Dawood *et. al.* Babcock Univ. Med. J.2026 9(2):61- 67
https://doi.org/10.38029/babcockuniv.med.j..v9i2.1253
eISSN: 2756-4657

RESEARCH ARTICLE OPEN ACCESS

Association between body mass index and hepatic ^{18}F-FDG standardised uptake value (SUV) in patients undergoing PET-CT scan

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Submitted: 15th August 2025
Accepted: 26th November 2025
Published: 30th June 2026
ID: Orcid ID

Abstract
Objectives: The study aims to measure the amount of radiopharmaceutical absorbed by a normal liver compared with a patient with liver cancer and to examine the effect of BMI on radiopharmaceutical absorption.
Method: The Study assessed75 males (40 patients and 35 normal) and 75 females (40 patients and 35 normal), aged between 31 and 75, with body weights ranging from 50 to 100 kg and heights ranging from 150 cm to 180 cm. Patients with a fasting blood sugar content exceeding 200 mg/dL were excluded.
Results: Differences ($P < 0.001$) were reported in the mean SUVs between the participants with normal livers and those with liver cancer of the same BMI, where, the average SUV was greater with liver cancer in the underweight, normal weight, overweight, and obese BMI categories, with kg/m² of 141%, 160%, 197%, and 253%, respectively. Furthermore, highly significant differences ($P < 0.01$) were found for the mean SUVs between the normal body weight and other BMI categories.
Conclusion: Our study suggests that the administration of FDG based on body weight can result in underestimation, which may lead to small, dormant tumours being overlooked. An overestimation could lead to unnecessary wastage of radioactive materials and increase the risk of harmful exposure for the participant. Caution is advised regarding greater amounts of fat tissue in overweight subjects when compared with those of normal weight; the former require a greater dose of FDG than the latter, leading to greater absorption of FDG with glucose by cancerous cells.

Keyword: PET scan, Oncology, SUV, Liver Cancer

Plain English Summary

The current research examines the impact of BMI on the functioning of a particular form of medical scanning process known as the PET scan. PET scans require the administration of a small dose of FDG radioactive sugar that enables one to visualise the functioning of various body tissues. Here, we compared individuals with liver cancer to healthy individuals across different BMI categories to understand whether there were any differences in the amount of such absorbed by the body in general and by the liver in particular.
We examined 150 adults, both males and females, aged between 31 and 75. We further studied the impact of body weight on scan results. The findings indicated that individuals with a greater BMI showed greater uptake of FDG into their blood and tissues. This identification is significant in that the results of a PET scan may be influenced by BMI. This might lead to difficulties in the interpretation of the scans that require a degree of consideration on the part of doctors before being able to offer an objective diagnosis to patients.

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Introduction

Positron Emission Tomography-Computed Tomography (PET-CT) represents a significant and vital leap in cancer detection by combining the functional imaging capabilities of PET with the anatomical accuracy of CT scans (1). This hybrid imaging technology enables clinicians to acquire extensive insights into both the metabolic activity of tissues (using fluorodeoxyglucose (FDG)) and these same tissues' structural characteristics (1).

Cancer is considered the most challenging disease affecting humans. It is further known to be one of the main causes of death worldwide. For this reason, many studies and research into the early diagnosis of cancer and the prevention of its metastasis have been conducted (3). One of the more advanced techniques used for diagnosing and detecting tumour metastasis is positron emission tomography (PET), which relies on two procedures: the intravenous injection of a radioactive material, fluorodeoxyglucose (FDG), the radiation from which is detected using Computed Tomography (CT) (4). The amount of radiation is measured by a CT scan and is referred to as the standard uptake value (SUV).

The technique itself is dependent on the injection of radioactive material, which is mixed with glucose intravenously, and which is then detected via CT scan (5, 6). The dose of FDG to be injected is calculated according to body weight (kg) (7). The mode of action of such technologies depends on the cellular absorption of glucose (which is conjugated to the radioactive substance) for metabolism (8). Since tumours, regardless of their type and location, typically show relatively rapid growth and an associated rapid proliferation, the metabolic rate in their constituent cells will be high, i.e., they need considerably more glucose than normal cells (9, 10). This procedure thus leads to cancer cells showing a higher uptake of radioactive materials than normal cells. For example, the radiation will be greater than the SUV of the tumour, and will be higher than normal for the organ in question (11, 12). Diabetics have abnormal glucose metabolism. Since their insulin level is disturbed, the cellular entrance of glucose and its consumption will be delayed (13).

The study aims to measure the amount of radiopharmaceuticals absorbed by individuals with healthy livers as compared to those with liver cancer, as well as study the effect of BMI on the absorption of radiopharmaceutical material.

Materials and Methods

The study was conducted in the Nuclear Medicine Department of the National Amal Hospital for Oncology Treatment, Baghdad, between November 2024 and April 2025. The study included 150 participants (75 males and 75 females). Among them, 80 were liver cancer patients (40 males, 40 females) and 70 were controls with normal livers (35 males, 35 females), aged between 35 and 80, and whose weight was between 55 and 98 kg. The height was between 155 and 170 cm.

The Participants were categorised into two distinct groups as follows:

The first group of subjects consisted of individuals who had no liver cancer and were designated the control group (the control group consisted of individuals with confirmed cancers in other parts of the body but with no clinical or radiological evidence of liver disease or metastasis). The second group included patients with liver cancer.

All the data collected from the patients themselves or from their reports are confidential, with patient permission to be involved in this study gained through their written consent.

After overnight fasting (6-8 hours), participants underwent PET/CT (Company: Limited Imaging Healthcare Co., Ltd - China. Medical Device Name: Positron Emission Tomography and Computed Tomography System. Model: uMI 780. Power Source: AC 3-380V/400V/415V/440V/460V/480V, 50/60 Hz. Input Power: 165 kVA. Operation Mode: Continuous operation. Blood glucose was measured before injection; scans were postponed if glucose was greater than 200 mg/dL. 18F-FDG was administered intravenously at a mean activity of 0.1± 0.01mCi/ Kg ; uptake time was mean ± SD minutes (70±10 minutes). PET images were reconstructed using Ordered-Subsets Expectation Maximisation (OSEM) with attenuation correction from low-dose CT. Volumes-of-interest (VOIs) were placed in the right hepatic lobe (segments V–VIII), avoiding lesions and major vessels; mean SUV (bw) was recorded. Image analysis was performed by two experienced readers; inter-reader variability (ICC) was assessed.

The patient was also recommended to take one litre of water two hours before FDG administration, and 0.5 litres post-administration. The patient was then placed in a supine position with their arm lifted. The device then recorded the irradiation due to FDG from the patient and determined the absorption of FDG by images as SUV. Their medical records were examined for data on body weight (BW) and stature, from which body mass index, commonly referred to as BMI, was calculated.

BMI (kg/m^2) = Weight (kg) / height (m^2) (14).

The control and liver cancer patients were subdivided into four categories according to their BMI, where each category contained 50 patients:
1. Underweight: less than 18.5 kg/m².
2. Normal Weight: above 18.5 and less than 25 kg/m².
3. Overweight: between 25 and less than 30 kg/m².
4. Obese: greater than 30 kg/m².

Statistical Analysis
Statistical analyses were conducted utilising version 22 of the Statistical Package for the Social Sciences (SPSS for Windows, IBM Inc.). Statistical analyses were performed using independent samples t-tests to compare SUV means between the normal liver and liver cancer groups within each BMI category. A p-value of less than 0.05 was considered statistically significant. Means and standard deviation were calculated, and statistical significance was taken as having a p-value of less than 0.05.

Results

Demographic characteristics of participants
The mean ± SD age was 52.25 ± 4.5 years for males, and 49.65 ± 3.5 years for females; the mean ± SD height was 175.65 ± 2 cm for males and 162.85 ± 1.5 cm for females; and the mean ± SD weight was 85.5 ± 4.75 kg for males and 82.45 ± 2.85 kg for females. Participants had a range of body mass indices (kg/m²).

Relationship between body mass index and the SUV of FDG for participants
Table 1 reports that the SUVs for FDG are higher in participants with liver cancer than in participants with normal livers. The average SUV for patients with liver cancer was 141% higher in the underweight group, 160% higher in the normal weight group, 197% higher in the overweight group, and 253% higher in the obese group of BMI categories, in kg/m². Highly significant differences ($P < 0.001$) were reported in the mean SUVs for the mean for normal subjects and subjects with cancer; see Figure 1.

Table 1: Relationship between BMI and the SUV of FDG

BMI (kg/m²)	Normal liver	Liver with cancer	P-value
Underweight	1.55 ± 0.15	3.75 ± 0.4	< 0.001
Normal weight	1.63 ± 0.17	4.24 ± 0.55	< 0.001
Overweight	1.71 ± 0.16	5.09 ± 0.59	< 0.001
Obesity	1.82 ± 0.16	6.44 ± 0.62	< 0.001

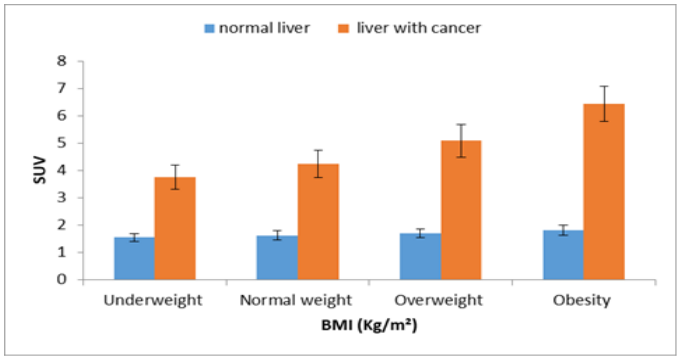


Figure 1: Relationship between different categories of BMI and SUV for ^{18}F-FDG in the liver for participants with normal livers and liver cancer.

Discussion
Cancer is recognised as one of the leading causes of death worldwide; further, its behaviour can be somewhat unexpected, be this in terms of aggression, metastasis, or proliferation (15). The liver is regarded as the most likely organ to be impacted by primary or secondary cancer.

One of the more important techniques used to diagnose cancer and detect its metastasis far from its point of origin in the body is the PET scan. Additionally, a doctor can recognise its size and behaviour (aggressiveness) (16). Regarding these benefits, a PET scan still carries a certain element

of risk due to irradiation, since the substance used in this technique is itself radioactive (14, 17).
The material used in the PET scan is FDG, which is a radioactive marker conjugated with glucose. Each tissue will take up sugar, but in this instance, with this marker attached, it will emit the radiation ultimately detected via PET scan. Since a tumour revealed a response rate as it will requires more glucose and oxygen than normal tissue. Consequently, cancer cells will release more radiation than normal tissue, so the SUV of cancer tissue is much higher than that of normal tissue (18, 19).
The protocol for this exam is dependent on the intravenous injection of this radioactive material in a dose equal to 0.1 mCi/kg of body weight (20, 21, 22).
The results obtained reveal the following:
In underweight patients, the SUV of the liver and the tumour is lower than in normal-weight patients and controls. This can be attributed to the amount of activity of FDG (although the amount is 0.1 mCi/kg for all participants) in the cancerous organ and other body tissue (23, 24).
Regarding normal weight controls and patients (according to BMI), there was an observed increase in the SUV of cancer tissue compared to normal liver tissue. This is expected since cancer cells have a high metabolic rate that matches the increased rate of their proliferation, as well as an increased oxygen consumption, which requires the formation of new blood vessels (25, 26).
Regarding underweight (BMI below 18.5 kg/m²) patients and controls, these subjects showed an increase in SUV of cancerous cells compared to healthy liver tissue. However, this increase was lower than in normal-weight patients and controls. This can be attributed to the fact that the FDG was injected according to the weight, and the dose was thus insufficient, which led to a reduction in the amount of glucose taken up, with conjugated radioactive material thus circulating in the blood (27).
The SUV of cancer and normal cells in overweight (BMI greater than 30 kg/m²) and obese participants was statistically higher than that recorded in normal weight patients and controls, as reported in Tables 1 and Figures 1. To explain this result, the cancer cell would be expected to have a higher SUV than normal liver tissue. However, the increase in SUV (in overweight and obese cases) would be statistically greater than in normal-weight patients and controls.
Since the protocol is dependent on the injection of an appropriate amount of radioactive material, dosage is calculated according to weight (0.1 mCi/Kg), with the organ of interest, the liver, being approximately the same in terms of weight and size. This means that for all participants, the patient received a greater dose of radioactive material than was indicated. This means that the amount of radioactive material conjugated with glucose will be greater than needed to detect a tumour. This results in an accumulation of excess radioactive material in the liver and all other organs, which is economically wasteful regarding both the pharmaceutical quantity used and the associated costs (28). It also means that the patient needs more time to excrete the radioactive substance, which is harmful not only to them but also to their relatives, who will likely be exposed to a greater dose of harmful radiation than is generally considered permissible.

Conclusion

In conclusion, the above can be explained as follows:
1. Examination by PET scan is useful to localise and gain information about cancer (size, behaviour, and metastasis).
2. Despite the benefits gained from this form of exam, it is nevertheless harmful because the patient will be exposed to radioactive material. Therefore, it is better to use this substance carefully with a long interval between each such exam.
3. The administration of FDG based on body weight can result in either an underestimate, which may lead to small, dormant tumours being missed, or an overestimate, which could lead to unnecessary wastage of radioactive material and an increased risk due to the participant's exposure to harmful radiation.
Subsequently, we make the following recommendations
1. Use BMI as a guide to calculate the dose needed for each patient.
2. Study other organs and the different stages of any tumours.
3. Further study is recommended (prospective, multicentre, dose by lean body mass vs weight).

Study Limitations

There were various limitations to this study, such as its single-centre design, potential selection bias, the use of a non-healthy control group (patients with other cancers), small sample sizes per

subgroup, and the absence of correction for blood glucose levels and other confounders.

List of Abbreviations

BMI: Body Mass Index
BW: Body Weight
CT: Computed Tomography
FDG: Fluorodeoxyglucose
mCi: Millicurie
PET: Positron Emission Tomography
PET-CT: Positron Emission Tomography–Computed Tomography
SD: Standard Deviation
SPSS: Statistical Package for the Social Sciences
SUV: Standardised Uptake Value
Tc-99m: Technetium-99m

Declaration

Ethics approval and consent to participate

We confirm that all the figures and tables in the manuscript belong to the current study. Figures and images which do not belong to the current study have received permission for republication, as attached to the manuscript. The authors note the ethical considerations' Approval-Ethical Clearance: the project was approved by the local ethical committee of the College of Medicine, University of Baghdad, and the cooperation of the National Amal Hospital for Oncology Treatment, according to the letter issued by the Deanship of the College of Medicine, University of Baghdad, No. 46161 on 30/12/2024.

Consent for publication

All the authors gave consent for the publication of the work under the Creative Commons Attribution-Non-Commercial 4.0 license.

Availability of Data

The data and materials related to this research are available from the corresponding author upon reasonable request.

Competing interests

None.

Funding

This research received no external funding.

Authors' contributions

Study conception and design: DNS and AUH.
Literature search: DNS and AUH.
Data analysis and interpretation: AUH, DNS and AMH.
Manuscript preparation: AUH, DNS and AMH.
Manuscript editing and review: DNS and AUH.

Acknowledgement

Nil.

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