PET Image Quality Evaluation at Upper and Lower Threshold of ^{18}F-FDG dose: A Pilot Study in Vietnamese Patients

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Abstract

^{18}F-FDG Positron Emission Tomography (PET) is the most common modality used in cancer diagnosis and monitoring. PET imaging results in patients being exposed to a certain level of radiation, which may be harmful to the body. Research has been conducted on reducing radiation dose in PET imaging in order to minimize radiation risks, at the same time still maintaining diagnostic image quality. This study was a pilot study conducted at the 108 Government Military Hospital in Hanoi, Vietnam, whereby randomly selected patients regardless of body weight were sent for whole body ^{18}F-FDG PET imaging with a dose of 0.1 mCi/kg, which is the lower threshold in the recommended dose range in the guidelines on the Society of Nuclear Medicine and Molecular Imaging website. Another group of patients underwent the same PET procedure with dose calculation using the upper threshold of the same range (0.15 mCi/kg). Image quality, manifested through the Signal-to-Noise Ratio (SNR), was compared between the low-dose and high-dose groups. No statistically significant difference in image quality was revealed between the two groups, suggesting that dose reduction in a certain limit did not affect PET image quality.

Keywords: PET, ^{18}F-FDG, BMI

1. Introduction

Positron Emission Tomography (PET) has been widely accepted as a method of oncology diagnosis and staging [1]. In clinical practice, ^{18}Fluorine-Fluorodeoxyglucose (^{18}F-FDG) has been used as the most common tracer to locate suspicious cancer and/or metastasis sites [2]. Besides the advantages of PET in oncology, there remains the fact that in PET imaging, patients are exposed to a certain level of radiation. The principle ALARA (As Low as Reasonably Achievable) is established and followed in dose calculation for PET imaging in order to minimize radiation doses to patients while still maintaining the image quality for diagnostic purposes [3]. The most common method of dose calculation in PET is based on patient body weight [4]. According to the guidelines on the website of the Society of Nuclear Medicine and Molecular Imaging (http://www.snmmi.org/ClinicalPractice/), the recommended dose is 0.1 to 0.15 mCi/kg. In reality, physicians tend to apply the upper threshold rather than the lower threshold for certainty. But dose minimization is alway critical for radiation protection. This study was a pilot quantitative study conducted at the Government Military Hospital that applied the lower and upper thresholds in the recommended range to calculate doses for whole body PET imaging in randomly selected patients. We hypothesized that dose reduction did not affect the image quality, manifested through the signal-to-noise ratio (SNR) of images.

2. Materials and method

Participants

Patients were selected from a random cohort including both female and male patients coming to the Governmental Military Hospital, Hanoi, Vietnam for whole body PET both for screening and diagnostic purposes. There were 12 patients in whom radiation dose was calculated at 0.15 mCi/kg (high-dose group) and 10 patients in whom radiation dose was calculated at 0.1 mCi/kg (low-dose group). High-dose group included 5 females (aged 41.4 ± 14.5) and 7 males (aged 60.7 ± 5.5), low-dose group 6 females (aged 56.7 ± 7.9) and 4 males (aged 51 ± 18.7). A two-sample t-test revealed no age difference between high-dose group (52.7 ± 13.8) and low-dose group (54.4 ± 12.6).

Image acquisition and analysis

Each patient was injected with ^{18}F-FDG via the vein. The injected dose of ^{18}F-FDG for high-dose group was 8.4 ± 1.12 mCi, significantly higher than

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that for low-dose group, which was 6.4 ± 0.78 mCi. Whole body PET/CT was performed on a GE DSTE 16 Slice system 60 mins after tracer injection. For each patient, a static PET image was reconstructed with Ordered Subset Expectation-maximum 3D (OSEM3D) at a resolution of 1.95 mm × 1.95 mm × 3.27 mm (Figure 1) and a CT image was reconstructed at an in-plane resolution of 0.98 mm × 0.98 mm, slice thickness of 3.27 mm, field of view of 512 × 512 pixels to be used as the reference image.

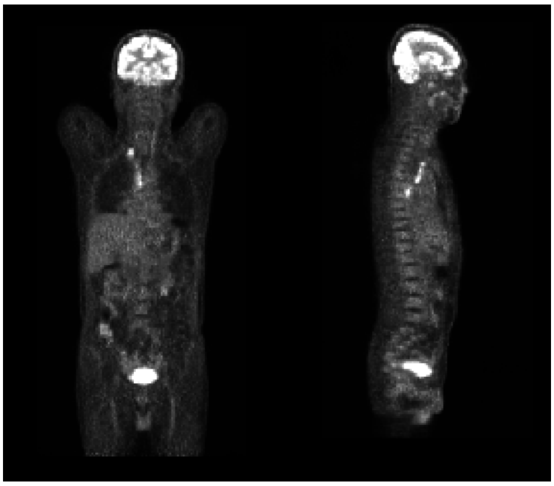

Fig. 1. Front view (left) and lateral view of a whole-body PET image of a patient

Image quality was quantitatively assessed by calculating the SNR. The SNR for each image was calculated as the ratio of mean to standard deviation of 50 non-neighboring voxels in a volume of interest (VOI) of 10 × 10 × 10 pixels [5] [6] [8]. The VOI was manually selected from the liver using FSL as the liver is the organ having the most homogenous uptake of FDG [6] (Fig. 2). The VOI was selected far enough from the liver's edge to avoid partial volume effect.

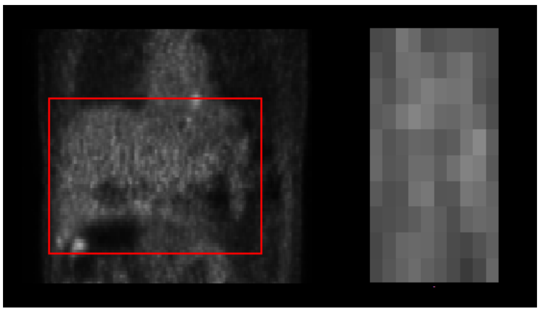

Fig 2. The liver (red rectangle) where a VOI was selected (left) and the selected VOI of 10 × 10 × 10 pixels (right)

A two-sample t-test was performed to compare the SNR between high-dose (N = 12) and low-dose group (N = 10) with $p \leq 0.05$ indicating statistical significance.

3. Result and discussion

As expected, the SNR calculated for a VOI in the liver was not significantly different between high-dose (6.6 ± 1.6) and low-dose group (6.5 ± 1.4) (Figure 3), indicating that PET image quality was not affected when radiation dose was reduced in order to minimize patient's exposure.

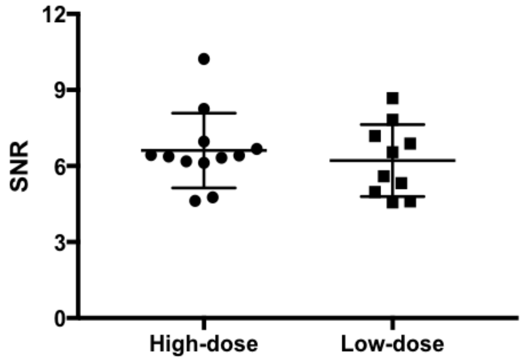

Fig 3. SNR was not significantly different between high-dose (N = 12) and low-dose group (N = 10). Data expressed as Mean ± SD.

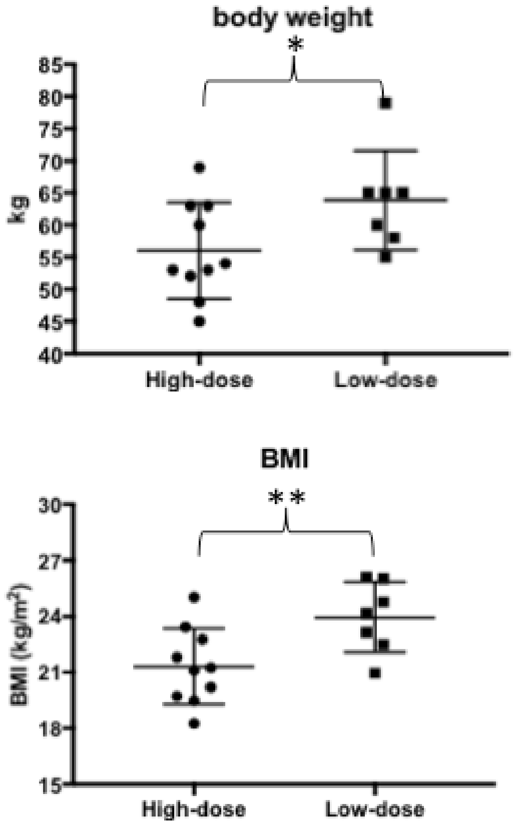

Fig 4. High-dose group (N = 10) exhibited significantly lower body weight (upper) and BMI (lower) compared to low-dose group (N = 7). Data expressed as Mean ± SD. (*) $p < 0.05$, (**) $p < 0.01$

Interestingly, significantly higher body weight (63.9 ± 7.8 kg) and Body Mass Index (BMI) (24 ± 1.9 kg/m2) were associated with the low-dose group rather than the high-dose group (56 ± 7.5 kg and 21.3 ± 2.9 kg/m2) (Fig. 4). It should also be noted that there were two patients that were considered overweight in the low-dose group (BMI > 25).

Correlations between BMI and SNR and between dose and SNR were calculated for the whole population using both Pearson and Spearman correlations. However, neither BMI nor dose showed any correlation with SNR (Fig. 5).

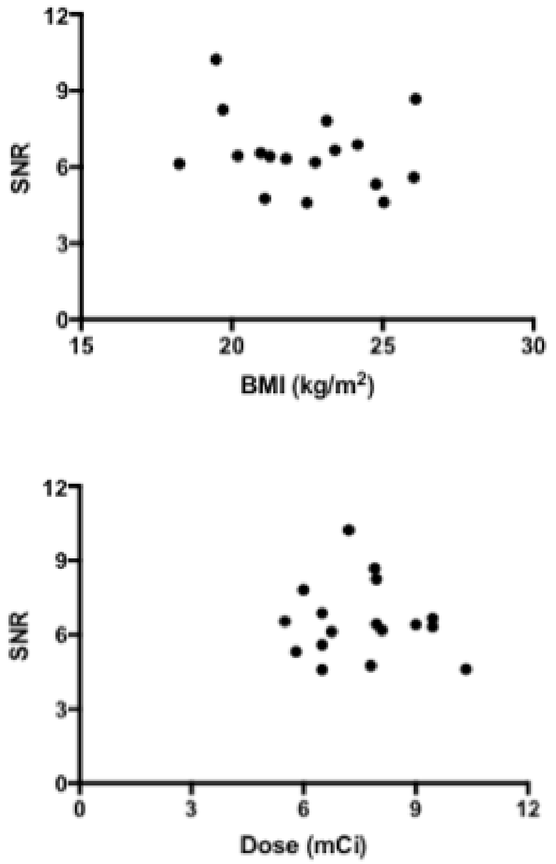

Fig. 5. There was no correlation between SNR and BMI (upper), and between SNR and dose (lower).

The fact that low-dose and high-dose PET images exhibited no difference in SNR, and that low doses were applied to the group with higher body weight and BMI, suggests that dose reduction without image quality trade-off is feasible in PET imaging. Within the recommended dose range, it could be expected that there exists no correlation between dose and SNR, which was corroborated by our data.

As a pilot study, this study has quantitatively shown that reasonably low dose is achievable in PET imaging. This study, however, has several limitations. First, the number of participants could have been greater to increase the statistical robustness. Additionally, the number of patients with body weight and height recorded was smaller than the total number of participants. Second, the study could not recruit participants in the over-weight and under-weight ranges. Given that PET image quality is commonly reported to degrade in obese patients [7], it would be highly important to conduct the dose reduction investigation in over-weight and obese patients in order to reach a consensus. Another approach that could have been taken is to base dose calculation on other parameters rather than body weight, such as BMI, lean mass or body surface area. These approaches have reported mixed results regarding dose reduction in PET imaging and necessitate further research.

4. Conclusion

The current study has shown that dose reduction within certain limits is possible in PET imaging to still guarantee diagnostic quality. While this pilot study was based on body weight, future studies can be conducted basing on other parameters in order to establish an optimal dose calculation protocol to minimise radiation risks to patients while ensuring consistent image quality.

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