East European Journal of Physics. **1.** 241-245 (2023)
DOI:10.26565/2312-4334-2023-1-32 ISSN 2312-4334

EVALUATION OF THE INFLUENCE OF BODY MASS INDEX AND SIGNAL-TO-NOISE RATIO ON THE PET/CT IMAGE QUALITY IN IRAQI PATIENTS WITH LIVER CANCER†

Aya B. Hade, Samar I. Essa*
Department of Physics, College of Science, University of Baghdad, Baghdad, Iraq
**Corresponding author: samar.o@sc.uobaghdad.edu.iq*
Received February 1, 2023; revised February 5, 2023; accepted February 7, 2023

Image quality has been estimated and predicted using the signal to noise ratio (SNR). The purpose of this study is to investigate the relationships between body mass index (BMI) and SNR measurements in PET imaging using patient studies with liver cancer. Three groups of 59 patients (24 males and 35 females) were divided according to BMI. After intravenous injection of 0.1 mCi of ^{18}F-FDG per kilogram of body weight, PET emission scans were acquired for (1, 1.5, and 3) min/bed position according to the weight of patient. Because liver is an organ of homogenous metabolism, five regions of interest (ROI) were made at the same location, five successive slices of the PET/CT scans to determine the mean uptake (signal) values and its standard deviation. We obtained the liver's Signal-to-Noise Ratio from the ratio of both. Weight, height, SNR, and Body Mass Index were determined using a spreadsheet, and graphs were created to show the relationship between these variables. The graphs demonstrated that SNR decreases when BMI increases and that, despite an increase in injection dose, SNR also decreases. This is because heavier individuals take higher doses and, according to reports, have lower SNR. These results show that, despite receiving larger FDG doses, heavier patients' images, as measured by SNR, are of lower quality than thinner patients' images.
Keywords: *Body mass index, Signal-to-noise ratio, Image quality; ^{18}F- FDG, PET/CT*
PACS: 87.57.-s, 87.57.-C, 87.57.U-, 87.57.uk

1. INTRODUCTION

Worldwide, cancer ranks as the second largest cause of mortality among humans, caused by unhealthy lifestyles and lack of physical activity. Late disease identification is one of the causes contributing to such a high mortality rate [1,2]. Therefore, early identification is critical because it is the single most important factor in increasing a patient's chances of survival [3]. Cancers typically exhibit morphological, physiological, and molecular characteristics that can be imaged using a variety of clinical imaging techniques that visualize internal organs in an effort to diagnose the disease. As a result of advancements in computer and imaging technology, multiple clinical imaging modalities are now available, making it possible to diagnose the problem, track its evolution, and plan the appropriate follow-up treatments, some of these methods—such as X-ray radiography, computed tomography (CT), magnetic resonance imaging (MRI), and ultrasonography—are classified as anatomical imaging techniques. Functional imaging techniques include Single Photon Emission Computed Tomography (SPECT) and Positron Emission Tomography (PET) [4].

In oncology, PET has been widely used with ^{18}F-FDG as a significant imaging technique for cancer, which allows for the monitoring of glucose consumption in vivo, with a focus on tumor glucose metabolism. As a result, a PET image depicts the distribution of an injected tracer throughout the body of a patient based on the metabolic rate of each region. ^{18}F-FDG is distinguished by its relatively short half-life (109.8 minutes) that emits gamma rays at 1020 keV. The energy is sufficiently high to exit with minimal interactions with other tissues in the body [5].

PET imaging has been characterized by a relatively low image quality due to its low sensitivity as well as the acquisition of random and scattered coincidences during the imaging process. in an effort to evaluate PET image quality. The image noise is one of the different metrics that have historically been relied upon. It is directly determined from the image and calculated as the standard deviation of the counts in a region of interest. For ^{18}F-FDG PET/CT, images must be of adequate quality to accomplish many functions, such as disease identification, staging, and therapy response monitoring, with the recent increase in the number of PET/CT operations, it is becoming increasingly necessary to limit patient exposure to radiation without compromising image quality [6].

Recent improvements in PET/CT technology have led to better image quality than standard PET. This is because CT-based attenuation correction is less noisy, and scintillator crystals and detector electronics work better. Image noise has been used as an indicator of image quality since the higher the image noise at a fixed signal level, the lower the signal-to-noise ratio of the object of interest and hence the ability to detect the object. Even PET/CT images of obese patients, however, are frequently of poor quality. Several studies have suggested that optimizing radiopharmaceutical acquisition durations or administered doses is required to improve image quality in obese patients [7]. The purpose of our study was to assess the effects of injected dose and body mass index on 18F-FDG PET/CT image quality.

2. MATERIALS AND METHODS

Participants in the study ranged in age from 15 to 85 years old and were referred to the Al-Andalus Specialist Hospital between November 2022 and January 2023. There were 24 male participants and 35 female participants in the

† ***Cite as:*** A.B. Hade, and S.I. Essa, East Eur. J. Phys. **1**, 241 (2023), https://doi.org/10.26565/2312-4334-2023-1-32

study. The mean age of the participants was 58.01± 13.18. Before proceeding with the PET/CT scans, we made sure to get the patients' informed consent first. The hospital's ethics committee had previously given its blessing to our study.

In the course of our investigation, we made use of a Discovery IQ PET/CT scanner (GE Healthcare, Milwaukee, WI, USA). This scanner's detector was made up of Bi4Ge3O12 (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. We obtained a matrix with a dimension of 192 by 192, and the thickness of each slice was 3.27 millimeters. The amount of slice overlap that occurred between beds was 19 slices.

Patients who had had a blood sugar concentration in their fasting blood that was more than 200 mg/dL at the time of the examination were not permitted to take part 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. Before giving the patient 18F-FDG, an intravenous cannula was inserted in either the patient's arm or the palm of their hand, and a blood sample was taken to determine the patient's glycaemia. Images were taken 45–90 minutes following injection of the contrast agent. 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. In order to evaluate the connection between these factors and the 18F-FDG PET image quality, the patient-dependent parameters for each patient were gathered or calculated. This was done in order to conduct the study. The patient files were searched for information regarding body weight (BW) and body height. The body mass index, sometimes known as BMI, was determined.

$$BMI = \frac{Weight\ in\ kg}{(height\ in\ m)^2} \quad (1)$$

Body mass index (BMI), was categorized according to the World Health Organization classification, namely 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) [8]. The evaluation of image quality with regard to contrast and noise is a key parameter that is frequently applied to tumor 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. The liver's SNR was employed as an indicator of image quality since it is the only human organ with a somewhat uniform absorption of FDG. The SNR is defined as the difference between the measured region's mean pixel value (mean) and standard deviation (SD) [9]:

$$SNR = \frac{mean}{SD} \quad (2)$$

2.1. Statistical Analysis

To express all results, the mean and standard deviation (SD) were utilized. All statistical analysis was performed using Microsoft Office Excel 2013. The definition of statistical significance was a p-value less than 0.05.

3. RESULTS AND DISCUSSION

Table 1 shows that when the BMI increased, the dose/weight and SNR decreased. The mean injection dose for the normal group was 7.12 mci, 9.66 mci for obese, and the injection mean dose for the overweight group was 8.78mci.

Table 1. Results for Administered ^{18}F-FDG.

Groups	Mean ± SD					
	Weight (kg)	Height (m)	BMI kg/(m)^2	Injection dose (mci)	Dose/weight (mci/kg)	SNR
Normal weight	58.47±6.10	1.61±0.08	22.66 ± 2.24	7.12 ± 0.5	0.12 ± 0.008	6.23 ± 2.95
Overweight	76.71±8.46	1.68±0.08	27.06 ±1.45	8.78 ± 0.73	0.11 ± 0.007	4.33 ± 2.26
Obese	92.22±12.55	1.62±0.06	36.04 ± 6.82	9.66 ± 0.55	0.1 ± 0.01	3.83 ± 1.68

* p-value < 0.05 between BMI vs SNR.

After filling in all the values in the Table 1 about mean, deviation, SNR, weight (in kg), height (in m), and BMI, several graphs related to SNR and BMI were made to see which were the results. All the graphs were made with the values of the PET to see if there were any significant differences between them. BMI (kg/m2) and SNR for normal weight group was (mean BMI 22.66 ± 2.24, and SNR 6.23 ± 2.95, p value < 0.05).

The value of BMI and SNR for overweight group is (27.06 ±1.45) and (4.33 ± 2.26), respectively with also significant. For obese group the mean values for both BMI and SNR were (mean BMI 36.04 ± 6.82, and SNR 3.83 ± 1.68, with p value < 0.05). The relationships between the SNR and BMI for (normal, overweight, and obese) groups are shown in Figures 1(a), (b), and (c) respectively. The figures clearly show that SNR decreases with a BMI increase.

For clinical whole-body FDG-PET scans for oncology, full 3D data acquisition is now the standard protocol. But noise components like random and scatter have a big effect on the quality of the image. Before a doctor makes a diagnosis, the quality of the PET image should be looked at to see if it is good enough for a diagnosis or not, but there is no standard way to do this yet [10].

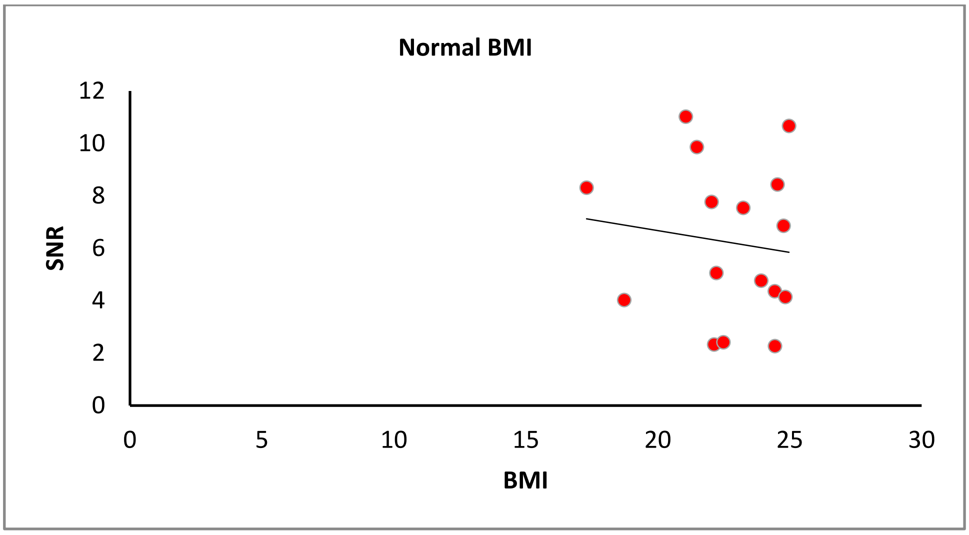

Figure (1a): Relation between BMI (normal) and SNR on the PET.

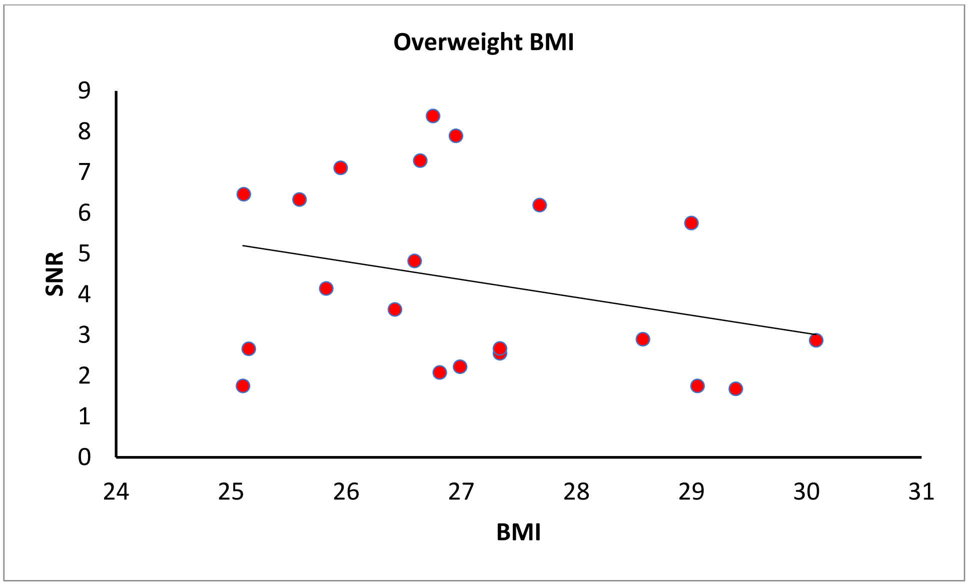

Figure (1b): Relation between BMI (overweight) and SNR on the PET.

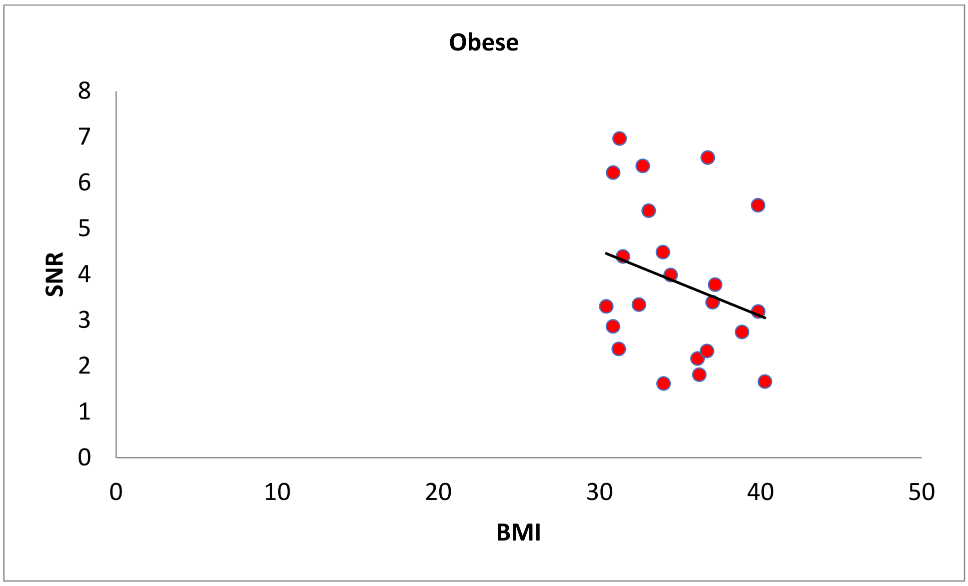

Figure (1c): Relation between BMI (obese) and SNR on the PET.

Investigating the impact of body mass index on image noise measures in PET scans was the purpose of this effort. Our evaluation of SNR was carried out on bed frames covering the livers of all of the patients. Because the liver is the largest organ in the body and has a radiotracer uptake that is relatively consistent and uniform, we decided to use this bed position. As a measure of image noise, we used the SD of the pixel values inside the area of interest (ROI). Despite being often utilized in clinical imaging research, the SD of ROI has limitations as a noise indicator. The term "noise" refers to the degree of radioactive fluctuation (SD) in image of uniform uptake. Image noise is a result of numerous variables. The quantity of photons detected determines stochastic noise. The reconstruction process produces structured noise, which is impacted by visual field heterogeneity [11].

Numerous patient-related problems could affect the signal-to-noise ratio. The administration of FDG is the first. The second factor is body size, specifically the total volume of the body where FDG is dispersed and diluted. Thirdly, the mean path length of photons from the liver to the detector depends on the size of the subject. As a result, larger people will exhibit increased photon attenuation. The "half distance"—analogous to the half-life—over which 511 keV photons in water attenuate 50% of their counts is 7.3 cm. Consequently, the count density may be significantly impacted by increased abdominal girth. Fourthly, although it wouldn't be anticipated that patient movement would correlate with body size indices, it would also reduce the signal-to-noise ratio [12].

After filling in all the values in the Table (1) about mean, standard deviation, SNR, injection dose (in mci), weight (in kg), height (in m) and BMI, several figures related to BMI and SNR were made to see which the results were. All the figures were made with the values of the PET to see if there are any significant differences between them. Our findings indicate that the signal-to-noise ratio (SNR) and image noise worsen dramatically with rising BMI. This is due to the loss of real coincidence events, most likely as a result of greater attenuation in larger patients. However, the quality appears to be optimal when the patient's weight is regarded as normal (between the BMI values of 18 and 24, approximately).

Figure (1a, b, and c) shows a scatter plot of the SNR versus BMI for both scanners. Here each dot in the figure represents a single patient. The figures indicate that SNR decreases more quickly at lower BMI values than at higher values, indicating that image quality deteriorates more quickly as BMI increases from low values. More dosage cannot, however, be injected to compensate for poorer image quality in larger individuals. These findings confirm earlier research that was extrapolated from phantom data and published. By extending the scan time, it may be possible to improve image quality in this patient population [13,14].

Individual variability in liver metabolism, attenuating tissue thicknesses, image reconstruction parameters, and aberrations such as respiratory motion blur impair the ability of hepatic SNR to distinguish between image quality [15]

4. CONCLUSION

Based on the outcomes of this investigation, it is safe to conclude that weight plays a significant effect in the quality of the PET/CT image. It is affects the liver's SNR. The more heavy the patient is, the less SNR the image. This was also true for the BMI, which considers height. Changing specific settings, such as attenuation correction or others, to reduce random and scatter noise may be good for fat people, but it is not a cure. Adjusting these parameters may result in an image with a greater SNR and a smoother appearance, but it may reduce the ability to identify lesions. Furthermore, each nuclear medicine department has its own protocols and logistics; hence, changing methods, such as scanning every patient for extended periods of time, may not be appropriate.

ORCID IDs

Aya B. Hade, https://orcid.org/0000-0002-1246-3024; **Samar I. Essa,** https://orcid.org/0000-0001-9821-2279

REFERENCES

[1] N. Waeleh, M.I. Saripan, M. Musarudin, S. Mashohor, and F.F.A. Saad, "Correlation between 18F-FDG dosage and SNR on various BMI patient groups tested in NEMA IEC PET phantom", Applied Radiation and Isotopes **176**, 109885 (2021). https://doi.org/10.1016/j.apradiso.2021.109885

[2] A.K. Yadav, and N.S. Desai, "Cancer stem cells: acquisition, characteristics, therapeutic implications, targeting strategies and future prospects", Stem Cell Rev. Reports, **15**, 331 (2019). https://doi.org/10.1007/s12015-019-09887-2

[3] M.C. Liu, G.R. Oxnard, E.A. Klein, C. Swanton, M.V. Seiden, CCGA Consortium, "Sensitive and specific multi-cancer detection and localization using methylation signatures in cell-free DNA", Ann. Oncol. **31**, 745 (2020). https://doi.org/10.1016/j.annonc.2020.02.011

[4] E. Hubbell, C.A. Clarke, A.M. Aravanis, and C.D. Berg, "Modeled reductions i late-stage cancer with a multi-cancer early detection test", Canc. Epidemiol. Biomarkers Prev. **30**, 460 (2020). https://doi.org/10.1158/1055-9965.EPI-20-1134

[5] M.R. Hasan, S.M. Kadam, and S.I. Essa, "Diffuse Thyroid Uptake in FDG PET/ CT Scan cCan Predict Subclinical Thyroid Disorders", Iraqi Journal of Science, **63**(5), 2000 (2022). https://doi.org/10.24996/ijs.2022.63.5.15

[6] S. Kalman, and T. Turkington, "Introduction to PET instrumentation (multiple letters)", J. Nucl. Med. Technol. **30**, 63 2002. PMID: 12055279

[7] N. Shimada, H. Daisaki, T. Murano, T. Terauchi, H. Shinohara, and N. Moriyama, "Optimization of the scan time is based on the physical index in FDG-PET/CT (in Japanese with English abstract)", Nihon Hoshasen Gijutsu Gakkai Zasshi, **67**(10), 1259 (2011). https://doi.org/10.6009/jjrt.67.1259

[8] World Health Organization, *Builiding foundations for health, progress of member states: report of the WHO Global observatory for health*, (World Health Organization, 2006).

[9] E.H. de Groot, N. Post, R. Boellaard, N.R.L. Wagenaar, A.T.M. Willemsen, and J.A. van Dalen, "Optimized dose regimen for whole-body FDG-PET imaging", EJNMMI Research, **3**, 63 (2013). https://doi.org/10.1186/2191-219x-3-63
[10] R.D. Badawi, P.K. Marsden, B.F. Cronin, J.L. Sutcliffe, and M.N. Maisey, "Optimization of noise-equivalent count rates in 3D PET", Phys. Med. Biol. **41**, 1755 (1996). https://doi.org/10.1088/0031-9155/41/9/014
[11] Y. Masuda, C. Kondo, Y. Matsuo, M. Uetani, and K. Kusakabe, "Comparison of imaging protocols for 18F-FDG PET/CT in overweight patients: optimizing scan duration versus administered dose", J. Nucl. Med. **50**, 844 (2009). https://doi.org/10.2967/jnumed.108.060590
[12] Y. Sugawara, K.R. Zasadny, A.W. Neuhoff, and R.L. Wahl, "Reevaluation of thestandardized uptake value for FDG: variations with body weight and methods for correction", Radiology, **213**, 521 (1999). https://doi.org/10.1148/radiology.213.2.r99nv37521
[13] M. Danna, M. Lecchi, V. Bettinardi, M. Gilardi, C. Stearns, G. Lucignani, and F. Fazio, "Generation of the acquisition specific NEC (AS-NEC) curves to optimize the injected dose in 3D ^{18}F-FDG whole body PET studies", IEEE Trans. Nucl. Sci. **53**, 86 (2006). https://doi.org/10.1109/TNS.2005.862966
[14] C.C. Watson, M.E. Casey, B. Bendriem, J.P. Carney, D.W. Townsend, S. Eberl, S. Meikle, and F.P. DiFilippo, "Optimizing injected dose in clinical PET by accurately modeling the counting-rate response functions specific to individual patient scans", J. Nucl. Med. **46**, 1825 (2005). PMID: 16269596
[15] Z.S. Mohammad, and J.M. Abda, "Positron Interactions with Some Human Body Organs Using the Monte Carlo Probability Method", Iraqi Journal of Physics, **20**(3), 50 (2022). https://doi.org/10.30723/ijp.v20i3.1026

ОЦІНКА ВПЛИВУ ІНДЕКСУ МАСИ ТІЛА ТА СПІВВІДНОШЕННЯ СИГНАЛ-ШУМ НА ЯКІСТЬ PET/CT-ЗОБРАЖЕНЬ У ПАЦІЄНТІВ ІРАКУ З РАКОМ ПЕЧІНКИ

Ая Б. Хаде, Самар І. Есса
Факультет фізики, Науковий коледж, Багдадський університет, Багдад, Ірак

Якість зображення було оцінено та передбачено за допомогою співвідношення сигнал/шум (SNR). Метою цього дослідження є дослідження зв'язків між вимірюваннями індексу маси тіла (BMI) і SNR при PET -зображенні з використанням досліджень пацієнтів із раком печінки. Три групи з 59 пацієнтів (24 чоловіки та 35 жінок) були розділені відповідно до BMI. Після внутрішньовенної ін'єкції 0,1 mCi ^{18}F-FDG на кілограм маси тіла проводили PET -сканування випромінювання протягом (1, 1,5 і 3) хв/положення ліжка відповідно до ваги пацієнта. Оскільки печінка є органом однорідного метаболізму, п'ять областей інтересу (ROI) були зроблені в одному місці, п'ять послідовних зрізів сканування PET/CT, щоб визначити середні значення поглинання (сигналу) та його стандартне відхилення. Ми отримали співвідношення сигнал-шум печінки із співвідношення обох. Вага, зріст, SNR та індекс маси тіла були визначені за допомогою електронної таблиці, а графіки були створені, щоб показати зв'язок між цими змінними. Графіки продемонстрували, що SNR зменшується, коли BMI збільшується, і що, незважаючи на збільшення дози ін'єкції, SNR також зменшується. Це пояснюється тим, що люди з більшою вагою приймають вищі дози і, згідно з повідомленнями, мають нижчий SNR. Ці результати показують, що, незважаючи на отримання більших доз FDG, зображення важких пацієнтів, виміряні SNR, нижчої якості, ніж зображення тонших пацієнтів.

Ключові слова: *індекс маси тіла; співвідношення сигнал/шум; якість зображення; ^{18}F-FDG, PET/CT*