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PROTOCOL FOR ^{18}F-FDG QUANTIFICATION IN PET-CT WHOLE-BODY EXAMS

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Abstract – The aim of the present work is to propose a protocol for quantification of ^{18}F-FDG activities at organ level through whole body exams with Positron Emission Tomography. They were selected patients with normal uptake or a single tumor. In the period 2004-2005, 745 patients were studied. Among then, it was selected 97 adults for the normal uptake control group. The main studies were: intestine; colon, rectum, lung, lymphoma and melanoma, liver, esophagus, gonads and breasts. For "prospective screening", it were selected 20 patients with the identical physical characteristics of the control group. For internal dosimetry, the main organs should be elected according the kinetics of ^{18}F-FDG, either considering normal uptake or pathologies. Absorbed doses due to Computed Tomography and F-FDG uptake were estimated. Comparisons between internal and external exposures, for the same organ, point out higher doses due to external irradiation, except for bladder and kidneys. For individual dose estimation, parameters such the effective half-life should be known and this information may be achieved by an adaptation of the routine protocol.

Key words: Positron emission tomography, internal dosimetry, computed tomography, external dosimetry.

INTRODUCTION

PET is presently the most accurate method for the determination of activity concentrations in tissue. PET imaging can be considered for treatment planning but ideally requires the use of a radioisotope from the same element as that used for treatment (3). In Brazil, at this moment, there is only ^{18}F-FDG supply and it is not possible to have another radiotracer for treatment planning. Since absorbed doses in organs or tissues should be calculated for diagnosis or therapy, the parameters for calculation are: *(i)* mass of the target organ; *(ii)* number of disintegrations in the target organ; *(iii)* effective half-life of radiopharmaceutical. The uptake in organs and the organ mass may be estimated, respectively, thought *PET* e *CT* fusioned images. Recent studies have demonstrated that variations in activity concentration in organs, mainly in regions of major densities (specific activity) may be more observed with PET/CT equipment rather than with PET equipment (9). The absorbed doses in organs or tissues due to whole-body PET/CT may be optimized by changes in acquisition protocols (2). Some details in instrumentation of PET systems may interfere in the image quality, activity quantification and, as a consequence, in the individualized internal dosimetry (11). For computed tomography, there are controversies if it must be used low dose techniques (for attenuation correction and anatomical localization in PET studies) or high dose computed tomography used for diagnosis (10). The aim of the present work is to set up a protocol for quantification of ^{18}F-FDG activities at organ level through whole body screening with PET-CT and to compare internal and external doses to the patient due to this protocol.

MATERIAL AND METHODS

Computed tomography (CT)

It was used SIEMENS Somatom Plus 4 Volume Zoom. In routine, it was used for whole-body scan and thorax incidence for respiratory correction movement. For dosimetry it was used Radcal 20x6-3CT ionization chamber pencil type and Radcal 2026C unit reader. The quantity measured was length-exposure product for estimation $CTDI_{ar,100mm}$ (eq. 1).

$$CTDI_{ar,100} = \frac{1}{T} 8{,}764 x 10^{-3}\ \overline{X} \times l \qquad (1)$$

Where: $\overline{X}$ the exposure (chamber corrected reading) in R; l is the chamber active length, 100 mm; T is the axis

collimation in mm and $8{,}764x10^{-3}$ is the constant for R and mGy units.

The measurements were done three times in a single day, since it was used the same protocol for all patients and the methodology used for dosimetry didn't allow patient size corrections. The main entrance parameters used for the two techniques (whole-body and thorax) were: 120 kV; 0.5 sec; 10 mm and 2.5 for axis and detector collimation, respectively; 12 mm/rotation and 130 mAs and 30 mAs for whole-body and thorax, respectively. The parameters used for brain region were: 120 kV; 30 mAs; 2.5 mm for detector collimation; time of rotation between 0.5 and 0.75 sec; axis collimation between 10 and 16 mm. For external dose estimation, it was used the Software "IMPACT CT Patient Dosimetry Calculator" v. 0.99x (8) and CT doses coefficients (7).

PET FDG

It was used Siemens-CTI ECAT EXACT 921/47 equipment with BGO scintillation detector and Software E. Soft. It was followed the EANM protocol (1): 5 h fast, 60 min uptake phase, etc. The image acquisition was 40-60 min, 2D mode, screening from the brain basis to the proximal femur with 6 min per region. For selected patients, it may be necessary urinary tract preparation. According to the protocol (1), it is not recommended to carry out PET-CT exam before 4 weeks surgery or invasive diagnosis and 3 months radiotherapy. For recent chemotherapy, the toxicity in the bone marrow and gastrointestinal tract may change the radiopharmaceutical kinetics (1). For internal organ doses estimations, it was used conversion dose factors (4), (5).

RESULTS AND DISCUSSION

Computed tomography

The brain techniques were similar with thickness variations according axis collimation. According to ImPACT (8), for the equipment used, $CTDI_{ar,100}$/100 mAs (10mm collimation) was 25 mGy/100 mAs. The tube output was 13% higher than the expected. Since the measurements were performed with the brain irradiation technique and the protocol is the whole-body, the value for trunk $CTDI_{ar,100}$/100 mAs (10mm collimation) of 17,5 mGy/100 mAs was corrected in 13%, so the tube output for brain protocol was 19.8 mGy/100 mAs. The absorbed doses calculated for whole-body and thorax were added and vary between 10.8 mGy for red bone marrow and 20.5 for thyroid, with intermediate values of 12.0 for gonads, 14.6 for breasts and 18.0 for lung (Table 1).

PET FDG

In the period 2004-2005, 745 patients were studied (351 male and 394 female). For retrospective study, it was selected a control group of 97 adults (50 male and 47 female), distributed among 18-40 years (n=12), 41-60 years (n=46) and up to 60 years (n=41). The corporal weight varied between 79.5±13.1 kg and 63.5±11.5 kg for male and female, respectively. The height varied between 175.6±6.5 cm and 160.6±6.9 cm, for male and female, respectively. The group has physical characteristics similar to ICRP mathematical simulators (6)**.** According previous procedures, the group realized chemotherapy (n=40), radiotherapy (n=25) and surgery (n=50). Among then, 25 had metastases and were excluded (Table 2). The studies included: intestine, colon e rectum (n=27), lung (n=20), lymphoma and melanoma (n=9), liver and esophagus (n=8), gonads (n=5) and breasts (n=5). The mean activity of ^{18}F-FDG was 430.68±66.23 MBq (5.42 MBq/kg) for male and 422.91±78.81 MBq (6.66 MBq/kg) for female.

Table 1. Internal and external organ absorbed doses

Organs	**Absorbed doses (mGy)**	
	External	**Internal**
Gonads	12.0	4.7±0.1
Red marrow	10.8	4.7±0.1
Lungs	18.0	6.5±0.6
Bladder/kidneys	14.1	31.4±2.7
Breasts	14.6	3.3±0.6
Thyroid	20.5	4.3±0.6
Bone surface	20.6	4.7±0.6
Liver	13.5	10.3±0.5
Heart wall	-	29.3±2.4
Brain	-	19.8±0.8

Table 2. Control-group and previous procedures to PET/CT per gender and age (n = 97)

Age (years) and gender	Procedures		
	CM	RT	SG
> 17 e < 40 (n = 11)			
Male (n=6)	1	-	3
Female (n=5)	3	1	2
40-60 (n = 45)			
Male (n=20)	7	1	8
Female (n=25)	10	12	12
> 60 (n = 41)			
Male (n=25)	10	5	13
Female (n=16)	9	6	11
Total (n=97)	40	25	50

CM (chemotherapy); RT (radiotherapy); SG (surgery)

Comparisons between internal and external exposures for the same organ (Table 1) have showed higher doses for external irradiation, except for bladder and kidneys (31.4±2.7 mGy). Two organs have absorbed doses only due to ^{18}F-

FDG uptake, heart wall (29.3±2.4 mGy) and brain (19.8±0.8 mGy). The internal dosimetry is based on general models (4), (5) and may not correspond to a specific patient. For individual dose estimation, it is necessary knowing the individual parameters. For the estimation of effective half-lives, at least two measurements of ^{18}F-FDG uptakes were necessary for the same organ. For the second one, besides the whole-body exam, it is proposed in this paper an adaptati0on of the routine protocol, adding an exam of the organ of interest. The increasing of, at least, 6 min second image to the first 40-60 min exam should be adequate for retaining the patient at the facility and previously communicated to him.

For internal dosimetry, the principal organs should be elected according the corresponding ^{18}F-FDG kinetics, either for normal or pathological conditions. It must be pointed out that different kinds of sicknesses may result in distinct uptakes and, in this case, the internal dosimetry models (4), (5) may be inadequate, because correspond to normal uptake in healthy individuals. Both for internal or external exposures, among the evaluated organs, the most relevant for the stochastic effects were gonads, breasts and thyroid. With the introduction of "multi-slice" computed tomography, the breasts absorbed doses have increased due to the external irradiation in studies including thorax. In PET-CT techniques, both internal and external exposures should be optimized.

Other articles in this theme issue include references (12-19).

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