THE MEDICAL BULLETIN OF
SISLI ETFAL HOSPITAL

DOI: 10.14744/SEMB.2020.80270
Med Bull Sisli Etfal Hosp 2021;55(1):12–17

Original Research

Comparison of MRI and 18F-FDG PET/CT in the Liver Metastases of Gastrointestinal and Pancreaticobiliary Tumors

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Abstract

Objectives: To compare the efficacy of 18F-fluorodeoxyglucose positron emission tomography (18F-FDG PET/CT) and magnetic resonance imaging (MRI) in the detection of liver metastases originating from the gastrointestinal system (GIS) and the pancreaticobiliary (PB) system.

Methods: This retrospective study included 42 patients with primary GIS (stomach or colorectal) or PB system malignancies that metastasized to the liver, histopathologically confirmed diagnoses, and MRI and 18F-FDG PET/CT images. The MRI and 18F-FDG PET/CT images were analyzed. Student's t-test was used to compare the two modalities in terms of determining the number of metastases, and Cohen's kappa test was conducted to determine the agreement between the modalities.

Results: Twenty-eight (66.7%) of the patients included in this study were male, and the mean age was 60.67±9.4 years. Colon (n=25; 59.5%) and pancreatic (n=7; 16.6%) adenocarcinomas were the most common primary tumors that had metastasized to the liver. MRI detected more metastases in 12 (28.5%) patients, less in seven (16.6%), and an equal number of metastases in 23 (54.7%). No statistically significant difference was observed between the number of metastases detected by MRI and 18F-FDG PET/CT (7.55±7.96 and 6.36±7.28, respectively; p=0.11). There was a moderate agreement between the two modalities (kappa value=0.423). Most of the metastases detected on MRI but not seen on 18F-FDG PET/CT (n=10, 23.8%) were lesions smaller than 10 mm. For the eight (19%) patients with lymph node metastases, the number of metastatic lymph nodes detected by MRI and 18F-FDG PET/CT was similar (12 and 14, respectively, p>0.05).

Conclusion: MRI can detect small lesions at an early stage, and 18F-FDG PET/CT shows the metabolic activity of lesions; therefore, the combined use of the two modalities can potentially offer a beneficial outcome for patients.

Keywords: Liver metastasis; gastrointestinal tumor; pancreatic tumor; magnetic resonance imaging; positron emission tomography.

Please cite this article as "Tahtabasi M, Erturk SM, Basak M. Comparison of MRI and 18F-FDG PET/CT in the Liver Metastases of Gastrointestinal and Pancreaticobiliary Tumors. Med Bull Sisli Etfal Hosp 2021;55(1):12–17".

Due to its rich blood supply, the liver is the most common organ in which tumor cells originating from the gastrointestinal system (GIS) metastasize using the hematogenous route.[1] Metastatic spread occurs through the portal and systemic veins. The frequency of metastatic tumors is 20 times higher than that of primary tumors in

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Submitted Date: November 24, 2020 **Accepted Date:** December 08, 2020 **Available Online Date:** March 17, 2021

the liver.[1,2] Early diagnosis and surgical treatment of liver metastases, especially in colorectal cancer cases, increase five-year survival from 0% to 33% compared to medical treatment. In pancreatic tumors, although primary tumor resectability plays an important role, the most important factor determining survival is the presence of liver metastasis.[3-6]

Although the availability of medical treatment methods for liver metastases, such as hepatic arterial chemoembolization, radiofrequency ablation, systemic chemoembolization, surgical resection of lesions, an early diagnosis remains the most effective method known and an important treatment option that increases long-term survival. Therefore, imaging methods are of considerable importance concerning the early diagnosis of liver metastases and determining the extent of the disease.[7-9]

Computed tomography (CT), which can detect the liver's metastatic lesions, is still a frequently used and highly sensitive modality.[7] However, in recent years, magnetic resonance imaging (MRI) has become the first preferred modality to evaluate liver metastases, especially in colorectal cancers due to its higher sensitivity compared to CT, notably for lesions smaller than 10 mm. MRI and especially diffusion-weighted imaging performed significantly better than CT in detecting liver metastases (sensitivity of 86.7% and specificity of 97.5% versus 53.3% and 77.8%, respectively).[10] Also, positron emission tomography (PET) is utilized very frequently to staging GIS tumors.[11] The importance of MRI in liver imaging is increasing every day. Especially in cases where other modalities, such as CT and ultrasound (US) are insufficient, MRI offers excellent advantages in detecting and characterizing pathological tissue and demonstrating its relationship with the surrounding tissue.

In this study, the 18F-FDG PET/CT and MRI images and pathological and surgical results of cases with primary GIS (stomach and colorectal) or pancreaticobiliary (PB) tumors were retrospectively analyzed. The efficacy of the 18F-FDG PET/CT and MRI methods in detecting hepatic and accompanying extrahepatic (adrenal, intraabdominal lymph node, or peritoneum) metastatic lesions was compared.

Methods

Patient Data

This study included 42 patients with primary GIS (stomach and colorectal) or PB tumors that had metastasized to the liver, who presented to our hospital between January 2012 and April 2015. Patients who underwent 18F-FDG PET/CT and abdominal MRI examinations at an interval of six weeks or shorter and who did not receive any treatment between the two examinations were included in the present study. The clinical findings, pathology reports and surgical notes were obtained from the patients' electronic medical records. The abdominal MRI and 18F-FDG PET/CT images were accessed from the picture archiving and communication system (PACS) and analyzed. Before this study, the local ethics committee approval was obtained (decision number: 382, date: October 28, 2014).

The histopathological diagnosis of all patients' primary tumors was made by examining preoperative biopsy material or surgical specimen after surgery. The diagnosis of patients with colorectal and gastric cancers was made by examining the surgical specimen, and the diagnosis of those with cholangiocellular carcinomas was undertaken based on a percutaneous core needle biopsy or the examination of the surgical specimen. In cases with pancreatic tumors, the diagnosis was performed using surgical specimens for operable patients and CT-guided biopsy for the patients that were not eligible for surgery. The diagnosis of metastatic liver lesions was confirmed histopathologically. Benign liver lesions other than liver metastases were confirmed by radiological follow-up.

MRI Technique

All examinations were performed with a 1.5 Tesla MRI device (Avanto; Siemens, Erlangen, Germany). The abdominal MRI protocol applied for all patients was as follows: slice thickness, 3-5 mm; interslice gap, 0.6-1 mm (%20); matrix, 190×256; sensitivity encoding factor, 2; and bandwidth, 260 Hz/px. The following routine MRI sequences were obtained: axial and coronal T2-weighted (W) turbo-spin echo (TSE), axial fat saturation T2W blade or T2W TSE (TR, 3000 ms; TE, 82 ms; FA, 150°; matrix, 384 x 276; number of slices, 29; FOV, 36 cm; NEX 2; acquisition time, 3.57 s; and bandwidth, 260 Hz/Px), axial in-phase and out-phase 2D T1W gradient echo (GRE), and axial and coronal volume interpolated breath-hold examination (VIBE) fat-saturated 3D GRE T1W before and after intravenous (I.V.) gadolinium (0.2 mmol/kg bolus) administration.

Interpretation of MRI and 18F-FDG PET/CT

The MRI and 18F-FDG PET/CT images of each case were analyzed prospectively by a radiology assistant with four years' experience and an abdominal radiologist with 15 years' experience based on consensus. The presence and number of liver metastases were evaluated, and the characterization of the lesions was performed. Also, the presence of accompanying intraabdominal metastatic lymph nodes and adrenal and peritoneal metastases was investigated. To determine the number of liver metastases, a classification from A to E was made. The patients with no metastases were categorized as A, those with one metastasis as B, 2-3 metastases as C, 4-5 metastases as D, and more than five metastases as E.

Statistical Analysis

All analyses are performed using SPSS (IBM SPSS Statistics Version 22.0. Armonk, NY: IBM Corp.) software. Categorical variables were expressed as frequency and percentages, while continuous variables were expressed as mean and standard deviation. The Kolmogorov-Smirnov test was used to test whether the variables were normally distributed, and those with p>0.05 were considered to be normally distributed. Normally distributed continuous variables were compared using Student's t-test, while the Mann-Whitney U test was conducted for non-normally distributed data. The statistical significance level was accepted as p<0.05. Also, Cohen's kappa test was performed to determine the consistency between the results of 18F-FDG PET/CT and MRI (Table 1).

Results

Twenty-eight (66.7%) of the patients included in this study were male, and 14 (33.3%) were female, and the mean age was 60.67±9.4 years. Colorectal adenocarcinoma (n=25; 59.5%) was the most common primary tumor, followed by pancreatic adenocarcinoma (n=7; 16.6%). Other primary malignancies are shown in Table 2.

Concerning the number of liver metastases detected, compared to 18F-FDG PET/CT, MRI showed fewer metastases in seven (16.6%) patients, a higher number of metastases in 12 (28.5%), and an equal number of metastases in 23 (54.7%).

No statistically significant difference was found between the number of metastases detected by MRI and 18F-FDG PET/CT (7.55±7.96 and 6.36±7.28, respectively; p=0.11). There was a moderate agreement between the two modalities (kappa value=0.423) (Table 1). MRI detected more metastases in patients with lesions smaller than 10 mm (n=10; 23.8%) than 18F-FDG PET/CT.

18F-FDG PET/CT detected fewer lesions than MRI in three (7.1%) patients with GIS or primary neuroendocrine tumors. The comparison of the number of metastases detected by both modalities is shown in Table 3.

In 8 (19%) of the patients, 12 metastatic lymph nodes (short-axis diameter >1cm) were detected on MRI, and 14 metastatic lymph nodes are showing 18-FDG involvement on 18F-FDG PET/CT. There was no statistically significant difference between the two modalities in terms of the number of metastatic lymph nodes detected (p>0.05). Both modalities detected one (2.3%) patient with bilateral adrenal metastasis.

Table 1. Kappa agreement table

Kappa value	Agreement level
0.93-1	Excellent
0.81-0.92	Almost perfect
0.61–0.80	Substantial
0.41–0.60	Moderate
0.21–0.40	Fair
0.01–0.20	None to slight
<0	No agreement

Table 2. Primary pathologies of metastatic liver lesions

Primary Tumor	n (%)
Colon adenocarcinoma	25 (59.5)
Colon neuroendocrine tumor	1 (2.3)
Gastric adenocarcinoma	2 (4.7)
Gastric gastrointestinal stromal tumor	2 (4.7)
Cholangiocellular carcinoma	4 (9.5)
Pancreatic adenocarcinoma	7 (16.6)
Pancreatic neuroendocrine tumor	1 (2.3)

Table 3. Distribution of number of lesions according to imaging methods; A: No lesion, B: 1 lesion, C: 2-3 lesions, D: 4-5 lesions, E: >5 lesions

MRI/PET	A	B	C	D	E
A	0	0	0	0	0
B	0	4	2	0	2
C	1	3	3	0	0
D	0	0	3	3	3
E	0	1	0	1	13

Although MRI revealed three liver hemangiomas in two (4.7%) patients and unilateral adrenal adenomas in two (4.7%) patients, these lesions were reported since they did not show significant 18-FDG uptake.

Figures 1 to 3 are representative MRI and PET-CT images.

Discussion

In the current study, 18F-FDG PET/CT and abdominal MRI with gadolinium were compared to detect primary GIS and PB tumors' liver metastases. According to the statistical analysis performed, there was a moderate agreement between the two modalities. In patients with lesions smaller than 10 mm (n=10; 23.8%), MRI was more sensitive and detected more metastases than 18F-FDG PET/CT. It was observed that MRI was more sensitive, especially in localizing small lesions, and this was associated with the lower spatial resolution of 18F-FDG PET/CT.[11] In addition to the high soft-tissue resolution of MRI, IV gado-

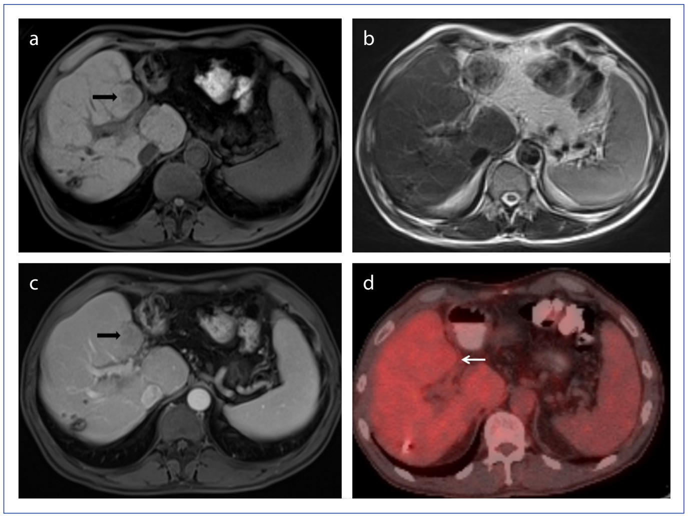

Figure 1. MRI and PET images of a 60-year-old patient with colorectal adenocarcinoma metastasis and a history of segmentectomy.**(a-c)** Pre- and post-contrast T1- and T2-weighted images show a faintly margined metastatic lesion in the left lobe with minimal peripheral enhancement (black arrows). The lesion cannot be seen on the PET fusion images **(d)** of the same patient (white arrow).

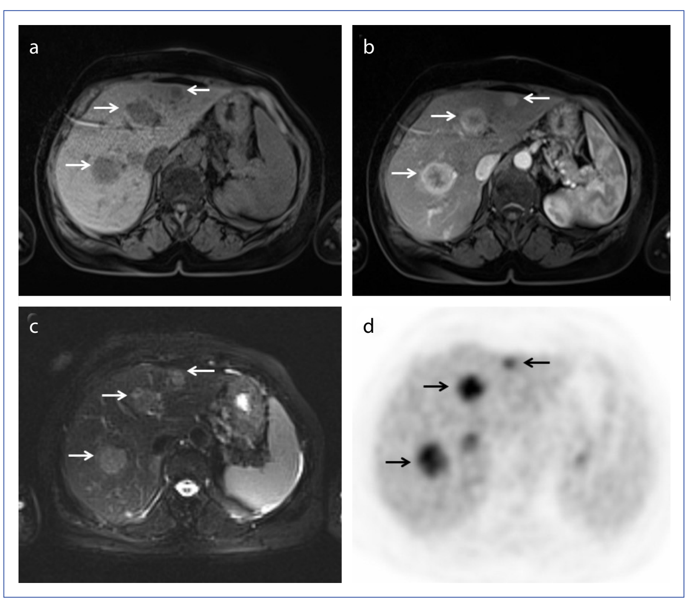

Figure 2. MRI and PET images of a 70-year-old man with a pancreatic neuroendocrine tumor. The axial pre- and post-contrast T1-weighted **(a, b)** and fat-suppressed T2-weighted **(c)** images show multiple peripheral-enhancing metastases in the liver parenchyma (white arrows). The PET images **(d)** of the same patient show the pathological FDG uptake of the metastatic lesions (black arrows).

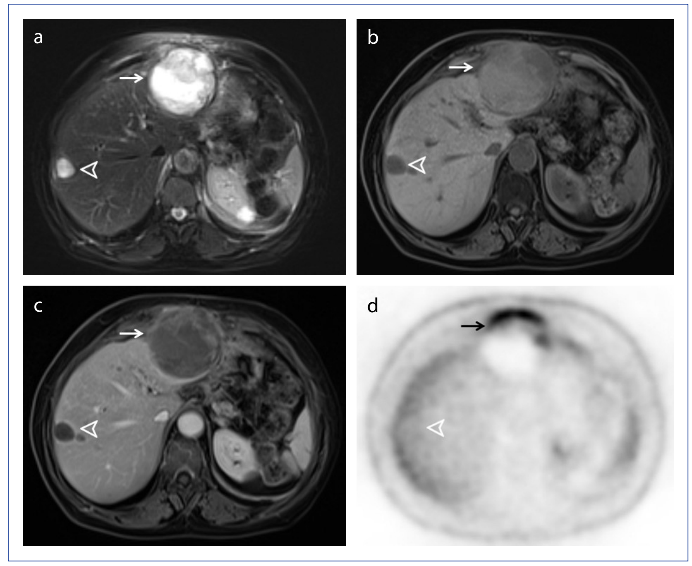

Figure 3. MRI and PET images of a 76-year-old female patient with a primary gastrointestinal stromal tumor. **(a-c)** Pre- and post-contrast T1-weighted and fat-suppressed T2-weighted images show a heterogeneously enhancing metastasis of cystic character in the left lobe (white arrows) and a metastasis with minimal peripheral capsular enhancement in the right lobe (arrowheads). **(d)** Although there is FDG uptake in the metastatic lesion in the left lobe (black arrow) on the PET images, no FDG uptake is observed in the metastatic lesion in the right lobe (arrowhead).

linium contrast agent that shortens the T1 effect of the liver parenchyma by creating a paramagnetic effect made a significant contribution to the detection of lesions. Yang et al.[12] compared abdominal MRI with gadolinium and 18F-FDG PET/CT to evaluate metastatic liver lesions and found their sensitivity to be 85.7% and 71%, respectively, indicating no statistically significant difference between the two methods. On the other hand, two large meta-analyses reported 18F-FDG PET/CT to be the most sensitive (90–94.6%) imaging modality in diagnosing liver metastases resulting from colorectal, gastric, or esophageal primary cancers. Compared with other non-invasive imaging modalities, the reported sensitivities of imaging methods from these extensive meta-analyses were 55% for US, 60.2% for non-helical CT, 64.7% for helical CT, 75.8% for 1.5-T MRI, and 94.6% for 18F-FDG PET/CT.[13]

PET works on the principle of detecting lesions based on the FDG uptake of tissues that use glucose excessively and have increased metabolic activity. Like the FDG uptake of malignant tissues, in acute and chronic inflammatory conditions, the glucose utilization of tissues increases, and FDG uptake is observed.[14,15] In addition to determining the primary tumor, 18F-FDG PET/CT also assists in staging the disease by identifying metastases in other parts of the body, and thus it is beneficial in predicting the survival time of the patient.[16] However, tumor type is one of the most critical factors determining FDG uptake. One of the disadvantages of 18F-FDG PET/CT is that false-negative results may be obtained, mainly due to the mucinous tumors of colorectal and esophageal origin, and in some neuroendocrine tumors.[17,18] Consistent with this situation, in our study, we observed that PET provided false-negative results in patients with GIS and neuroendocrine tumor metastases, while MRI accurately detected more metastases.

18F-FDG PET/CT is a modality with a sensitivity varying depending on the size of lesions. Frohlich et al.[19] reported that in cases with metastatic colorectal carcinoma, the sensitivity of 18F-FDG PET/CT in detecting liver metastases was 14% for lesions of <1.5 cm, 84% for those between 1.5 and 3 cm, and 100% for those above 3 cm. In our study, most of the lesions seen on MRI but not detected by 18F-FDG PET/CT were those smaller than 10 mm. Since PET can show the metabolic activity of lesions and MRI can detect lesions due to high soft-tissue resolution at an early stage, it is considered that the combined use of 18F-FDG PET/CT and MRI can provide more benefits for patients. PET/MRI, which has been used in recent years and is predicted to replace other modalities shortly, will play a significant role in diagnosing lesions and evaluating patient response to treatment.

This study had certain limitations, such as the retrospective design and lack of randomization. Also, since this study was conducted in a single-center, the number of patients included in the sample was limited. Another limitation, albeit negligible, was that the interval between the 18F-FDG PET/CT and MRI examinations reaching six weeks in some patients.

Conclusion

Abdominal MRI with gadolinium, which has high spatial resolution, plays a significant role in detecting liver metastases in cases with GIS and PD tumors. In this study, MRI was more sensitive than 18F-FDG PET/CT in detecting metastases at an early stage, especially in small lesions. However, since 18F-FDG PET/CT shows the whole body's metabolic activity, it significantly contributes to the determination of extrahepatic spread, disease staging and survival prediction. When the disease is first detected, it is necessary to evaluate the liver parenchyma with MRI before deciding on surgical resection. Therefore, the evaluation of these cases with both 18F-FDG PET/CT and MRI is of considerable importance for deciding on surgical resection following the early diagnosis of the disease, staging the disease and increasing the survival of the patients. Lastly, it is foreseen that diagnostic sensitivity will further increase with the two modalities' hybrid use.

Disclosures

Ethics Committee Approval: This study was approved by the Clinical Research Ethics Committee of Sisli Hamidiye Etfal Teaching and Research Hospital (decision number: 382, date: October 28, 2014). This study was conducted in accordance with the Helsinki Declaration and Good Clinical Practices guideline.

Peer-review: Externally peer-reviewed.

Conflict of Interest: None declared.

Authorship Contributions: Concept – S.M.E., M.B., M.T.; Design – S.M.E., M.T.; Supervision – S.M.E., M.B.; Materials – M.T.; Data collection &/or processing – M.T., S.M.E.; Analysis and/or interpretation – M.T., S.M.E.; Literature search – M.T.; Writing – M.T., S.M.E.; Critical review – M.T., S.M.E., M.B.

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