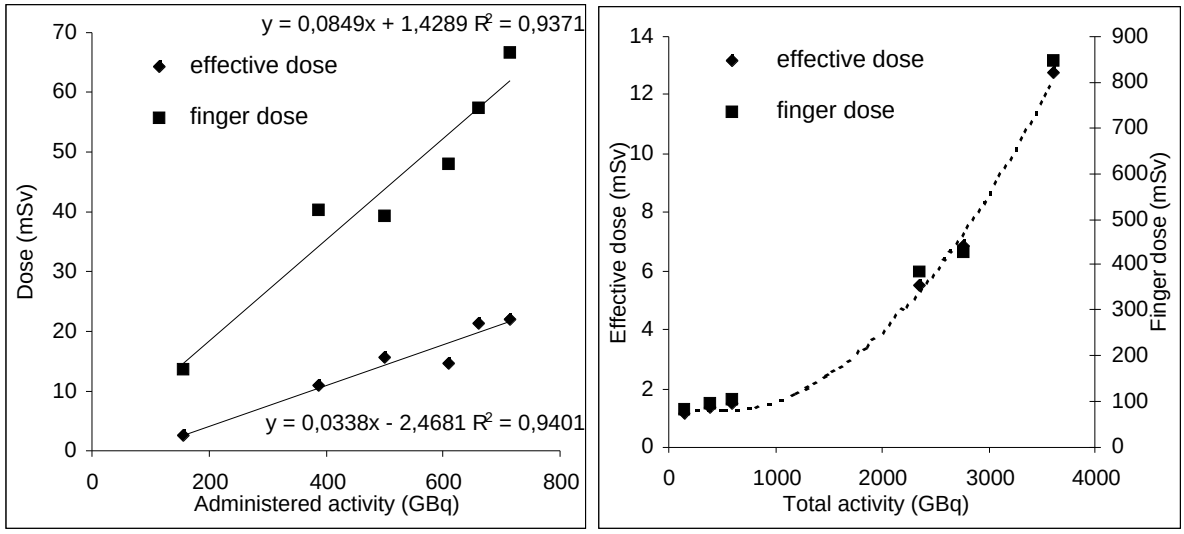

Figure 4. Collective dose for nurses (left) and technicians (right) as a function of the activity managed for each group

4. DISCUSSION

Mean activity per study showed a stabilization through the period 1996-2001 with a small reduction, except in the case of ^{18}F-FDG. That radiopharmaceutical was used in the 85 % of the 7032 studies, with mean activity of 421 MBq, higher than the activity reported by others [2,3].

Over the studied period mean effective dose per activity administered to the patient was 0.029μSv/MBq, higher than 0.018 μSv/MBq reported by Benatar [2]. In our Center, nurses use lead shielded holder (2.5 cm) with handle for transporting the syringe with the tracer to the injection room, and lead pig (5 cm) for dose injecting, minimizing radiation doses to their fingers. Thus, their effective doses could be explained by prolonged periods of time near the patient. Another point of difference between centers (that depends on the particular procedures and radiopharmaceuticals used, and considering that the nurse is in contact with the patient at the end of the tracer uptake and at the end of the exploration) is that for a given amount of activity delivered to the patient and due to radioactive decay, the shorter the uptake and the scan time are the higher the effective dose received is.

Optimized procedures in the laboratory are as follow: Radiotracers are handled in a manipulation hot cell (with 5 cm thick lead shield) within a dedicated hot laboratory. For each patient a small volume of tracer is transferred automatically from the synthesis module (placed in another hot cell) to a vial, lead shielded, placed in the manipulation hot cell. The technician draws up manually the tracer into a syringe and measures its activity. Finally, technician places the syringe into a lead shielded holder in order to transfer to the injection zone.

Our Center was not originally planed for ^{18}F-FDG distribution. When this new activity started in 1998, we designed a Type A package [1] and adapted the laboratory procedures to this new activity. Here, ^{18}F-FDG is transferred automatically to the manipulation hot cell into a vial placed inside the dose calibrator. When the desired amount of activity is reached, the transference is stopped. A pneumatic driven system is used to move the vial out the dose calibrator for removing with a nipper the sterile filter, and then activity is measured again. Following, the vial is introduced with a nipper into a 3 cm lead container with handle, that it will be placed into the package for its transport to other PET centers.

This study showed that: 1) for each group (technicians and nurses) a significant correlation exists between doses received and activity manipulated; 2) there is also correlation between effective dose and finger dose; 3) technicians dosimetry is predominantly due to the activity distributed; 4) special lead containers and syringe manipulators were designed and have proved to be efficient for reducing personnel doses; and 5) basic automation and procedures optimization in the laboratory during the first two years provided safety methods when we started ^{18}F-FDG distribution.

5. REFERENCES

1. Martí-Climent JM, Peñuelas I, Calvo R, García-Velloso MJ, Richter JA. Regional distribution or 18F-FDG for Positron Emission Tomography. Eur J Nucl Med 1998; 1177.
2. Benatar NA, Cronin BF, O'Doherty MJ. Radiation dose rates from patients undergoing PET: implications for technologists and waiting areas. Eur J Nucl Med 2000; 27:583-589.
3. Brix G, Nosske D, Glatting G, Minkov V, Reske SN. A survey of PET activity in Germany during 1999. Eur J Nucl Med 2002; 29:1091-1097.