VIA MEDICA

Nuclear Medicine Review 2021, 24, 2: 51–57
DOI: 10.5603/NMR.2021.0015

ISSN 1506–9680, e-ISSN 1644–4345

Original

Patterns of [^{18}F]FDG myocardial uptake in oncology patients as a predictor of myocardial ischaemia on stress myocardial perfusion imaging

Ahmed Fathala, Abdulaziz Alsugair, Moheieldin Abouzied, Ahmed Almuhaideb
King Faisal Hospital, Riyadh, Saudi Arabia

[Received 5 X 2020; Accepted 15 III 2021]

Abstract

Background: There is variable cardiac uptake observed on oncological ^{18}F-fludeoxyglucose ([^{18}F]FDG) positron emission/computed tomography (PET/CT). The main purpose of this study is to evaluate patterns of overnight fasting myocardial [^{18}F]FDG uptake in oncological PET/CT and analyse the relationship between myocardial [^{18}F]FDG uptake and myocardial ischaemia on stress single-photon emission CT (SPECT) myocardial perfusion imaging (MPI).

Material and methods: A total of 362 subjects underwent both oncological PET/CT and stress SPECT MPI within 3 months of each other. Subjects with focal-mass-like [^{18}F]FDG myocardial uptake raising the suspicion of cardiac metastasis and subjects with coronary artery disease (CAD) were excluded. The myocardial [^{18}F]FDG uptake was classified into four patterns.

Results: Abnormal SPECT MPI was noted in 91 (25%) patients; 220 (61%) patients had completely absent [^{18}F]FDG uptake, 80 (22%) had diffuse [^{18}F]FDG uptake, 39 (11%) had focal on diffuse [^{18}F]FDG uptake, and 23 (6%) had focal or regional myocardial [^{18}F]FDG uptake, the regional [^{18}F]FDG myocardial uptake was the most predictive of myocardial ischaemia on SPECT MPI, and there were positive associations between age, sex, hypertension, tobacco smoking, hypercholesterolemia, and left ventricular ejection, a fair agreement was noted between the focal or regional FDG uptake and presence of ischaemia on SPECT, K = 0.394 (95% CI 0.164 to 0.189).

Conclusions: Based on the presented findings, the physiological myocardial [^{18}F]FDG uptake in fasting oncology patients is variable. The regional myocardial [^{18}F]FDG uptake pattern is the most frequent pattern associated with myocardial ischaemia on stress SPECT MPI, however, the agreement between regional FDG uptake and presence of ischaemia on SPECT is fair.

KEY words: myocardial ischaemia; myocardial [^{18}F]FDG uptake; oncological PET/CT; CAD risk stratification

Nucl Med Rev 2021; 24, 2: 51–57

Introduction

While normal myocardial ^{18}F-fludeoxyglucose ([^{18}F]FDG) activity can be defined as absent or diffusely, focally, or regionally increased, myocardial [^{18}F]FDG uptake in oncology patients is non-uniform and variable [1]. There is high spatial and temporal heterogeneity of the [^{18}F]FDG myocardial metabolism patterns in cancer patients free of cardiac disease [2]. This variability may occur in daily cardiac evaluation, and it may affect the interpretation of cardiac studies in certain disease evaluations, such as cardiac sarcoidosis and myocardial viability [3]. Some data suggest that metabolic alteration may occur in oncology patients; for example, metabolic alteration in cardiac glucose uptake may arise in patients with Hodgkin's lymphoma independent of skeletal muscle uptake [4]. The regional myocardial uptake in patients with stable angina is homogenously low and comparable to that of healthy subjects [5]. However, in patients with ischaemic cardiomyopathy or severe re-perfused myocardial injury, the myocardial utilization at rest is increased because the oxidative metabolism is reduced. In this case, to

Correspondence to: Ahmed Fathala
King Faisal Specialist Hospital and Research Centre,
PO Box 3354, Riyadh 11211
phone: +966 55-253-2402; fax: +96-64-422-481
e-mail: ahm35799@hotmail.com

support adenosine triphosphate production from glycolysis, the primary substrate of energy metabolism becomes glucose [6, 7].

Studies have also shown that, in patients with severe coronary artery disease (CAD) and unstable angina, myocardial glucose utilization is enhanced in the absence of clinical, electrocardiographic, or detectable perfusion evidence of acute ischaemia [8]. Also, studies have shown that patients with clinical suspicion of CAD have a higher incidence of focal myocardial uptake and coronary artery calcification but the FDG uptake is often observed in sites remote from those with calcification [9]. However, it is difficult to diagnose the presence of an ischaemic myocardium by fasting [^{18}F]FDG positron emission/computed tomography (PET/CT) imaging alone because the glucose metabolism in the fasting state is quite heterogeneous, even in normal myocardium [10, 11]. Myocardial glucose utilization increases in many conditions, such as myocardial ischaemia, pressure overload, and during exercise; myocardial regional ischaemia leads to the translocation of both glucose transporters, GLUT 4 and GLUT 1, to the sarcolemma in vivo; also, myocardial ischaemia stimulates adenosine monophosphate-activated protein kinase, which may increase cardiac glucose uptake [12]. Thus, the authors wanted to explore the [^{18}F]FDG myocardial uptake patterns in routine overnight fasting oncology patients, and it was hypothesized that focal or regional myocardial [^{18}F]FDG uptake would be associated with myocardial ischaemia on stress single-photon emission CT (SPECT) myocardial perfusion imaging (MPI) due to the myocardial metabolic shift from oxidation of free fatty acid to glucose uptake. Finally, the authors wanted to explore whether the level of blood glucose at the time of injection of [^{18}F]FDG would have any influence on the myocardial [^{18}F]FDG uptake.

Material and methods

Population and study design

This retrospective study was approved by the hospital institutional review board. Subjects who underwent both oncological PET/CT and stress SPECT MPI within 3 months of each other were identified through a search of the radiology and cardiology database for appropriate clinical indications between January 2017 and December 2019. Ten patients were excluded because they had a focal-mass-like [^{18}F]FDG myocardial uptake raising the suspicion of cardiac metastasis or tumour involvement; this needed further correlative imaging with other imaging modalities, such as echocardiography or cardiac magnetic resonance imaging. A stress/rest SPECT MPI was performed for clinically appropriate indication per referring physicians such as symptomatic patients with chest pain and high-risk patients undergoing major surgery for pre-operative risk stratification. Also, patients with established CAD, such as patients with prior myocardial infarction, prior coronary artery bypass surgery (CABG), or prior percutaneous coronary intervention (PCI), were excluded.

[^{18}F]FDG PET/CT imaging

All patients fasted overnight before the PET/CT studies. For imaging, 370–740 MBq (10–20 mCi) of [^{18}F]FDG was injected intravenously, and scanning started 60 minutes later. No intravenous contrast was administered. The studies were conducted on a hybrid PET/CT scanner (GE, Discovery, Wisconsin, USA). All patients were in a supine position. CT images were acquired from the head to mid-thigh using the following standard parameters: 10 Kvp; current, 180 mA; pitch, 0.981:1; and single round tube rotation, 0.85. CT data were used for attenuation correction and PET images were reconstructed using ordered-subsets expectation maximization (OSEM); 2 iterations, 20 subsets, and a matrix size of 128 × 128 pixels were used in the reconstruction. To assess the myocardial [^{18}F]FDG uptake, the images were reconstructed with attenuation correction, reoriented, and displayed in traditional cardiac planes (short axis, vertical long axis, and horizontal long axis) for interpretation; the myocardial [^{18}F]FDG uptake was classified into the four following patterns: pattern 1, completely absent or mild myocardial [^{18}F]FDG uptake (Fig. 1a); pattern 2, diffuse (moderate or intense) myocardial [^{18}F]FDG uptake (Fig. 1b); pattern 3, patchy or multifocal myocardial [^{18}F]FDG uptake (Fig. 1c); and pattern 4, focal or regional myocardial [^{18}F]FDG uptake (anterior and septal myocardial [^{18}F]FDG uptake, lateral wall myocardial [^{18}F]FDG uptake, or inferior wall myocardial [^{18}F]FDG uptake (Fig. 1d).

Stress SPECT MPI acquisition and analysis

Patients underwent rest-stress myocardial perfusion imaging studies with either two-conductive separate day or low-dose high-dose same-day protocol. The acquisition parameters and post-processing were performed according to the guidelines of the American Society of Nuclear Cardiology (ASNC) for nuclear cardiology procedures [13]. The images were analysed in consensus by experienced nuclear medicine physicians in short, vertical, and horizontal views utilizing Auto SPECT (Cedars-Sinai Medical Center, Los Angeles, California). A reversible defect was defined as a perfusion defect on stress images that partially or completely reversible on rest images in two or more contiguous segments. A fixed perfusion defect was defined as a perfusion defect on stress images in two or more contiguous segments that persist on rest images. An abnormal perfusion scan was taken to indicate the presence of a reversible or fixed defect or both. Finally, gated short-axis images were processed with quantitative SPECT software, to measure the ejection fraction. In the visual analysis, the 17 segments were scored for perfusion defects on a 4-point system (0 = normal; 1 = mild; 2 = moderate; and 3 = severe), for both the stress and rest images. The perfusion defects based on perfusion scores at stress and rest were used to form the final interpretation of the studies. Perfusion abnormalities in the apical, anterior wall and septal perfusion defect were considered left anterior descending (LAD) artery territory; a lateral wall defect indicated left circumflex (LCX) artery territory, and an inferior wall perfusion defect indicated right coronary artery (RCA) territory.

Statistical analysis

Statistical analysis was performed using SPSS version 20 (IBM, USA). Continuous variables were reported as means ± standard deviation, and categorical variables were reported as percentages. Group means were compared using the *t*-test, and the association between categorical variables was assessed using the Chi-square test. Binomial logistic regression was performed to ascertain the effects of age, sex, hypertension, hypercholesterolemia, tobacco smoking, left ventricular ejection fraction, myocardial [^{18}F]FDG

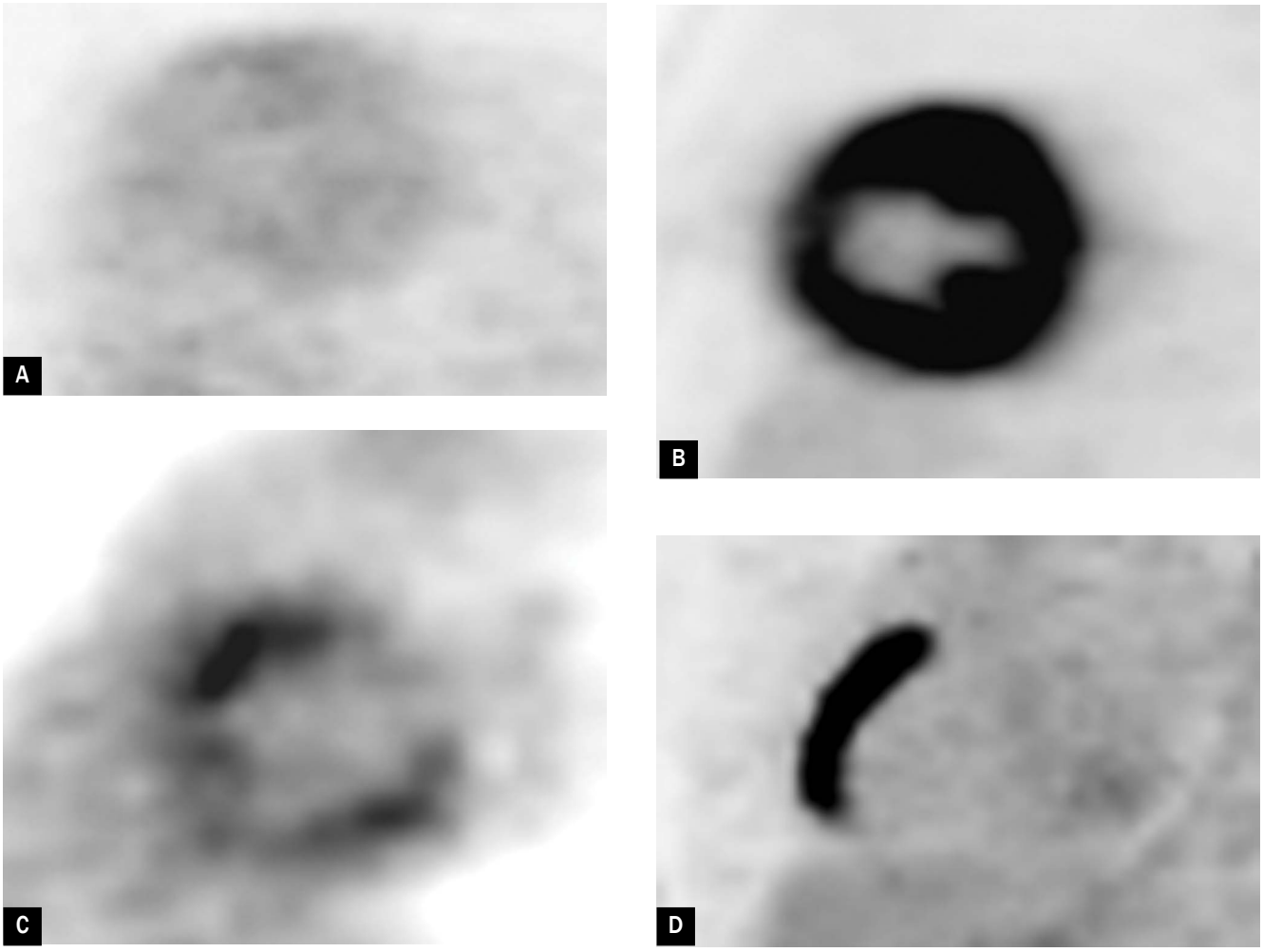

Figure 1. Selected axial [18F]FDG PET images demonstrating four patterns of myocardial FDG uptake; **A.** Completely absent myocardial [18F]FDG uptake; **B.** Diffuse intense myocardial [18F]FDG uptake; **C.** Patchy with focal myocardial [18F]FDG uptake; **D.** Regional/focal [18F]FDG uptake in the septal and anteroseptal wall (arrow)

uptake, and abnormal SPECT MPI. Cohen's K was run to determine if there was an agreement between focal/ regional myocardial FDG uptake and the presence of ischaemia on myocardial stress SPECT in 9 patients. The Type I error rate was set at 5%.

Results

Baseline characteristics of study subjects

A total of 362 subjects were included in the study; the average age was 65 ± 10-years, and 219/362 (60.5%) patients were male. In addition, the mean blood glucose level at the time of FDG injection was 104 ± 36 mg, and the mean left ventricular ejection fraction was 57 ± 9%. Furthermore, 24.3% 91/362 (25%) patients had abnormal SPECT MPI consistent with stress-induced myocardial ischaemia. Among the study subjects, 210/362 (58%) patients were hypertensive, 195/362 (53%) were diabetic, 42/362 (12%) smoked, and only 5/362 (1.4%) had a positive family history of CAD (Tab. 1). Type of cancer and oncological indication for FDG PET/CT are summarized in Table 2.

Table 1. Patient characteristics (N = 362)

Factor	Total number, %
Gender	
Male	219 (60.5%)
Female	143 (39.5%)
Age, years ± SD	65 ± 10
CAD risk actors	
Hypertension	210 (58%)
Diabetes mellitus	195 (54%)
Hypercholesterolemia	68 (16%)
Smoking	42 (11.6%)
Family history of CAD	5 (1.4%)
LVEF%, mean ± SD	57 ± 9
Mean blood Glucose at the injection of [18F]FDG mmol/L ± SD	104 ± 36
Abnormal SPECT, number, %	91 (25%)

CAD — indicates coronary artery disease; [18F]FDG — fluorodeoxyglucose; LVEF — left ventricular ejection fraction; SD — standard deviation; SPECT — single-photon emission computed tomography

Table 2. Type of oncologic indication for FDG PET/CT study, sample study (n = 362)

Type of Malignancy	Number	Percent [%]
Head and neck	47	12.9
Breast	67	18.5
Lung	21	5.8
GI/GU	53	14.6
Lymphoma	54	14.9
Others	120	33.1
Total	362	100

Patterns of myocardial [^{18}F]FDG uptake and its relationship with blood glucose level

The mean blood glucose level was 104 ± 36. Moreover, 220/362 (61%) of the study subjects had completely absent or mild [^{18}F]FDG myocardial uptake, 80/362 (22%) had diffuse myocardial [^{18}F]FDG uptake, 39/362 (11%) had patchy or multifocal myocardial [^{18}F]FDG uptake, and 23/362 (6%) had regional myocardial [^{18}F]FDG uptake. There was no statistically significant association between the glucose level and pattern of myocardial [^{18}F]FDG uptake, p = 0.762 (Tab. 3).

Relationship between the pattern of myocardial [^{18}F]FDG uptake and myocardial ischaemia on stress SPECT MPI

A significant statistical association was noted between the pattern of myocardial [^{18}F]FDG uptake and myocardial ischaemia on stress SPECT MPI, p = .025; the most predictive pattern of myocardial [^{18}F]FDG uptake associated with ischaemia was regional or focal myocardial [^{18}F]FDG, in 14/23 (39%) patients. The percentages of other patterns observed on stress SPECT MPI were relatively low; for example, the percentage of patients with a complete absence of myocardial [^{18}F]FDG uptake was 20%.

Relationship between CAD risk factors and myocardial ischaemia on stress SPECT MPI

There was a statistically significant association between the patient age, male gender, hypertension, hypercholesterolemia, and tobacco smoking and abnormal SPECT MPI. In contrast, there was no association between diabetes mellitus and a history of CAD and abnormal SPECT MPI (Tab. 3).

Logistic regression predicting likelihood of SPECT based on CAD risk factors, left ventricle ejection fraction, and [^{18}F]FDG uptake

Binomial logistic regression was performed to ascertain the effects of age, sex, hypertension, hypercholesterolemia, tobacco smoking, (left ventricular ejection fraction LVEF), and myocardial [^{18}F]FDG uptake on the SPECT results. Of the seven predictive variables, only age, hypercholesterolemia, smoking, LVEF, and [^{18}F]FDG uptake were associated with abnormal SPECT (Tab. 4).

The agreement between focal myocardial FDG uptake and presence of ischaemia on SPECT

Cohen's K was run to determine if there was an agreement between focal/regional myocardial FDG uptake and presence of ischaemia on myocardial stress SPECT in 9 patients, there was an agreement between 6 patients with focal FDG uptake and the presence of ischaemia on SPECT, however, there

Table 3. Baseline characteristics of patients with normal and abnormal SPECT

Characteristic	Overall (N = 362)	Patients with normal SPECT 271	Patients with abnormal SPECT 91	p-value
Demographics				
Age, (SD) [y]	65 ± 10	63 ± 10	68 ± 10	0.00001
Male	219	151	68	0.001
Female	143	120	23	
Hypertension	210	141	69	0.000
Diabetes mellitus	195	141	54	0.226
Hypercholesterolemia	28	30	58	0.0001
Smoking	42	18	42	0.0001
Family history of CAD	5	2	3	0.070
SPECT				
LVEF [%]	57 ± 9	58 ± 7	51 ± 7	0.0001
[^{18}F]FDG- PET/CT				
Blood glucose level	104 ± 36	104 ± 36	103 ± 7	0.762
Myocardial FDG uptake				0.025
Total Absent	220	175	45	
Diffuse uptake	80	53	27	
Focal on diffuse uptake	39	29	10	
Focal/regional uptake	23	14	9	

CAD — indicates coronary artery disease; [^{18}F]FDG — fluorodeoxyglucose; LVEF — left ventricular ejection fraction; SD — standard deviation; SPECT — single-photon emission computed tomography

Table 4. Logistic regression predicting the likelihood of SPECT based on CAD risk factors, LVEF, and [^{18}F]FDG uptake

	p-value	Odds ratio	95% confidence interval of odds ratio	
			Lower	Upper
Age	0.012	1.039	1.009	1.070
Sex	0.45	0.519	0.273	0.966
Hypertension	0.055	0.534	0.882	1.014
Hypercholesterolemia	0.000	0.258	0.126	0.526
Smoking	0.000	0.233	0.105	0.514
LVEF	0.000	0.924	0.897	0.953
FDG uptake	0.023	1.405	1.049	1.881

CAD — indicates coronary artery disease; [^{18}F]FDG — fluorodeoxyglucose; LVEF — left ventricular ejection fraction; SD P-value standard deviation; SPECT — single-photon emission computed tomography

Table 5. The agreement between Focal myocardial [^{18}F]FDG uptake and presence of ischaemia on SPECT

	Regional FDG uptake	Concordant FDG uptake and Ischaemia	Discordant FDG uptake and no ischaemia
LAD	4	3	1
LCX	2	1	1
RCA	3	2	1
Total	9	6	3

[^{18}F]FDG — fluorodeoxyglucose; LAD — left anterior descending coronary artery; LCX — left circumflex artery; RCA — right coronary artery; SPECT — single-photon emission computed tomography

was a discordant between FDG uptake and ischaemia on 3 patients. a fair agreement was noted between the FDG uptake and presence of ischaemia on SPECT, K = 0.394 (95% CI: 0.164 to 0.189) (Tab. 4 and 5).

Discussion

In this study, it was found that up to 61% of overnight fasting routine oncology patients had absent to mild myocardial [^{18}F]FDG uptake; the remaining 39% of patients had variable physiological patterns. No association was found between blood glucose level at the time of [^{18}F]FDG intravenous injection and pattern of myocardial [^{18}F]FDG uptake, and finally and most importantly, a significant statistical association was found between the pattern of myocardial [^{18}F]FDG uptake and the presence of myocardial ischaemia on stress SPECT MPI; the most significant predictive pattern of myocardial [^{18}F]FDG uptake for myocardial ischaemia was regional or focal myocardial [^{18}F]FDG uptake. However, the agreement between focal or regional FDG uptake and the presence of myocardial ischaemia is fair, K = 0.394. Studies have shown that the myocardial glucose uptake during fasting is variable, which reflects the availability and flexibility of myocardial substrate utilization [14, 15]. Among the 362 subjects in this study, 220 subjects had completely absent or minimal [^{18}F]FDG uptake; these results were consistent with previous studies.

Understanding myocardial [^{18}F]FDG uptake variability is crucial in the interpretation of myocardial viability, cardiac sarcoidosis, and [^{18}F]FDG PET/CT studies for the detection of coronary atherosclerosis. Fasting alone cannot explain the variability of myocardial metabolism, which may be due in part to the level of substrates, such as glucose and free fatty acids; physiological and cellular processes, such as myocardial blood flow; and levels of hormones, such as insulin, glucagon, dopamine and thyroxine [3]. One study showed that ageing, left ventricular hypertrophy, diabetes mellitus, and obesity cause alterations in substrate metabolism of either glucose or fatty acids [16]. In addition, hypertensive patients with increased cardiac workload may have a metabolic shift favouring glucose oxidation over fatty acids [17].

Our study showed that, despite overnight fasting, 39% of the study subjects had different physiologic patterns of myocardial [^{18}F]FDG uptake. This finding is somewhat consistent with the results of another study, in which 38% of enrolled individuals still demonstrated physiological myocardial [^{18}F]FDG uptake despite prolonged fasting of up to 18 hours [18]. A high-fat, low-carbohydrate diet may facilitate the switching of the myocardial substrate metabolism from glucose to fatty acids [14, 19]. Despite these results, the optimum dietary manipulation before [^{18}F]FDG PET/CT study for certain indications, such as evaluation of cardiac sarcoidosis, has not been defined or standardized [20].

Our study showed a significant association between the [^{18}F]FDG myocardial uptake pattern and the presence of myocardial ischaemia on stress SPECT MPI, particularly in terms of regional or focal myocardial [^{18}F]FDG. Studies have shown that CAD is associated with left ventricular uptake in oncology patients in a fasting state; the association between myocardial ischaemia and regional myocardial [^{18}F]FDG uptake is due to stimulation of glycolysis and suppression of fatty acid oxidation by the ischaemic myocardium [21]. This metabolic shift is a prerequisite for continued energy production and cell survival. It appears that these alterations in the myocardial substrate may persist after the resolution of myocardial ischaemia in so-called ischaemia memory [22, 23]. One study suggested that this metabolic fingerprint appears superior to perfusion imaging for the detection of CAD and assigning a prognosis in patients with established CAD, and metabolic imaging with [^{18}F]FDG or [^{123}I]beta methyl-P-iodophenyl pentadecanoic acid ([^{123}I]BMIPP) has been used for ischaemia detection during stress testing [24–27]. However, despite these promising studies about metabolic imaging for the detection of myocardial ischaemia, several questions remain to be answered, such as the optimal imaging protocol and a significant amount of diagnostic or prognostic data obtained from these metabolic studies that might alter patient management. Nevertheless, these results suggest that patients with regional myocardial [^{18}F]FDG uptake at a relatively increased risk of myocardial ischaemia compared with other patterns, such as diffuse uptake or minimal [^{18}F]FDG uptake, may benefit from further testing with stress SPECT MPI to diagnose myocardial ischaemia.

Study limitations

Our study is retrospective, and it has some limitations. The number of enrolled subjects was relatively small, which weakens the strength of the presented findings, especially for patients with regional [^{18}F]FDG uptake and positive SPECT MPI for myocardial

ischaemia. Although the research looked at 362 patients who underwent both oncological PET/CT and stress SPECT MPI within 3 months, despite this limitation, the present finding is worth noting because it is the first study comparing the correlation of myocardial [^{18}F]FDG uptake in oncological patients and the presence of myocardial ischaemia on stress SPECT MPI. The stress SPECT MPI results were not correlated with other cardiac imaging studies, such as those involving invasive coronary angiography or coronary CT angiography. The duration of overnight fasting in hours was not reported, since this variable was not controlled. The documented information in the chart was reviewed, but clearly, the duration of fasting could be quite variable from one patient to another. Finally, the myocardial [^{18}F]FDG uptake was evaluated visually and not quantitatively because the myocardial [^{18}F]FDG location and severity were evaluated.

Conclusions

Based on the presented findings, the physiological myocardial [^{18}F]FDG uptake in overnight fasting oncology patients is quite variable. While a complete absence or minimal [^{18}F]FDG uptake is the commonest pattern, the variability may affect the interpretation of cardiac sarcoidosis involvement or myocardial viability studies. Thus, further dietary manipulation and/or extended prolonged fasting before these studies must be considered. The regional myocardial FDG uptake pattern is the commonest pattern associated with myocardial ischaemia on stress SPECT MPI. However, there was a fair agreement between the focal FDG myocardial FDG uptake and the presence of ischaemia on SPECT. Therefore, patients with regional FDG uptake on oncological PET/CT may benefit from additional studies to exclude myocardial ischaemia. Exploration of the relationship between regional [^{18}F]FDG uptake and myocardial ischaemia must be explored in a larger cohort to determine the relationship between variable myocardial FDG uptake in overnight fasting oncologic patients and the presence of ischaemia on SPECT MPI.

Conflict of interest

The authors declare that they do not have a conflict of interest.

Acknowledgments

We acknowledge Prof. Egesta Lopci, MD,PHD, PET and Nuclear Medicine Department, IRCCs Istituto Clinico Humanitas, Milano, Italy for her help in the statistical analysis and comments on the manuscript.

References

1. Maurer AH, Burshteyn M, Adler LP, et al. How to differentiate benign versus malignant cardiac and paracardiac 18F FDG uptake at oncologic PET/CT. Radiographics. 2011; 31(5): 1287–1305, doi: 10.1148/rg.315115003, indexed in Pubmed: 21918045.
2. Inglese E, Leva L, Matheoud R, et al. Spatial and temporal heterogeneity of regional myocardial uptake in patients without heart disease under fasting conditions on repeated whole-body 18F-FDG PET/CT. J Nucl Med. 2007; 48(10): 1662–1669, doi: 10.2967/jnumed.107.041574, indexed in Pubmed: 17873124.
3. Thut DP, Ahmed R, Kane M, et al. Variability in myocardial metabolism on serial tumor (18)F-FDG PET/CT scans. Am J Nucl Med Mol Imaging. 2014; 4(4): 346–353, indexed in Pubmed: 24982820.
4. Heckmann MB, Totakhel B, Finke D, et al. Evidence for a cardiac metabolic switch in patients with Hodgkin's lymphoma. ESC Heart Fail. 2019; 6(4): 824–829, doi: 10.1002/ehf2.12475, indexed in Pubmed: 31278857.
5. Camici P, Ferrannini E, Opie LH. Myocardial metabolism in ischemic heart disease: basic principles and application to imaging by positron emission tomography. Prog Cardiovasc Dis. 1989; 32(3): 217–238, doi: 10.1016/0033-0620(89)90027-3, indexed in Pubmed: 2682779.
6. Schwaiger M, Schelbert HR, Ellison D, et al. Sustained regional abnormalities in cardiac metabolism after transient ischemia in the chronic dog model. J Am Coll Cardiol. 1985; 6(2): 336–347, doi: 10.1016/s0735-1097(85)80169-8, indexed in Pubmed: 3874892.
7. Lopaschuk GD, Stanley WC. Glucose metabolism in the ischemic heart. Circulation. 1997; 95(2): 313–315, doi: 10.1161/01.cir.95.2.313, indexed in Pubmed: 9008441.
8. Araujo LI, Camici P, Spinks TJ, et al. Abnormalities in myocardial metabolism in patients with unstable angina as assessed by positron emission tomography. Cardiovasc Drugs Ther. 1988; 2(1): 41–46, doi: 10.1007/BF00054251, indexed in Pubmed: 3154693.
9. Garcia JR, Soler M, Fuertes S, et al. [Incidence of focal myocardial (18) F-FDG uptake and correlation with coronary calcifications by PET/CT]. Rev Esp Med Nucl. 2011; 30(1): 8–13, doi: 10.1016/j.remn.2010.09.002, indexed in Pubmed: 21208695.
10. de Groot M, Meeuwis APW, Kok PJM, et al. Influence of blood glucose level, age and fasting period on non-pathological FDG uptake in heart and gut. Eur J Nucl Med Mol Imaging. 2005; 32(1): 98–101, doi: 10.1007/s00259-004-1670-2, indexed in Pubmed: 15605289.
11. Gropler RJ, Siegel BA, Lee KJ, et al. Nonuniformity in myocardial accumulation of fluorine-18-fluorodeoxyglucose in normal fasted humans. J Nucl Med. 1990; 31(11): 1749–1756, indexed in Pubmed: 2230987.
12. Young LH, Russell RR, Yin R, et al. Regulation of myocardial glucose uptake and transport during ischemia and energetic stress. Am J Cardiol. 1999; 83(12A): 25H–30H, doi: 10.1016/s0002-9149(99)00253-2, indexed in Pubmed: 10750583.
13. Dorbala S, Di Carli MF, Delbeke D, et al. SNMMI/ASNC/SCCT guideline for cardiac SPECT/CT and PET/CT 1.0. J Nucl Med. 2013; 54(8): 1485–1507, doi: 10.2967/jnumed.112.105155, indexed in Pubmed: 23781013.
14. Williams G, Kolodny GM. Suppression of myocardial 18F-FDG uptake by preparing patients with a high-fat, low-carbohydrate diet. AJR Am J Roentgenol. 2008; 190(2): W151–W156, doi: 10.2214/AJR.07.2409, indexed in Pubmed: 18212199.
15. Lee HY, Nam HY, Shin SK. Comparison of myocardial F-18 FDG uptake between overnight and non-overnight fasting in non-diabetic healthy subjects. Jpn J Radiol. 2015; 33(7): 385–391, doi: 10.1007/s11604-015-0428-z, indexed in Pubmed: 25981760.
16. Herrero P, Gropler RJ. Imaging of myocardial metabolism. J Nucl Cardiol. 2005; 12(3): 345–358, doi: 10.1016/j.nuclcard.2005.03.010, indexed in Pubmed: 15944540.
17. Mäki MT, Haaparanta MT, Luotolahti MS, et al. Glucose uptake in the chronically dysfunctional but viable myocardium. Circulation. 1996; 93(9): 1658–1666, doi: 10.1161/01.cir.93.9.1658, indexed in Pubmed: 8653871.
18. Masuda A, Naya M, Manabe O, et al. Administration of unfractionated heparin with prolonged fasting could reduce physiological 18F-fluorodeoxyglucose uptake in the heart. Acta Radiol. 2016; 57(6): 661–668, doi: 10.1177/0284185115600916, indexed in Pubmed: 26339041.
19. Harisankar CN, Mittal BR, Agrawal KL, et al. Utility of high fat and low carbohydrate diet in suppressing myocardial FDG uptake. J Nucl Cardiol. 2011; 18(5): 926–936, doi: 10.1007/s12350-011-9422-8, indexed in Pubmed: 21732228.
20. Chareonthaitawee P, Beanlands RS, Chen W, et al. Joint SNMMI-ASNC Expert Consensus Document on the Role of F-FDG PET/CT in Cardiac Sarcoid

Detection and Therapy Monitoring. J Nucl Med. 2017; 58(8): 1341–1353, doi: 10.2967/jnumed.117.196287, indexed in Pubmed: 28765228.

21. Neely JR, Morgan HE. Relationship between carbohydrate and lipid metabolism and the energy balance of heart muscle. Annu Rev Physiol. 1974; 36: 413–459, doi: 10.1146/annurev.ph.36.030174.002213, indexed in Pubmed: 19400669.
22. Abbott BG, Liu YH, Arrighi JA. [18F]Fluorodeoxyglucose as a memory marker of transient myocardial ischaemia. Nucl Med Commun. 2007; 28(2): 89–94, doi: 10.1097/MNM.0b013e328013eaa5, indexed in Pubmed: 17198348.
23. McNulty PH, Jagasia D, Cline GW, et al. Persistent changes in myocardial glucose metabolism in vivo during reperfusion of a limited-duration coronary occlusion. Circulation. 2000; 101(8): 917–922, doi: 10.1161/01.cir.101.8.917, indexed in Pubmed: 10694532.
24. Kawai Y, Tsukamoto E, Nozaki Y, et al. Significance of reduced uptake of iodinated fatty acid analogue for the evaluation of patients with acute chest pain. J Am Coll Cardiol. 2001; 38(7): 1888–1894, doi: 10.1016/s0735-1097(01)01634-5, indexed in Pubmed: 11738290.
25. He ZX, Shi RF, Wu YJ, et al. Direct imaging of exercise-induced myocardial ischemia with fluorine-18-labeled deoxyglucose and Tc-99m-sestamibi in coronary artery disease. Circulation. 2003; 108(10): 1208–1213, doi: 10.1161/01.CIR.0000088784.25089.D9, indexed in Pubmed: 12939208.
26. Abramson BL, Ruddy TD, de Kemp RA, et al. Stress perfusion/metabolism imaging: A pilot study for a potential new approach to the diagnosis of coronary disease in women. Journal of Nuclear Cardiology. 2000; 7(3): 205–212, doi: 10.1016/s1071-3581(00)70008-0.
27. Dilsizian V, Bateman TM, Bergmann SR, et al. Metabolic imaging with beta-methyl-p-[(123)I]-iodophenyl-pentadecanoic acid identifies ischemic memory after demand ischemia. Circulation. 2005; 112(14): 2169–2174, doi: 10.1161/CIRCULATIONAHA.104.530428, indexed in Pubmed: 16186423.