Iraqi Journal of Science, 2024, Vol. 65, No. 8(SI), pp: 4704- 4709
DOI: 10.24996/ijs.2024.65.8(SI).2

ISSN: 0067-2904

Evaluation of the Effect of the Injected Dose and Body Mass Index on the Signal-to-Noise Ratio (SNR) Detected using a PET/CT Scan

Aya B. Hade, Samar I. Essa*
Department of Physics, College of Science University of Baghdad, Baghdad, Iraq

Received: 14/12/2022 Accepted: 21/7/2023 Published: 10/9/2024

Abstract

This study aims to investigate, using patient studies, the impact of Injected Dose (ID), Body Mass Index (BMI), and image noise assessments in PET imaging. This study included 59 liver cancer patients weighing between 45 and 107 kg. After intravenously injecting 0.1 millicurie (mCi) of ^{18}F-FDG per kilogram of body weight, PET scans were obtained for 1, 1.5, and 3 min/bed position based on the patient's weight.

Weight, height, and body mass index were calculated using a spreadsheet.

Five regions of interest (ROIs) were placed at the same site in the liver, which was considered to have a homogeneous metabolism, in five successive slices of PET/CT scans to determine the mean uptake (signal) values and their standard deviation (noise). The ratio of both gives the liver's Signal-to-Noise Ratio (SNR).

Graphs were created to determine the relationship between these characteristics. The plots demonstrated that the dose injected increased when body weight and/or BMI increased, and that the SNR fell even as the dose administered increased. This is owing to the fact that heavier patients having a higher administered dose and, have a lower SNR even when greater ^{18}F-FDG doses are delivered. These data indicate that the image quality, as measured by the SNR, is inferior in heavier persons compared to those who are thinner.

Keywords: ^{18}F-FDG-PET/CT; liver, weight, BMI, signal to noise ratio.

تقييم تأثير الجرعة المحقونة ومؤشر كتلة الجسم على نسبة الإشارة إلى الضوضاء *(SNR)* المكتشفة باستخدام التصوير المقطعي بالإصدار البوزيترون(PET/CT)

ايه بلال هادي، ، سمر عمران عيسى*
قسم الفيزياء، كلية العلوم، جامعة بغداد، بغداد، العراق

الخلاصة

تهدف هذه الدراسة إلى التحقيق ، باستخدام دراسات المريض ، في تأثير الجرعة المحقونة (ID) ، ومؤشر كتلة الجسم (BMI) ، وتقييمات ضوضاء الصورة في التصوير المقطعي الانبعاث البوزيتروني. شملت هذه الدراسة 59 مريضا بسرطان الكبد تزن ما بين 45 و 107 كجم. بعد حقن 0.1 mci من ^{18}F–FDG لكل كيلوغرام من وزن الجسم عن طريق الوريد ، تم الحصول على فحوصات انبعاث PET خلال 1 و 1.5 و 3 دقائق / سرير بناءً على وزن المريض.

*Email: samar.o@sc.uobaghdad.edu.iq

تم وضع خمس مناطق (ROIs) في نفس الموقع في الكبد ، والتي كانت تعتبر ذات استقلاب متجانس ، في خمس شرائح متتالية من فحوصات PET / CT لتحديد متوسط قيم الامتصاص (الإشارة) وانحرافها المعياري (الضوضاء)). قدمت لنا نسبة كلاهما نسبة إشارة الكبد إلى الضوضاء.
تم حساب الوزن والطول ونسبة الإشارة إلى الضوضاء (SNR) ومؤشر كتلة الجسم باستخدام جدول بيانات ، وتم إنشاء الرسوم البيانية لتحديد العلاقة بين هذه الخصائص. أظهرت المخططات أن الجرعة المحقونة تزداد عندما يزداد وزن الجسم و / أو مؤشر كتلة الجسم ، وأن SNR ينخفض حتى مع زيادة الجرعة المعطاة. هذا يرجع إلى حقيقة أن الأفراد الأثقل يتم إعطاؤهم جرعة أعلى ، كما هو موضح ، لديهم نسبة SNR أقل. حتى عندما يتم تسليم جرعات أكبر من FDG ، تشير هذه البيانات إلى أن جودة الصورة ، كما تم قياسها بواسطة نسبة الإشارة إلى الضوضاء (SNR) ، تكون أقل شأنا في الأشخاص الأثقل وزنًا مقارنة بأولئك الأقل وزنا.

1. Introduction

In the evaluation of a wide variety of oncologic processes, Positron Emission Tomography/ Computed Tomography (PET/CT) scanning has been developed into a beneficial technique over the past decade. The imaging technique known as Positron Emission Tomography (PET) pictures metabolic pathways and other biological processes using positron-emitting isotopes connected to specific tracers. PET scanning is sometimes referred to as metabolic imaging because it often investigates specific biochemical processes involved in substrate utilization. However, because PET scanning can also image a range of molecular targets and physiological processes, it is more accurately classified as a form of molecular imaging [1].

The most used radiopharmaceutical in this technique is fluorine-18 fluorodeoxyglucose (^{18}F-FDG), which measures the body's glucose usage. The image quality of ^{18}F-FDG PET is crucial for accurate cancer diagnosis [2]. Recent advancements in PET/CT technology have resulted in higher image quality than that of conventional PET, owing to CT-based attenuation correction that is less noisy and the superior performance of scintillator crystals and detector electronics [3]. However, the quality of PET/CT scans of patients who are overweight is frequently decreased [4]. Several studies have demonstrated the importance of modifying acquisition times or injected radiopharmaceutical dosage in order to improve the image quality of obese patients, who require a larger dose per kilogram of body weight (more than 8 MBq/kg) [5,6]. It is not known, however, which of these two factors—a larger injected dose per kilogram of body weight or a lower body weight per second—is essential for defining the image quality because these studies were carried out retrospectively with a constant dose. In addition, the amounts of ^{18}F-FDG that are advised to be administered per kilogram of body weight vary greatly from country to country. As a result, it is still unknown whether or not an increased administered dose is truly required, as well as which strategy—a longer scan time or an increased dose— more effectively improves the quality of PET images of overweight individuals.

This paper aims to examine the effects of dose injected, Body Mass Index (BMI), and Signal-to-Noise Ratio (SNR) in the assessment of PET imaging.

2. Materials and methods

In this study, 59 patients with liver cancer were enrolled in this study, ranging in age from 15 to 85 years old, who were referred to the Al-Andalus Specialist Hospital between November 2022 and December 2022. Before proceeding with the PET/CT scans, the patients' consent was obtained. The hospital's ethics committee had previously given its approval to our study.

In this investigation, a Discovery IQ PET/CT scanner (GE Healthcare, Milwaukee, WI, USA) in the Al-Andalus Specialist Hospital was used. This scanner's detector is made up of $Bi_4Ge_3O_{12}$ (BGO) crystals, each of which measured 6.3 by 6.3 by 30 millimeters. At the one-bed position, the transaxial field of vision (FOV) measured 700 millimeters, the axial field of view measured 260 millimeters, and 79 axial slices were acquired. The window width for the energy range was 435–650 keV, and the window width for the coincidence time range was 9.5 ns. For this study, a matrix with a dimension of 192 by 192 was obtained. The thickness of each slice was 3.27 millimeters. The amount of slice overlap that occurred between beds was 19 slices.

Patients who had a blood sugar concentration in their fasting blood of more than 200 mg/dL at the time of the examination were not permitted to participate in any aspect of the study.

Before receiving an injection of ^{18}F-FDG, all of the patients went without food for at least four to six hours, and a blood sample was taken to determine the patient's glycemia. Images were taken 45–90 minutes following the intravenous injection of the ^{18}F-FDG. Patients were placed in a supine position with both of their arms elevated. The time required to acquire an emission was (1-3) minutes for each bed position.

The Body Mass Index (BMI) was determined as follows:

$$BMI = \frac{weight\ in\ kg}{(height\ in\ m)^2} \;\ldots\ldots (1)$$

The patient body weight (BW) and body height were obtained from their hospital medical records.

The World Health Organization categorizes BMI as follows: underweight (BMI> 18.5 kg/m^2), normal (18.5 – 24.99 kg/m^2), overweight (25 – 30 kg/m^2), and obese (≥30 kg/m^2) [7].

The Body Surface Area (BSA) was calculated using the following formula [8]:

$$\mathrm{BSA}\ (\mathrm{m}^2) = (\text{weight in kg})^{0.425} \times (\text{height in m})^{0.725} \times 0.007184 \;\ldots. (2)$$

The evaluation of image quality with regard to contrast and noise is a key parameter frequently applied to tumour identification. SNR, which is correlated with the number of events found, was determined to measure the PET scanner's effectiveness in terms of the object's visibility. SNR of a PET/CT scan for the cancerous liver was employed as an indicator of image quality since it is the only human organ with a somewhat uniform absorption of ^{18}F-FDG.

The SNR is defined as the ratio of the measured region's mean pixel value (mean) to the Standard Deviation (SD) [9]:

$$SNR = \frac{mean}{SD} \qquad \ldots\ldots (3)$$

2.1 Statistical Analysis

To express all results, the mean and SD were utilized. All statistical analyses were performed using Microsoft Office Excel, 2013. A paired and unpaired Student’s t-test was used to compare data between variables. A result was considered statistically significant if $P < 0.05$.

3. Results

Table 1 lists the demographic and clinical characteristics of the participating patients. There were 59 participants (24 males and 35 females) with an average age of 59.09 ±13.78 years. The average injected dose and injected dose/weight were (8.55 ± 1.06 mCi), (0.11 ± 0.011) mCi/kg, respectively.

The SNR exhibited significant differences with BMI (all p-values < 0.01), and the SNR dropped along with the increase in the BMI groups. In obese patients, the SNR had the lowest value, which indicated the poorest image quality. This result was expected. According to Figure 1, it was found that the SNR was most accurately modelled by the dose that was injected ($R^2 = 0.12$).

The relationships between the dose injected with BMI and weight are shown in Figures 2 and 3, respectively. The figures clearly show that the dose injected increases with the increase in BMI and weight; there was a statistical correlation between BMI and the dose injected ($R^2 = 0.96$). A similar correlation was observed between weight and dose injected ($R^2 = 0.86$, $p < 0.05$).

Table 1: The demographic information of the patients

Parameters	patient cohort
Age ,years	59.09 ±13.78
Body mass, kg	76.59 ±15.12
Height, m	1.63 ±0.076
BMI, Kg/m^2	28.66 ± 5.39
Dose injected, mci	8.55 ± 1.06
Dose injected /weight, mci/kg	0.11 ± 0.011

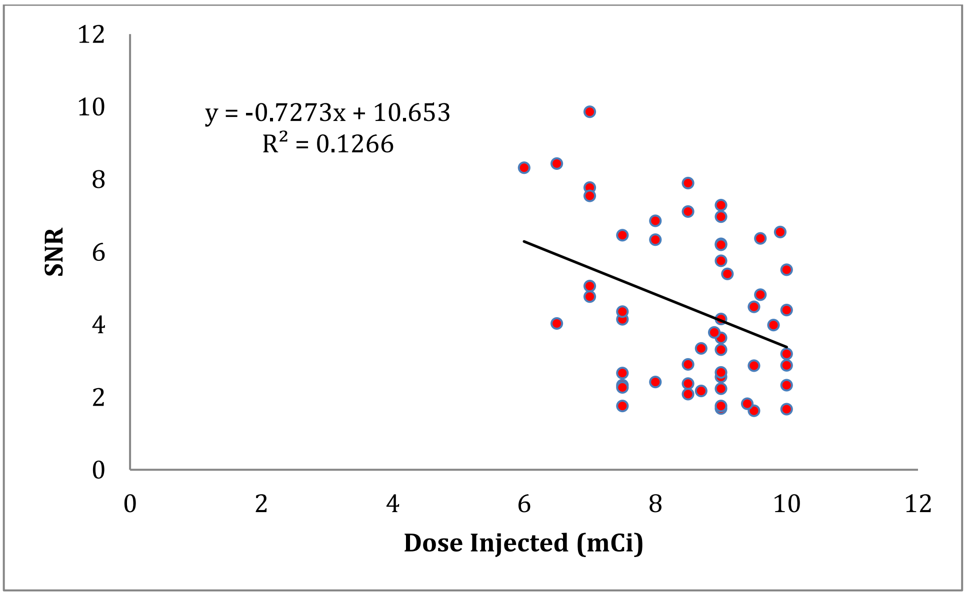

Figure 1: Relation between SNR and dose injected.

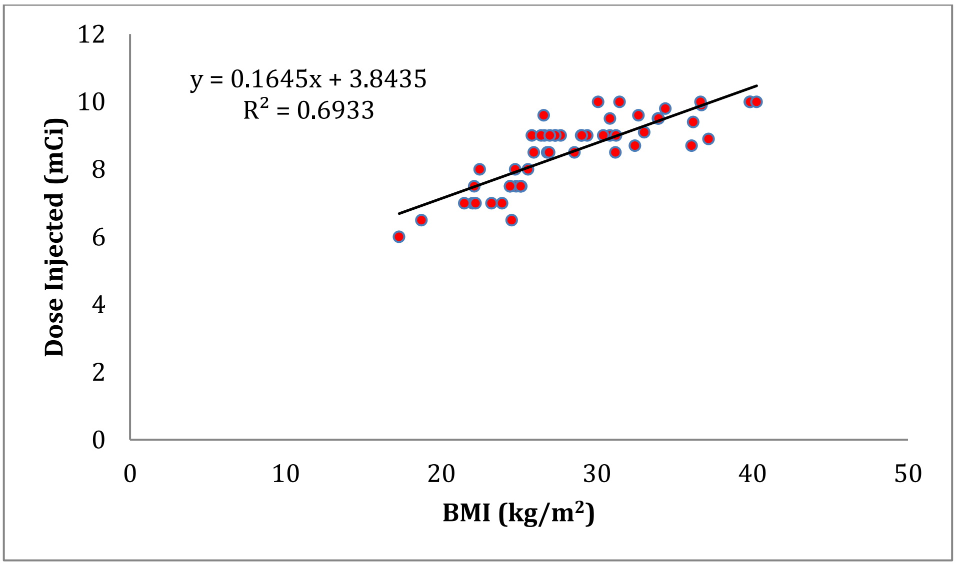

Figure 2: Relation between BMI and dose injected.

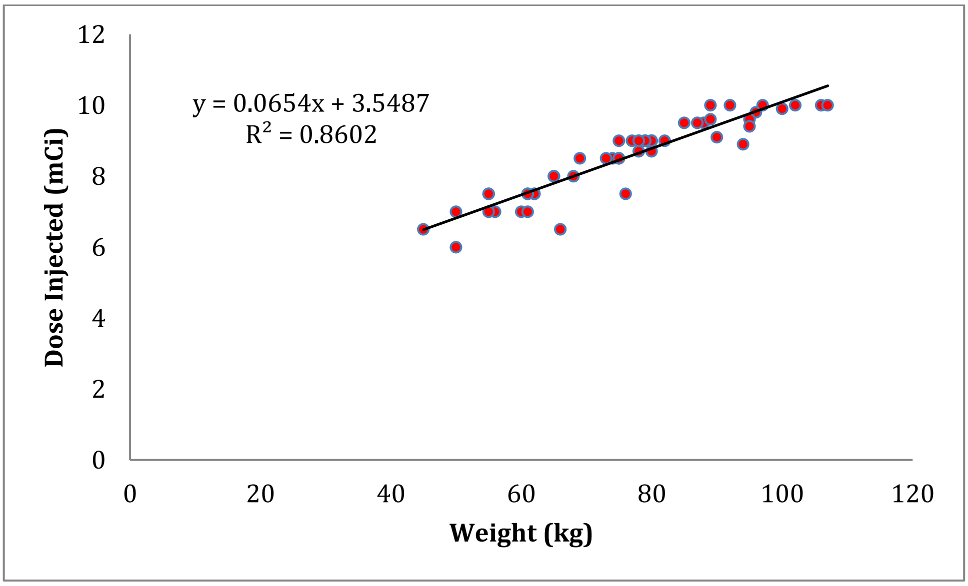

Figure 3: Relation between weight and dose injected.

4. Discussion

As shown in Figure 1 of the injected dose and the SNR, it can be seen that as the injected dose increased, the SNR decreased. This is because, at least in this study, patients who got higher doses were heavier, and it was concluded that as weight increases, so should the dose. Figure 2 shows the relationship between BMI and the dose injected; the dose increases as the BMI rises.

Figure 3, relating the weight to the injected dose, reveals that, as the weight increases, the injected dose increases almost linearly. This is expected as the administered dose depends on body weight.

Since the invention of PET/CT, the use of ^{18}F-FDG PET for the diagnosis and staging of malignant diseases has become significantly more widespread. It was found that the image quality decreased with a lower true coincidence rate in overweight patients of 75 kg or more than in underweight patients. Due to significant photon attenuation and scatter, obesity has a

negative impact on the quality of PET images [10]. On the other hand, increasing the administered dose of ^{18}F-FDG does not affect the image quality of overweight patients.
As a result, alternate methods that require longer acquisition times ought to be implemented to compensate for the reduction in image quality [11].

5. Conclusion

Based on the results of this study, it is concluded that weight significantly affects the quality of the PET/CT images. Even when ^{18}F-FDG doses are linearly tuned to patient weight, the SNR of the image decreases according to the patient's weight.
This was also true for the BMI, which takes height into account. Adjusting approaches in certain parameters, such as attenuation correction or others, to reduce random and scatter noise could be beneficial for obese individuals, but it is not the cure. Adjusting these parameters may result in an image with a higher SNR and a smoother appearance, but the identification of lesions may be diminished. In addition, each nuclear medicine department has its own procedures and logistics; therefore, it may not be ideal to alter practices, such as scanning every patient for longer periods of time.

6. Disclosure and conflict of interest

There are no conflicts of interest.

References

[1] M. R. Hasan, S. M. Kadam and S. I. Essa, “Diffuse Thyroid Uptake in FDG PET/ CT Scan Can Predict Subclinical Thyroid Disorders,” *Iraqi Journal of Science*, vol. 63, no. 5, pp. 2000-2005,2022.

[2] G. J. Kelloff, J. M., Hoffman, B.Johnson, H.I.Scher, B.A. Siegel, E.Y. Cheng, E. B.Cheson, j. O'shaughnessy, K.Z. Guyton, D.A. Mankoff, L.Shankar, S.M. Larson, C.C. Sigman, R.L. Schilsky and D.C. Sullivan," Progress and promise of FDG-PET imaging for cancer patient management and oncologic drug development," *Clin Cancer Res*, vol. 11**,** pp. 2785-808, 2005a.

[3] M.J. Martinez, Y.Bercier, M. Schwaiger and S.I. Ziegler, "PET/CT Biograph Sensation 16: performance improvement using faster electronics," *Nuklearmedizin*, vol. 45, pp. 126–133, 2006.

[4] B. S. Halpern, M. Dahlbom, M.A .Auerbach, C. Schiepers, B. J. Fueger, W. A. Weber, D.H S. Silverman and O. Ratib, J.Czernin, “Optimizing imaging protocols for overweight and obese patients: a lutetium orthosilicate PET/CT study,” *J. Nucl. Med*, vol. 46, pp. 603–607, 2005.

[5] H. Everaert , C. Vanhove, T. Lahoutte, K.Muylle, V. Caveliers, A. Bossuyt and P. R .Franken ,“Optimal dose of 18F-FDG required for whole-body PET using an LSO PET camera,” *Eur J Nucl Med Mol Imaging*, vol. 30, no. 12, pp. 1615–1619, 2003.

[6] M. Tatsumi, P. A. Clark, Y. Nakamoto and R. L. Wahl, “Impact of body habitus on quantitative and qualitative image quality in whole-body FDG-PET,” *Eur J Nucl Med Mol Imaging*, vol. 30, no. 1, pp. 40–45, 2003.

[7] W. H. Organization, "Building foundations for eHealth: progress of Member States: report of the WHO Global Observatory for eHealth," *World Health Organization*, 2006.

[8] C. P. W. Cox, D. M. E. van Assema, F. A. Verburg, T. Brabander, M. Konijnenberg and M. Segbers ,” A dedicated paediatric FDG PET/CT dosage regimen”, *EJNMMI Res* , vol. 11, pp. 65, 2021

[9] E. H. de Groot, N. Post, R. Boellaard, N. R. L. Wagenaar, A. Willemsen and J. A. van Dalen, “Optimized dose regimen for whole-body FDG-PET imaging,” *EJNMMI Res*, vol. 3, no. 1, pp. 1–11, 2013.

[10] E. H. de Groot, N. Post, R. Boellaard, N. R. L. Wagenaar, A. Willemsen and J. A. van Dalen, “Optimized dose regimen for whole-body FDG-PET imaging,” *EJNMMI Res*, vol. 3, no. 1, pp. 1–11, 2013.

[11] P. Zanzonico, “Positron emission tomography: a review of basic principles, scanner design and performance, and current systems,” *Seminars in nuclear medicine*, vol. 34, no. 2, pp. 87–111, 2004.