Patient preparation importance for diagnostic quality of PET-CT images

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ABSTRACT

Objective: to evaluate the importance of patient preparation for diagnostic quality of PET-CT images.

Methods: prospective study of 188 patients' who underwent PET-CT examination at our Nuclear medicine department has been carried out. Patients were asked to fill in questionnaire about preparation for PET-CT. Then PET-CT images were analysed and attributed to one of the five quality categories, assigning score from 1 to 5. Additionally, average and maximum standardized uptake values (SUV) were calculated in the standard size (200cm3) region of interest (ROI) placed on the left ventricle of the heart. P<0.05 was considered statistically significant.

Results: diabetes was found in 14 (7.5%), obesity in 44 (23.4%) patients. Mean patients' glycaemia prior 18F-FDG injection – 5.42±1.02 mmol/l. Most of the patients' (n=186; 98.9%; p<0.001) had their last meal more than 6 hours before PET-CT. One hundred sixteen (61.7%; p<0.001) patients consumed 3-4 glasses (0.75-1 litre) of water during last 6 hours. Patients have followed low carbohydrates low fat containing products diet (n=97; 51.6%), low carbohydrates diet – 32 (17.0%), high proteins diet – 15 (8.0%), high fat diet – 2 (1.1%). SUVmax – 2.78±1.36, SUVav – 1.63±0.79. Most of the PET-CT images were considered as high quality (p<0.05): 82 (43.6 %) images were assigned for 4 points, 48 (25.5%) - 5 points. PET-CT images of diabetic patients' were significantly lower quality compared with non-diabetic patients (p<0.001) and in obese patients compared with non-obese (p<0.001). Mean quality of PET-CT images was associated with glycaemia (r=-0.29; p<0.001), SUVav (r=-0.38; p<0.001). SUVmax (r=0.2; p=0.006) and SUVav (r=0.19; p=0.01) were associated with glycaemia.

Conclusions: Eighty percent of the patients' have followed the instructions of preparation for PET-CT examination. Quality of PET-CT images was lower in patients' with diabetes, obesity and higher pre-test glycaemia. Higher glycaemia levels were associated with higher SUVmax and SUVav in the left ventricle of the heart.

Keywords: patient's preparation, positron emission tomography – computed tomography, quality of images.

INTRODUCTION

In clinical practice, 18F-FDG PET-CT is commonly used in the evaluation and management of many types of cancer, including tumour diagnosis, staging, restaging, treatment monitoring, and radiation therapy planning [1]. 18F-FDG is glucose analogue, therefore, accumulation of this radiopharmaceutical is detected in these locations of organism where use of glucose is increased. Due to high activity of hexocinase and higher amount of GLUT-1 transporters activated, cancerous cells use more glucose for their metabolism, which manifests in increased accumulation of 18F-FDG during PET-CT examination [2]. Therefore, accumulation of 18F-FDG can be detected in normal tissues, particularly in brain and heart, which complicates evaluation of images and can lead to false positives results [3]. Thus, appropriate patient preparation and comprehensive clinical and anamnestic data are important to reduce risk of inaccurate interpretation of PET-CT images. Appropriate preparation include restrictions in diet and physical activity, management of blood glucose levels in diabetic patients, as well as an awareness of the effect of medications and environmental conditions [1]. While patients are usually instructed to avoid any meal and insulin injection for 4-6 hours before their study, it is not uncommon to encounter

diabetic patients who are not following instructions. This can result in increased diffuse cardiac and/or skeletal muscle uptake [4]. By analysing patients' questionnaires and PET-CT images, we aim to evaluate the importance of patient preparation for diagnostic quality of PET-CT images.

METHODS

Prospective study of patients' who underwent PET-CT examination at Nuclear medicine department of our hospital from 2017 September to 2017 November has been carried out. Permission number: BEC – LSMU (R)-28 received from our Bioethical institution. One hundred eighty eight patients were investigated. Of these 108 (57.4%) were men and 80 (42.6%) were women. Oldest patient was 87 years old, youngest – 15 years. Mean patients' age (± standard deviation) 57.1±16.7 y. In order to find out how patients followed the recommendations of preparation for PET-CT examination, they had to fill in questionnaire (appendix 1).

Additional patients' data collected from nuclear medicine department: gender, metabolic disorder (diabetes, obesity), other conditions that can affect quality of images (infection, fever, use of antibiotics, interventional procedure, smoking). All patients were measured (height, weight) and glycaemia results were acquired prior 18F-FDG injection. Patients were divided into two groups according their glycaemia levels prior 18-FDG injection: first group - glycaemia up to 4.5 mmol/l (n=37; 19.7%) and second group - glycaemia >4.5 mmol/l (n=151; 80.3%). A whole-body PET-CT from skull to mid-thigh was performed with GE Discovery VCL device 60 minutes after 18F-FDG injection. Patients' PET-CT images were analysed and assigned to one of the five categories of quality (1-5): inappropriate for evaluation, insufficient, average with some restrictions, good, perfect quality. Additionally, average and maximum standardized uptake values (SUV) were calculated in the standard size (200 cm3) ROI placed on the left ventricle of the heart.

Statistical analysis was done using „IBM SPSS Statistics 23" and „Microsoft Excel 2013" software. Statistical averages of quantitative variables were evaluated using Stjudents's (t) test. Categorical variables interrelations evaluated using Pearson's $\chi 2$ and Fisher's exact. Cramér's V test was used to measure association between two nominal variables. $P<0.05$ was considered statistically significant.

RESULTS

One hundred eighty eight patients' body mass index (BMI) was calculated. Patients with BMI more than 29.9 were considered obese (n=44; 23.4%). Fourteen (7.5%) patients were diabetic, 8 (4.3%) of these had obesity too. All patients exept one used metformin for treatment of diabetes. Mean patients' glycemia prior 18-FDG injection – 5.42±1.02 mmol/l, highest - 8.50 mmol/l, lowest - 2.80 mmol/l.

Questionnaire analysis showed that most of the patients' (n=186; 98.9%) had their last meal more than 6 hours before PET-CT. Also four (2.1 %) patients had tea or coffee with sugar less than 6 hour before examination. The majority of patients' consumed enough water during last 6 hours: 0.75-1 litre - 116 (61.7%), up to 2 litres – 15 (8.0%), more than 2 litres – 1 (0.5%). Unfortunately, 53 (28.2%) patients had insufficient amount of water consumed (less than 0.5 l) and 3 (1.6%) hadn't any water. Statistically significant relationship between consumed amount of water and quality of PET-CT images wasn't found ($p>0.05$).

All patients were advised to follow diet prior PET-CT examination. Patients had followed low carbohydrates and low fat containing products diet (n=97; 51.6%), low carbohydrates diet only – 32 (17.0%), high proteins diet – 15 (8.0%), high fat diet – 2 (1.1%), low carbohydrates and high proteins diet – 8 (4.3%), low carbohydrates, low fat and high proteins containing diet – 13 (6.9%). Twenty one (11.2%) patients hadn't followed any diet. There wasn't statistically significant relationship between diet and quality of PET-CT images ($p>0.05$)

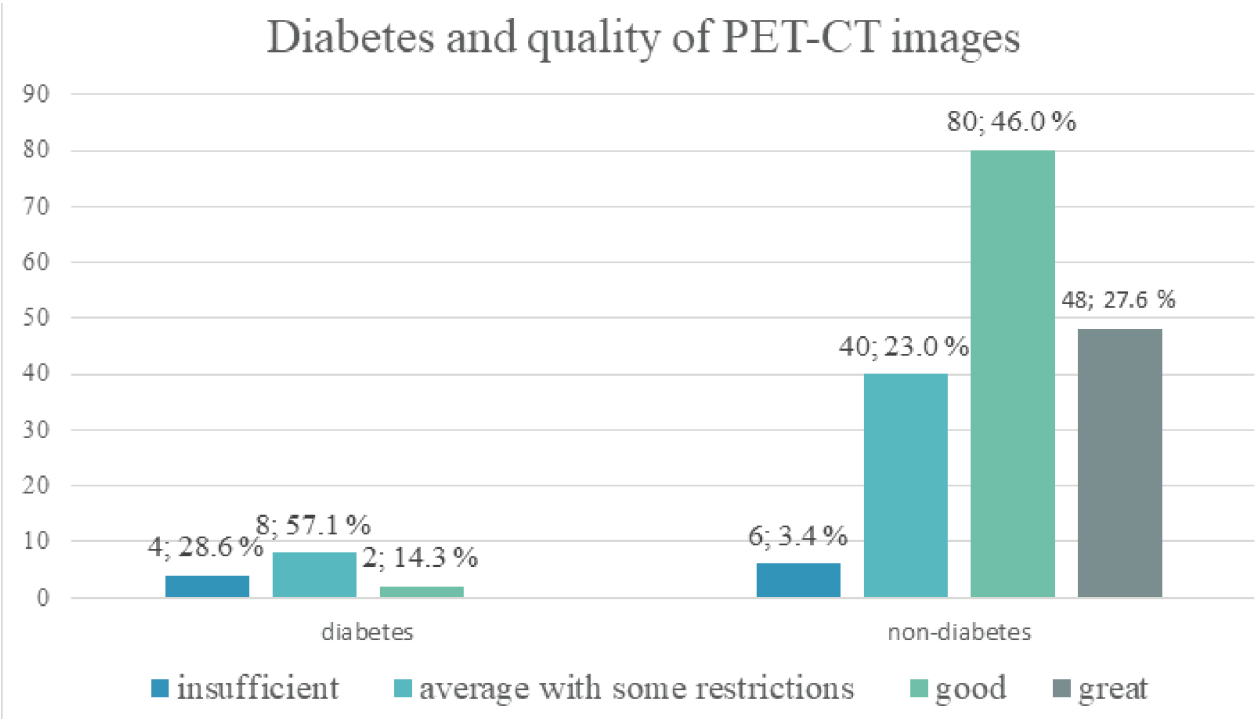
In our questionnaire we provided the list of

products which shouldn't be used before PET-CT examination. Patients were asked to select products from the list which they used during last 24 hours. Eighty seven patients (46.3%) had chosen at least one product from the list, while 101 (53.7 %) hadn't chosen any. The next question was if the patients had used any of the listed products during last 6 h. Most of the patients (n=162; 86.2%) hadn't used any products during last 6 hours, while twenty six (13.8%) consumed at least something. Due to discordance of answers to the last question, this question considered unreliable and was excluded from the final analysis.

PET-CT images analysis showed that SUVmax values of left ventricle of the heart varied between patients' from 1.4 to 11.0 (SUVmax – 2.78±1.36). SUVav values - from 0.9 to 7.0 (SUVav –1.63±0.79).

Most of the PET-CT images were considered as high quality ($p<0.05$): 82 (43.6 %) images were assigned for 4 points, 48 (25.5%) - 5 points. Forty eight (25.5%) images were evaluated as average with some restrictions (3 points) and ten (5.3%) - insufficient quality (2 points). There were no inappropriate quality images. For more accurate statistical analysis, mean score of PET-CT quality of images (3.89±0.85) was calculated. Statistically significant relationship between diabetes and diagnostic quality of PET-CT images ($p<0.001$) was found. PET-CT images of diabetic patients' were significantly lower quality compared with non-diabetic patients (Picture 1).

Picture 1: diabetes and quality of PET-CT images interrelation.



Statistically significant relationship between obesity and quality of PET-CT images was found ($p<0.001$). PET-CT images of non-obese patients' were significantly higher quality than obese group (Picture 2). Average glycaemia was significantly higher ($p<0.001$) in obese patients' group (6.03±0.85 mmol/l) than non-obese group (5.23±0.99 mmol/l).

Picture 2: obesity and quality of PET-CT images relationship.

Our analysis showed that PET-CT images were significantly higher quality (p=0.17; CI 0.07-0.67) in patients with glycaemia below 4.5 (4.19±0.81) when compared with glycaemia levels over 4.5mmol.l (3.82±0.84). Mean quality of PET-CT images was associated with glycaemia (r=-0.29; p<0.001).

We calculated SUVav and SUVmax in the ROI placed on the left ventricle of the heart and found negative linear correlation between SUVav and quality of PET-CT images. As SUVav increases, quality of PET-CT images decreases (r =-0.38; p<0.001). Negative linear correlation between SUVmax and quality of PET-CT images was also found (r=-0.42; p<0.001). As glycaemia increase, SUVmax (r=0.2; p=0.006) and SUVav values (r=0.19; p=0.01) increases.

Appendix 1: questionnaire about preparation for PET-CT

Questionnaire about preparation for PET-CT

(underline appropriate answers)

Date.....

When was your last meal?

1. Less than hour ago.
2. 1-3 hours ago.
3. 3-6 hours ago.
4. More than 6 hours ago.

Have you consumed any of the listed drinks during last 6 hours?

1. Water.
2. Tea or coffee with sugar.
3. Sweet beverages.
4. Other.

How much water you consumed during last 6 hours?

1. Didn't drink at all.
2. 1-2 glasses (0,5 liter).
3. 3-4 glasses (1 liter).
4. Up to 2 liters.
5. More than 2 liters.

Have you followed any specific diet during last 24 hours?

1. Low carbohydrates (sugars) diet.
2. High protein diet.
3. High fat diet.
4. Low carbohydrates and low fat diet.
5. Haven't followed any diet.

Underline the products which you used during last 24 hours:

Bread, donuts, pasta, potatoes, rice, cookies, sandwich, toast, crackers, muffins, peanut butter, jam, yogurt, curd, peanuts, juice, candies, chewing gum, cough drops, beans.

Which of these products listed above you used during last 6 hours?

DISCUSSION

In our hospital patients are invited to nuclear medicine department and instructed orally how to prepare for PET-CT, all the questions about the procedure are answered and written information forms are given to patients by nuclear medicine technologist. Low carbohydrate and low fat diet is recommended for 24 h before scanning. To minimize dietary glucose–related competitive inhibition of 18F-FDG uptake and reduce serum insulin to near basal levels, complete fasting for a minimum of 6 h before the scan is recommended. Similar recommendations with subtle differences are found in the various clinical societies guidelines [5-9]. Our results showed that most of the patients' had followed these instructions. Only six patients (3.2%) used any kind of carbohydrates intake less than 6 h before scan and a fifth of all patients hadn't followed dietary recommendations, in spite of very detailed oral and written instructions.

Statistically significant relationship between diabetes and diagnostic quality of PET-CT images was found. PET-CT images of diabetic patients' were significantly lower quality compared with non-diabetic patients. Most of the patients' were using metformin for treatment of diabetes. Gontier et.al prospective study showed that metformin significantly increases 18F-FDG uptake in colon and to a lesser extent in small intestine. This increase is typically intense, diffuse and continuous along the bowel, strongly predominant in colon in both digestive wall and lumen. It cannot

be confused with malignant focal bowel uptake, but it can mask an actual neoplastic bowel disease and can induce false-negative results [10].
Statistically significant relationship between obesity and quality of PET-CT images was found. Obese patients' quality of PET-CT images was significantly lower than of non-obese group. Zasadny and Wahl found out that in fasting woman, the normal SUV's of blood, liver and spleen are strongly correlated with body weight in similar way [11]. As 18F-FDG reaches tumour via the bloodstream, tumour SUV may correlate with body weight [11]. Because of body weight impact on diagnostic quality of PET-CT images, some investigators describe a SUV normalization procedure based on lean body mass or the body surface area to be a more reliable parameter to estimate glucose metabolism [12].
Our results showed negative linear correlation between glycaemia prior 18F-FDG injection and quality of PET-CT images. The biodistribution of 18F-FDG is affected by blood glucose levels. The main problem with increased levels of serum glucose is the associated increase in insulin levels. Increased insulin levels result in increased muscle uptake of 18F-FDG, decreasing the quality of the images [13]. That is why it is very important to follow up dietary instructions to prevent high glucose levels in the blood. Further studies should be performed in order to find out most common mistakes of preparation for PET-CT.

CONCLUSIONS

Eighty percent of patients' have followed instructions of preparation for PET-CT examination. Quality of PET-CT images was lower in patients with diabetes, obesity and higher pre-test glycaemia levels. Higher glycaemia levels were associated with higher SUVmax and SUVav in the left ventricle of the heart.

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