Comparison of standardized uptake values measured on ^{18}F-NaF PET/CT scans using three different tube current intensities*

Comparação dos valores de captação medidos nos estudos de ^{18}F-NaF PET/CT utilizando três intensidades diferentes de corrente do tubo de tomografia computadorizada

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Abstract   **Objective:** To analyze standardized uptake values (SUVs) using three different tube current intensities for attenuation correction on ^{18}F-NaF PET/CT scans.

Materials and Methods: A total of 254 ^{18}F-NaF PET/CT studies were analyzed using 10, 20 and 30 mAs. The SUVs were calculated in volumes of interest (VOIs) drawn on three skeletal regions, namely, right proximal humeral diaphysis (RH), right proximal femoral diaphysis (RF), and first lumbar vertebra (LV1) in a total of 712 VOIs. The analyses covered 675 regions classified as normal (236 RH, 232 RF, and 207 LV1).

Results: Mean SUV for each skeletal region was 3.8, 5.4 and 14.4 for RH, RF, and LV1, respectively. As the studies were grouped according to mAs value, the mean SUV values were 3.8, 3.9 and 3.7 for 10, 20 and 30 mAs, respectively, in the RH region; 5.4, 5.5 and 5.4 for 10, 20 and 30 mAs, respectively, in the RF region; 13.8, 14.9 and 14.5 for 10, 20 and 30 mAs, respectively, in the LV1 region.

Conclusion: The three tube current values yielded similar results for SUV calculation.

Keywords: ^{18}F-NaF PET/CT; SUV; Tube current; mAs.

Resumo   **Objetivo:** Analisar os valores de captação (SUVs) utilizando três diferentes intensidades de mAs para realização de correção de atenuação na ^{18}F-NaF PET/CT.

Materiais e Métodos: Um total de 254 exames de ^{18}F-NaF PET/CT foi estudado utilizando 10, 20 e 30 mAs. Os SUVs foram calculados utilizando volumes de interesse (VOIs) desenhados em três regiões do esqueleto: diáfise proximal do úmero direito (UD), diáfise proximal do fêmur direito (FD) e primeira vértebra lombar (VB1), totalizando 712 VOIs. Desse total, 675 regiões classificadas como normal foram analisadas (236, 232 e 207 na UD, FD e VB1, respectivamente).

Resultados: A média dos SUVs para cada região óssea foi 3,8, 5,4 e 14,4 para UD, FD e VB1, respectivamente. Quando os exames foram agrupados pelo valor da corrente mAs, a média de valores de captação foi 3,8, 3,9 e 3,7 para 10, 20 e 30 mAs, respectivamente, na UD; 5,4, 5,5 e 5,4 para 10, 20 e 30 mAs, respectivamente, na FD; e 13,8, 14,9 e 14,5 para 10, 20 e 30 mAs, respectivamente, na VB1.

Conclusão: As três correntes analisadas apresentaram resultados similares para o cálculo de SUV.

Unitermos: ^{18}F-NaF PET/CT; SUV; Corrente de tubo; mAs.

INTRODUCTION

Sodium fluoride (^{18}F-NaF) is a highly sensitive bone-seeking tracer utilized in positron emission tomography (PET) to detect skeletal abnormalities. The ^{18}F-fluoride uptake mechanism resembles that of ^{99m}Tc-MDP with bet-ter pharmacokinetic characteristics including faster blood clearance and two-fold higher uptake in bone[1].

In the last years there was a renewed clinical interest in the use of ^{18}F-NaF as a bone scanning agent[2]. Reasons for this resurgence include the recent periodic worldwide shortage of ^{99m}Tc needed for conventional bone scanning agents[3], and the improved sensitivity[4–6] and quantitative potential of ^{18}F-NaF PET/CT[7,8] as compared with ^{99m}Tc-based conventional bone scans.

In PET/CT apparatuses, computed tomography (CT) images may be acquired for attenuation correction of emis-

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sion images, anatomic localization of scintigraphic findings and radiographic characterization of abnormalities[9]. The CT protocol depends on the indications for the study besides the likelihood that radiographic findings will add diagnostic information. However, the need for additional diagnostic information should always be weighed against the increased radiation exposure involved in CT, and dose parameters should be consistent with the ALARA (*as low as reasonably achievable*) principles.

Due to the high bone-to-soft tissue activity ratio of ^{18}F-NaF bone scans, high quality images may be obtained even without CT for attenuation correction[10,11]. Nevertheless, the addition of CT seems to improve the ^{18}F-NaF PET specificity[4,5] and allows for calculation of SUVs[12].

SUV, which averages tracer uptake with respect to the injected dose and body weight, is the most widely used PET index for assessing tracer uptake in the routine clinical practice because it does not require blood sampling and is obtained by static PET acquisition[12–14]. Research reports demonstrate that SUVs can detect significant metabolic change in individual metastatic lesions even in cases where visual evaluation reveals little if any difference[7]. Additionally, in the field of oncology, earlier identification of metastatic involvement is possible and, in cases where it is important to assess the treatment response, quantitation may provide such information[7,8].

The tube current intensity (mAs) to be used in patients undergoing ^{18}F-NaF PET/CT scans has been subject of debate. The "SNM guideline for sodium ^{18}F-fluoride PET/CT bone scans" has established 30 mAs as an adequate current intensity for whole body CT[1]. However, there are scarce studies in the literature on the most appropriate mAs values. In the literature it is possible to find values ranging from 15 mAs[15] to 95 mAs[16]. Therefore, it is necessary to evaluate the adequate mAs values in light of current advances in technology as well as the ALARA principles.

The purpose of this study was to analyze SUVs using three different mAs intensities on CT scans for performing attenuation correction on ^{18}F-NaF PET/CT studies.

MATERIALS AND METHODS

Patient population

In the present cross sectional study, the images of the first 254 patients submitted to ^{18}F-NaF PET/CT scans in the author's department were analyzed. The patients were randomly allocated to undergo scans using three different mAs intensities. The patients' characteristics: weight, height, body mass index, age and sex were analyzed. Also, the statistical differences in such patients' characteristics among mAs groups were analized.

PET/CT images acquisition

The patients were injected with 111 to 203 MBq (mean 141 MBq) of ^{18}F-NaF. Approximately 60 min after injection, all patients underwent whole-body (vertex to toes) three-

dimensional PET/CT scan. Images were acquired in a time-of-flight capable Discovery 690 GE scanner (General Electric). Low-dose CT transmission scans were performed using one of three intensities of mAs values (10, 20 or 30 mAs) for attenuation correction. Other CT images parameters were the following: 120 kVp, 0.5-s rotation time, 1.375 pitch and axial slice thickness of 3.75 mm. Emission PET images were acquired at 1 min per bed position (15 cm slice thickness and 3 cm overlapping), with 13 to 15 bed positions per study. The PET image reconstruction was performed using iterative technique with 24 subsets for all studies.

Image analysis

A total of 254 PET/CT studies were analyzed: 73 with 10 mAs, 83 with 20 mAs and 98 with 30 mAs. The SUV values were calculated in volumes of interest (VOIs) drawn on three skeletal regions, namely: right proximal humeral diaphysis (RH), right proximal femoral diaphysis (RF), and first lumbar vertebra (LV1) in a total of 712 VOIs (Figure 1). Such regions were assessed for the presence of bone alterations and the ones classified as abnormal were excluded from analysis. Thus, 675 regions classified as normal were analyzed (236, 232 and 207 in RH, RF and LV1, respectively). All SUVs were based on body weight.

Figure 1. Volumes of interest drawn on three skeletal regions as follows: right proximal humeral diaphysis (UD), right proximal femoral diaphysis (FD), and first lumbar vertebra (VB1).

Statistical analysis

The ANOVA statistical test was used to assess the presence of statistical significant difference in SUVs values among the three mAs intensities groups for each one of the three skeletal regions. Also, the ANOVA (continuous variables) and chi-square (dichotomous variables) tests were utilizedo to assess the presence of statistical significant difference in patients' characteristics among mAs groups. The analyses were performed using Windows Excel® and SPSS®.

RESULTS

No statistically significant difference was observed in the patients' characteristics (weight, height, body mass index, age and sex) among groups ($p > 0.05$) (Table 1).

The mean SUV for each skeletal region as well as the number of patients analyzed in each mAs group are demonstrated on Table 2. The ANOVA did not show any statistically significant difference between mAs intensities groups for any one of the three skeletal regions (Table 2).

DISCUSSION

^{18}F-NaF was introduced as an imaging agent for bone lesions by Blau et al.[17] in 1962. Data from multiple small studies have shown that ^{18}F-NaF PET yields bone scans with higher sensitivity and specificity than ^{99m}Tc-based bone scans[18–22], and it is also superior to ^{18}F-FDG PET/CT and MRI[23].

The attenuation correction technique is normally used in PET studies to improve both quantification and uniformity in the field of view. Disadvantages of attenuation correction include errors arising from positional mismatches caused by patient motion or respiration differences, while its effect on lesion detection remains unclear. Because of low background uptake, there are few advantages of attenuation correction for bone scanning[10,11]. Also, CT scanning is useful for anatomic localization of the lesions[4,5] and also to calculate SUV[12].

However, the level of mAs on ^{18}F-NaF or ^{18}F-FDG PET/CT studies is a matter of discussion and a wide range of values may be found in the literature[15,16]. With the use of phantoms, some researchers have demonstrated that CT tube current intensity as low as 10 mAs could be appropriate to perform attenuation correction on PET/CT studies[24,25]. However, analyses in clinical studies are rare.

As regards phantoms analyses, Fahey et al.[24] have evaluated the dose from the CT portion of PET/CT to determine minimum CT acquisition parameters that provide adequate attenuation correction. Such authors have concluded that, for pediatric patients, adequate attenuation correction can be obtained with very-low-dose CT (80 kVp and 5 mAs), and such correction leads to a 100-fold dose reduction as compared with diagnostic CT. For adults undergoing CT with 5 mAs, the tube voltage should to be increased to 120 kVp to prevent undercorrection. Alessio et al.[25] have also used phantoms to analyze the impact of mAs and kVp on radiation exposure. For the smallest patients, such authors decided to use 10 mAs, which is close to the lowest allowable tube current (5 mAs) on the PET/CT equipment available in their department.

The feasibility of using very low mAs to calculate SUV in FDG PET/CT clinical studies was assessed by Kamel et al.[26]. Such authors have evaluated the effect of decreasing the tube current (ranging from 10 to 120 mAs) on the appropriateness of CT-based attenuation correction and its effect of tumor quantification in FDG PET studies, demonstrating that there was no substantial difference in the esti-

Table 1—Patients' characteristics (mean ± standard deviation) for the total group as well as for each of the mAs groups. The values are measured in: weight (kg), height (cm), body mass index (kg/m^2) and age (years).

	n	Weight (mean ± SD)	Height (mean ± SD)	Body mass index (mean ± SD)	Age (mean ± SD)	Sex (% female)
Total	254	69 ± 15	159 ± 8	27 ± 6	60 ± 14	66
10 mAs	73	68 ± 14	160 ± 9	27 ± 5	60 ± 12	62
20 mAs	83	70 ± 16	158 ± 8	28 ± 7	59 ± 15	67
30 mAs	98	67 ± 15	159 ± 8	27 ± 6	60 ± 14	67
p value		0.44	0.59	0.21	0.78	0.68

SD, standard deviation.

Table 2—Mean ± standard deviation SUVs in the three skeletal regions – right proximal humeral diaphysis (RH), right proximal femoral diaphysis (RF), and first lumbar vertebra (LV1) – for each one of the mAs intensities. The *p* values are higher than 0.05 for the three regions.

	RH		RF		LV1	
	Mean ± SD SUV	*n*	Mean ± SD SUV	*n*	Mean ± SD SUV	*n*
Total	3.8 ± 1.4	236	5.4 ± 2.1	232	14.4 ± 3.7	207
10 mAs	3.9 ± 1.3	67	5.4 ± 1.6	64	13.8 ± 3.3	60
20 mAs	3.9 ± 1.5	79	5.5 ± 2.0	79	14.9 ± 4.3	66
30 mAs	3.7 ± 1.4	90	5.4 ± 2.3	89	14.5 ± 3.5	81
p value	0.80		0.88		0.21	

SD, standard deviation.

mates of ^{18}F-FDG uptake or tumor size with varying tube current.

It is worth to say that besides implications in terms of reduction of radiation dose, the use of low mAs value might also reduce costs as the use of low current intensity extends the mean service life,of the tube that is the most expensive component of the CT system. This cost reduction is particularly important in ^{18}F-NaF PET/CT since the CT scans are performed throughout the whole body length and not only from the skull base to the upper part of the tight as in ^{18}F-FDG PET/CT studies.

Finally, the three mAs intensities analyzed seem to be similar for attenuation correction in the calculation of SUV for ^{18}F-NaF PET/CT studies, and the use of a very low tube current intensity as 10 mAs is appropriate to calculate such a parameter.

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