

Prognostic Value of PSMA Dominance on Dual-Tracer PET in Hepatocellular Carcinoma: A Prospective Single-Center Study

elgin ozkan

ozkanelgin@yahoo.com

ankara university faculty of medicine <https://orcid.org/0000-0001-8543-0744>

Cigdem Soydal

Ankara University faculty of medicine

Irem Mesci

Ankara university faculty of medicine

Ramazan Idilman

Ankara university faculty of medicine

Mine Araz

Ankara university faculty of medicine

Digdem Kuru Oz

Ankara university faculty of medicine

Atilla Halil Elhan

Ankar university faculty of medicine

Basak Gulpinar

Ankara university faculty of medicine

Gul Ayse Erden

Ankara University faculty of medicine

Acar Tuzuner

TOBB ETU faculty of medicine

Nuriye Ozlem Kucuk

Ankara University faculty of medicine

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Abstract

Background

To evaluate the prognostic value of prostate-specific membrane antigen (PSMA) findings in patients with hepatocellular carcinoma (HCC) and to assess its incremental prognostic value over fluorodeoxyglucose (FDG) positron emission tomography (PET) and established clinical factors.

Methods

In this prospective, single-center study, 18 patients with HCC (mean age: 65.3±11.5years, 78%male) underwent dual-tracer PSMA and FDG PET imaging for staging (n=14) and restaging (n=4), with a median interval of 6 days between scans. Clinical variables, including age, gender, serum alpha-fetoprotein (AFP), albumin-bilirubin (ALBI) grade, and Child-Pugh class, as well as imaging parameters derived from PSMA and FDG PET, were evaluated. Time to progression (TTP) and overall survival (OS) were assessed using the Kaplan–Meier method and compared with the log-rank test. Cox proportional hazards regression analysis was performed to identify independent predictors of survival. PSMA dominance was defined as PSMA-dominant uptake (PSMA>FDG).

Results

During a median follow-up of 15.5 months, 11 patients (61.1%) developed disease progression and 9 (50.0%) died. In Kaplan–Meier analysis, several clinical and imaging variables were associated with OS, including ascites, ALBI grade, Child-Pugh class, PSMA PET positivity, PSMA-detected extrahepatic disease (EHD), FDG-detected portal vein thrombosis (PVT), and PSMA dominance. For TTP, ascites, ALBI grade, Child-Pugh class, PSMA-detected EHD, and PVT detected on both PSMA and FDG were significant.

In multivariable Cox analysis, PSMA dominance emerged as an independent predictor of OS (HR: 37.85, 95% CI:2.42-592.84, $p = 0.010$), together with Child-Pugh class (HR: 81.02, 95% CI:4.09-1603.51, $p = 0.004$) and AFP ≥ 200 ng/mL (HR: 13.86, 95% CI:1.41-135.91, $p = 0.024$). For TTP, ascites (HR: 48.82, 95% CI:X-Y, $p = 0.004$) and PSMA-detected EHD (HR: 16.28, 95% CI:X-Y, $p = 0.024$) remained independently associated with shorter TTP.

Conclusion

In HCC, disease progression appears to be primarily driven by tumor burden and extent, whereas overall survival is additionally influenced by liver function and tumor biology. Among PET-derived markers, PSMA dominance emerged as a potential imaging biomarker and was independently associated with overall survival, suggesting that the incremental prognostic value of PSMA PET may lie primarily in its ability to capture biologic heterogeneity beyond FDG PET alone.

INTRODUCTION

Hepatocellular carcinoma (HCC) remains a major cause of cancer-related mortality worldwide, and accurate prognostic stratification continues to represent an important unmet clinical need (1). Prognosis in HCC is determined not only by tumor burden and stage, but also by underlying liver function and the biological heterogeneity of the tumor (2). As a result, outcome prediction in HCC remains challenging, and conventional clinical and imaging approaches may not fully capture the complex interplay between tumor extent, liver reserve, and tumor aggressiveness (2, 3).

Fluorine-18 (F-18) Fluorodeoxyglucose (FDG) positron emission tomography (PET) / computed tomography (CT) has been investigated in HCC as a functional imaging tool reflecting tumor glycolytic activity and dedifferentiation (4–6). Increased FDG uptake has been associated with aggressive tumor behavior and poorer prognosis; however, the sensitivity of FDG PET in HCC is variable, particularly in well-differentiated tumors, which limits its overall clinical utility (4–6). More recently, prostate-specific membrane antigen (PSMA) PET has emerged as a promising imaging modality in HCC. Unlike FDG, PSMA uptake in HCC is thought to primarily reflect tumor-associated neo vasculature rather than tumor cells metabolism, thereby offering a biologically distinct imaging signal (7). Previous studies have demonstrated encouraging detection rates with PSMA PET in HCC, supporting its potential role as a complementary imaging modality to conventional imaging approaches (7–8).

Despite these observations, the prognostic role of PSMA PET in HCC remains poorly defined. Most available studies and recent systematic reviews have primarily focused on lesion detection, diagnostic performance, and staging, whereas the potential contribution of PSMA PET to risk stratification and outcome prediction has not been systematically evaluated (8–10). Furthermore, the complementary prognostic value of combined PSMA and FDG PET findings in HCC has received little attention.

Accordingly, the aim of this study was to evaluate the prognostic value of PSMA PET findings in patients with HCC and to determine whether PSMA PET provides incremental prognostic information beyond FDG PET and established clinical factors. We also explored the association between PSMA dominance and clinical outcomes, including time to progression (TTP) and overall survival (OS), as a potential indicator of tumor heterogeneity.

MATERIAL-METHODS

Study Design and Patient Population

This prospective, single-center study included consecutive patients with hepatocellular carcinoma (HCC) who underwent both F-18 fluorodeoxyglucose (FDG) and Ga-68 prostate-specific membrane antigen (PSMA) PET/CT between February 2023 and December 2024 for either initial staging or restaging. A total of 18 patients met the eligibility criteria and were included in the final analysis (initial staging, $n = 14$; restaging, $n = 4$). The diagnosis of HCC was established either histopathological or based on accepted radiological criteria on contrast-enhanced computed tomography (CT) or magnetic resonance imaging (MRI). To ensure comparability between the two PET examinations, only patients who underwent both FDG and PSMA PET/CT within 10 days and without any intervening treatment were included. Patients with incomplete imaging data or insufficient follow-up for survival analysis were excluded.

The study protocol was approved by the institutional review board (Approval No.2022/567), and all procedures were conducted in accordance with the Declaration of Helsinki. Written informed consent was obtained from all participants. This project was funded by Ankara University Scientific Research Projects Coordination Unit with grant number of TSA-2023-2780.

PET/CT Imaging Protocol

All patients underwent both F-18 FDG and Ga-68 PSMA PET/CT within a median interval of 6 days (maximum 10 days), with no intervening treatment between the two examinations. For FDG PET/CT, patients fasted for at least 6 hours before tracer administration, and blood glucose levels were confirmed to be below 200 mg/dL prior to imaging. PET/CT acquisition was performed approximately 60 minutes after intravenous administration of F-18 FDG (3.7–5.2 MBq/kg). PSMA PET/CT imaging was performed using Ga-68 PSMA-11 PET acquisition was initiated 60 minutes after intravenous injection of the radiotracer (1.8–2.2 MBq/kg). All scans were acquired on dedicated one of the EARL accredited PET/CT systems (Discovery IQ or Discovery 710, GE Healthcare, Wisconsin, USA). A low-dose CT scan was obtained for attenuation correction and anatomical localization, followed by PET acquisition from the skull base to mid-thigh with an acquisition time of 2–3 minutes per bed position.

Image Analysis

All PET/CT images were independently reviewed by two experienced nuclear medicine physicians who were blinded to clinical outcomes. In cases of disagreement, the final interpretation was reached by consensus. Visual assessment was based on focal tracer uptake higher than the surrounding background and inconsistent with physiological biodistribution.

Semiquantitative analysis was restricted to hepatic HCC lesions. Tracer uptake was assessed relative to surrounding liver parenchyma, and lesions were considered positive when uptake exceeded background liver activity. Semiquantitative PET parameters assessed on both FDG and PSMA PET included SUVmax, SUVmean, SUVpeak, tumor-to-background ratio (TBRmax and TBRmean), and volumetric parameters. TBRmax and TBRmean were calculated by dividing lesion SUVmax and SUVmean, respectively, by the SUVmean of normal liver parenchyma. For volumetric analysis, lesion volumes were delineated using a 40% SUVmax threshold. Total lesion glycolysis (TLG) was calculated for FDG PET, whereas total lesion PSMA (TL-PSMA) was calculated for PSMA PET by multiplying tumor volume with SUVmean.

PSMA and FDG PET findings were categorized on a per-patient basis as positive or negative. A patient was considered PET-positive if at least one hepatic HCC lesion demonstrated pathologic tracer uptake above background liver activity. Presence of extrahepatic disease (EHD) and tracer uptake on portal vein thrombosis (PVT) were assessed separately for each tracer. Tracer uptake on PVT was considered positive when focal intravascular tracer uptake exceeding blood-pool activity was identified on PVT in corresponding CT slices.

PSMA dominance was defined on a per-patient basis according to hepatic tumor uptake pattern only. It was defined as PSMA-dominant hepatic disease, including the presence of FDG-negative and PSMA-positive hepatic lesions or visually higher uptake on PSMA PET than on FDG PET within the dominant hepatic tumor burden. Patients with equal uptake patterns or FDG-dominant hepatic involvement were classified as non-PSMA dominant disease. Presence of tracer uptake on PVT and EHD were not incorporated into the dominance definition and were analyzed separately for each tracer.

Clinical and Imaging Variables

Baseline clinical characteristics included age, gender, serum alpha-fetoprotein (AFP) level, Child-Pugh class, albumin-bilirubin (ALBI) grade, presence of ascites, and cirrhosis status and etiology. Serum AFP was categorized as < 200 ng/mL or ≥ 200 ng/mL using a previously prognostic cutoff 200 ng/mL (11). ALBI grade was calculated from serum albumin and bilirubin levels using the established formula and categorized into grades 1–3 according to validated cutoff values. Child-Pugh class was determined according to the standard Child-Pugh scoring system (classes

A, B, and C). As no patients with Child-Pugh class C were present in the study population, survival analyses were performed by comparing Child-Pugh classes A and B.

Imaging variables derived from FDG and PSMA PET included per-patient hepatic tracer positivity, PET-detected extrahepatic disease (EHD), and tracer uptake on portal vein thrombosis (PVT) for each tracer separately. In addition, PSMA dominance was included as an imaging marker of tumor heterogeneity.

Follow-up and Outcome Measures

Patients were followed clinically and by imaging after dual-tracer PET/CT evaluation. Time to progression (TTP) was defined as the time from the date of PSMA PET imaging to documented disease progression, based on radiological reports and clinical follow-up records, or censoring at the date of last follow-up. Overall survival (OS) was defined as the time from the date of PSMA PET/CT to death from any cause or censoring at the date of last follow-up.

Statistical Analysis

Categorical variables were compared using the Chi-Square test, Fisher's Exact test, or Fisher-Freeman-Halton exact test, as appropriate. Survival outcomes were estimated using Kaplan-Meier method and compared using log-rank test. Univariable Cox proportional hazards regression analysis was performed to identify potential predictors of time to progression (TTP) and overall survival (OS). Variables with a p-value < 0.25 in univariable analysis, together with clinically relevant variables (including serum AFP level), were entered into the multivariable Cox regression model using a purposeful selection approach. The number of variables included in the final multivariable models was limited according to the number of observed events to avoid model overfitting. Variables with p < 0.05 in the multivariable model were considered independent predictors of TTP or OS. The proportional hazards assumption was assessed using statistical testing and graphical evaluation of scaled Schoenfeld residuals. Hazard ratios (HRs) with corresponding 95% confidence intervals (CIs) were reported. All statistical analyses were performed using IBM SPSS Statistics version 30.0 (IBM Corp., Armonk, NY, USA). All tests were two-sided, and p-value < 0.05 was considered statistically significant.

RESULTS

Patient Characteristics

A total of 18 patients with HCC were included in the study. The mean age was 65.3±11.5 years (range: 28-81 years), and 14 patients (78%) were male. Dual-tracer PET/CT was performed for initial staging in 14 patients (77.8%) and for restaging in 4 patients (22.2%). Baseline patient characteristics are summarized in Table 1. The median interval between FDG and PSMA PET/CT was 6 days.

PET/CT Findings

For PSMA PET/CT, the mean hepatic lesion SUVmax, SUVmean, SUVpeak, TBRmax, TBRmean and TL-PSMA were 15.7±10.8, 9.2±6.3, 12.7±10.3, 5.02±3.7, 2.9±2.1 and 341.6±392, respectively. For FDG PET/CT, the corresponding hepatic lesion parameters were as follows: SUVmax 12.5 (6.3-42), SUVmean 7.2 (4.1-24.7), SUVpeak 10.3 (4.3-35.9), TBRmax 3.7 (2.2-14.5), TBRmean 2.1 (1.3-8.5), and TLG 222 (85-1377).

On a per-patient basis, PSMA PET was positive in 12 of 18 patients (66.7%), whereas FDG PET was positive in 6 of 18 patients (33.3%) for hepatic lesions. Tracer uptake on PVT was identified on PSMA PET in 2 patients (11.1%) and on FDG PET in 1 patient (5.6%). EHD was detected on PSMA PET in 4 patients (22.2%) and on FDG PET in 5 patients (27.8%) (Table 2). EHD consisted predominantly of lymph node metastases on both tracers, with one additional rib lesion detected by PSMA PET and one vertebral lesion detected by FDG PET. Two patients showed concordant nodal involvement on both tracers.

PSMA Dominance

PSMA dominant disease was observed in 9 patients (50.0%). Of these, 6 patients had PSMA-positive/FDG-negative hepatic lesions (Figure 1), whereas 3 patients demonstrated higher PSMA uptake than FDG uptake in hepatic lesions (Figure 2). Among the remaining 9 patients classified as non-PSMA dominant, 6 had no detectable uptake on either tracer (Figure 3), 2 demonstrated comparable uptake on both PSMA and FDG, and 1 showed FDG-dominant uptake (Figure 4) (Table 2).

Overall Survival

During a median follow-up of 15.5 months, 9 patients (50.0%) died. The mean OS for the entire cohort was 16.4±11.3 months. In Kaplan-Meier Analyses; patients with ascites had significantly shorter OS than those without ascites (5.2±2.4 vs 26.7±3.1, p=0.001). Higher ALBI grade was also associated with shorter OS, with ALBI grade 3 showing the poorest outcome (4.4±3.6 vs 18.4±4.5 vs 26.7±3.7, p=0.001 and p=0.04).

Similarly, patients with advanced Child-Pugh class had significantly shorter OS than those lower Child-Pugh class (7.4 ± 4.3 vs 26.8 ± 3.3 , $p=0.001$). Shorter OS was also observed in patients with PSMA PET positivity (15.2 ± 3.6 vs 29.5 ± 1.8 , $p=0.013$), PSMA-detected EHD (6.6 ± 3.4 vs 25.9 ± 3.2 , $p=0.009$), FDG-detected PVT (1.4 ± 0 vs 23.5 ± 3.3 , $p=0.007$), and PSMA-dominant disease (14.3 ± 4.1 vs 28.8 ± 1.7 , $p=0.010$) Kaplan Meier Curves for OS were represented in Figure 5.

In multivariable Cox regression analysis, presence of Child-Pugh class B (HR: 81.02, 95% CI: 4.09–1603.51, $p = 0.004$), serum AFP level higher than 200 ng/mL (HR: 13.86, 95% CI: 1.41–135.91, $p = 0.024$), and presence of PSMA dominance (HR: 37.85, 95% CI: 2.42–592.84, $p = 0.010$) remained independent predictors for OS (Table 3). The magnitude and precision of the independent prognostic effects are illustrated in the forest plot in Figure 6.

Time to Progression

During follow-up period, 11 patients (61.1%) developed disease progression. The mean time to progression-free survival (TTP) for the entire cohort was 10.3 ± 11.2 months. In Kaplan-Meier analysis, patients with ascites had significantly shorter TTP than those without ascites (1.9 ± 0.4 vs 20.8 ± 3.9 , $P=0.001$). Higher ALBI grades were associated with shorter TTP, with ALBI grade 3 showing significantly worse outcomes compared with lower ALBI grades (1.8 ± 0.9 vs 18.8 ± 4.3 , $p=0.005$). Similarly, advanced Child-Pugh class was associated with shorter TTP (3.4 ± 1.7 vs 20.3 ± 4.1 , $p=0.002$). Patients with PSMA-detected EHD (2.4 ± 0.8 vs 19.3 ± 3.9 , $p=0.004$), PSMA-detected PVT (2.6 ± 1.1 vs 18.2 ± 3.8 , $p=0.040$), and FDG-detected PVT (1.4 ± 0 vs 17.2 ± 3.7 , $p=0.007$) also had significantly shorter TTP. Kaplan Meier Curves for TTP were provided in Figure 7.

In multivariable Cox regression analysis, the presence of ascites (HR: 48.82, 95% CI: 3.39–703.69, $p=0.004$) and presence of PSMA-detected EHD (HR: 16.28, 95% CI: 1.45–182.91, $p = 0.024$) remained independently associated with shorter TTP (Table 4).

DISCUSSION

In this prospective study, we evaluated the prognostic significance of PSMA PET in patients with hepatocellular carcinoma (HCC) and its relationship with FDG PET and established clinical prognostic factors. While several clinical and imaging variables were associated with survival in univariable analyses, only a limited number remained independently associated with outcome in multivariable models. Notably, PSMA dominance emerged as an independent predictor of overall survival, supporting the concept that imaging-defined tumor heterogeneity may provide incremental prognostic information beyond FDG PET and established clinical factors.

Differences between PSMA and FDG uptake likely reflect complementary aspects of HCC biology. FDG uptake is generally associated with increased glucose metabolism and tumor dedifferentiation, whereas PSMA uptake predominantly reflects tumor-associated neovasculature rather than tumor cell expression (4–6, 12). Consequently, differences in tracer uptake may represent distinct biological tumor phenotype within the same patient. In our study, patients with PSMA-dominant disease demonstrated significantly shorter overall survival, suggesting that predominant PSMA uptake may identify a biologically distinct phenotype. Although the biological basis cannot be established from imaging findings alone, these observations support the hypothesis that PSMA dominance represents imaging-defined tumor heterogeneity with potential prognostic significance (13).

Importantly, PSMA dominance included both FDG-negative/PSMA-positive hepatic lesions and lesions demonstrating visually higher PSMA uptake than FDG. The predominance of FDG-negative/PSMA-positive lesions within this group suggest that PSMA PET may identify biologically relevant disease not detected by FDG PET alone, further supporting the complementary role of dual-tracer PET imaging in HCC. However, because the number of patients within each subgroup was limited, separate prognostic analyses of FDG-negative/PSMA positive lesions and visually PSMA-dominant lesions were not feasible. Therefore, these findings should be regarded as hypothesis-generating and require confirmation in larger prospective cohorts.

Another important finding of our study is the apparent distinction between predictors of disease progression and predictors of overall survival. Time to progression was independently associated with ascites and PSMA-detected extrahepatic disease, indicating that progression is primarily influenced by disease extent. In contrast, overall survival was independently predicted by Child-Pugh class, AFP level, and PSMA dominance, suggesting that long-term outcome in HCC reflects the combined effects of hepatic reserve and underlying tumor biology rather than tumor burden alone. This observation is consistent with the multifactorial nature of prognosis in HCC, in which both liver function and tumor biology contribute substantially to patient outcome (1–3).

Previous studies investigating PSMA PET in HCC have primarily focused on lesion detection, staging, and diagnostic performance (7–10). Recent systematic reviews have highlighted the complementary value of PSMA PET and FDG PET in lesion detection while also emphasizing the limited evidence regarding prognostic applications (9, 10). Our findings extend the current literature by suggesting that the incremental clinical value of PSMA PET simply be improved lesion detection, but also its ability to characterize imaging-defined tumor heterogeneity when interpreted together with FDG PET. To our knowledge, this is among the first studies to identify PSMA dominance as an independent imaging biomarker associated with overall survival in HCC.

This study has several limitations. First, the sample size was relatively small, which is reflected in the wide confidence intervals observed in the multivariable analyses. Second, the study was conducted at a single center, which may limit generalizability. Third, although the imaging protocol was prospective, the cohort included both staging and restaging indications, introducing potential clinical heterogeneity. In addition, the absence of lesion-level tumor burden metrics, including lesion size and number, were not incorporated into the analyses and may partly account for the observed association between PSMA dominance and survival. Quantitative PET parameters were also not evaluated as prognostic variables, limiting further characterization of imaging-derived tumor biology. Finally, treatment strategies after PET imaging were not standardized and may also have influenced survival outcomes. Therefore, these findings should be interpreted with caution and require validation in larger prospective multicenter studies.

CONCLUSIONS

Based on the results of this pilot analysis, we suggest that PSMA PET may provide clinically relevant prognostic information beyond FDG PET in patients with HCC. In particular, PSMA dominance appears to represent a promising imaging biomarker reflecting tumor heterogeneity with potential implications for risk stratification. Further prospective multicenter studies are warranted to validate these findings and to clarify the role of dual-tracer PET imaging in prognostic assessment of HCC.

Declarations

Funding

This project was funded by Ankara University Scientific Research Projects Coordination Unit with grant number of TSA-2023-2780.

Competing Interest

The authors have no relevant financial or non-financial interest to disclose.

Ethics Approval

The study protocol was approved by the institutional review board (Approval No.2022/567).

Consent to Participate

Written informed consent was obtained from every patient included in the study prior to imaging.

Author Contributions

All authors contributed to the study conception and design. Data collection was performed by Elgin Ozkan, Irem Mesci, Mine Araz, Ramazan Idilman, Acar Tuzuner. Image interpretation, and analysis were performed by Elgin Ozkan, Irem Mesci, Digidem Kuru Oz, Basak Gulpinar, Gul Ayse Erden, Mine Araz, Cigdem Soydal. Statistical analysis was done by Atilla Halil Elhan. The first draft of the manuscript was written by Elgin Ozkan and Cigdem Soydal. The manuscript was revised by Ramazan Idilman and Nuriye Ozlem Kucuk. All authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

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Tables

Table 1. Baseline Patient Characteristics

Variables	[n (%)] mean±SD
Age	65.3±11.5 years
Gender	
Male	14 (78%)
Female	4 (22%)
Cirrhosis status	
Absent	2 (11%)
Present	16 (89%)
Cirrhosis etiology	
HBV	14 (88%)
HCV	1 (6%)
ArLD	1 (6%)
Serum AFP level	
< 200 ng/mL	5 (28%)
≥ 200 ng/mL	13 (72%)
Child-Pugh Class	
A	14 (78%)
B	4 (22%)
C	0
ALBI grade	
1	10 (56%)
2	6 (33%)
3	2 (11%)

HBV, hepatitis B virüs; HCV, hepatitis C virüs; ArLD, alcohol-related liver disease; AFP, alpha-fetoprotein; ALBI, albumin-bilirubin

Table 2. Patient-Based Distribution of PSMA PET and FDG PET Findings

Patient ID	PSMA positivity in hepatic lesions	FDG positivity in hepatic lesions	PSMA-dominant uptake in hepatic lesions	PSMA-detected PVT	FDG-detected PVT	PSMA-detected EHD	FDG-detected EHD
1	yes	no	yes	no	no	no	yes
2	yes	no	yes	yes	no	yes	no
3	yes	no	yes	no	no	no	no
4	yes	no	yes	no	no	no	no
5	yes	no	yes	no	no	no	no
6	yes	no	yes	no	no	yes	no
7	yes	yes	yes	no	no	no	no
8	yes	yes	yes	no	no	no	no
9	yes	yes	yes	yes	yes	yes	yes
10	yes	yes	no	no	no	no	no
11	yes	yes	no	no	no	yes	yes
12	no	no	no	no	no	no	no
13	no	no	no	no	no	no	no
14	no	no	no	no	no	no	yes
15	no	no	no	no	no	no	no
16	no	no	no	no	no	no	yes
17	no	no	no	no	no	no	no
18	yes	yes	no	no	no	no	no

PVT, portal vein thrombosis; EHD, extrahepatic disease

Table 3. Univariable and multivariable Cox regression analysis for overall survival (OS)

Variable / Comparison	Univariable HR (95% CI)	<i>p</i>	Multivariable HR (95% CI)	<i>p</i>
Child_Pugh class	7.46 (1.813-30.678)	0.005	81.02 (4.09-1603.51)	0.004
AFP ≥ 200 ng/mL	3.87 (0.998-15.01)	0.050	13.86 (1.41-135.91)	0.024
PSMA dominance	6.73 (1.318-34.325)	0.022	37.85 (2.42-592.84)	0.010
ALBI grade 3 vs 1	32.19 (2.53-410.14)	0.007		
PSMA_PET positivity	9.35 (1.14-76.92)	0.038		
PSMA_detected EHD	6.11 (1.31-28.43)	0.021		
FDG_detected PVT	16.49 (1.03-263.76)	0.048		

AFP, alpha-fetoprotein; EHD, extrahepatic disease; PVT, portal vein thrombosis

Table 4. Univariable and multivariable Cox regression analysis for time to progression (TTP)

Variable / Comparison	Univariable HR (95% CI)	<i>p</i>	Multivariable HR (95% CI)	<i>p</i>
Ascites	28.46 (3.06-264.77)	0.003	48.82 (3.39-703.69)	0.004
PSMA_detected EHD	8.2 (1.57-42.43)	0.013	16.28 (1.45-182.91)	0.024
ALBI grade 3 vs 1	8.32 (1.28-53.91)	0.026		
Child_Pugh class	7.9 (1.73-36.04)	0.008		
FDG_detected PVT	16.49 (1.03-263.76)	0.048		

Figures

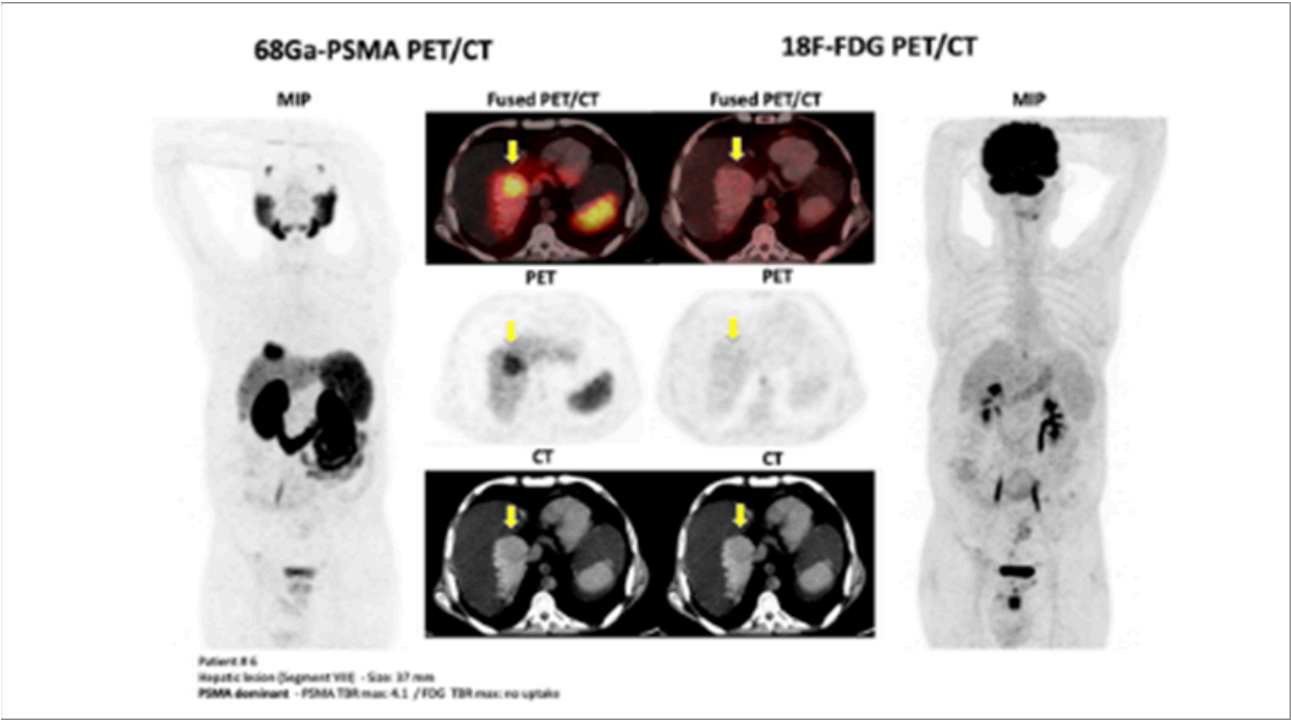


Figure 1
Representative PET/CT images of patient 6 with PSMA-dominant disease, showing a PSMA-positive/FDG-negative hepatic lesion.

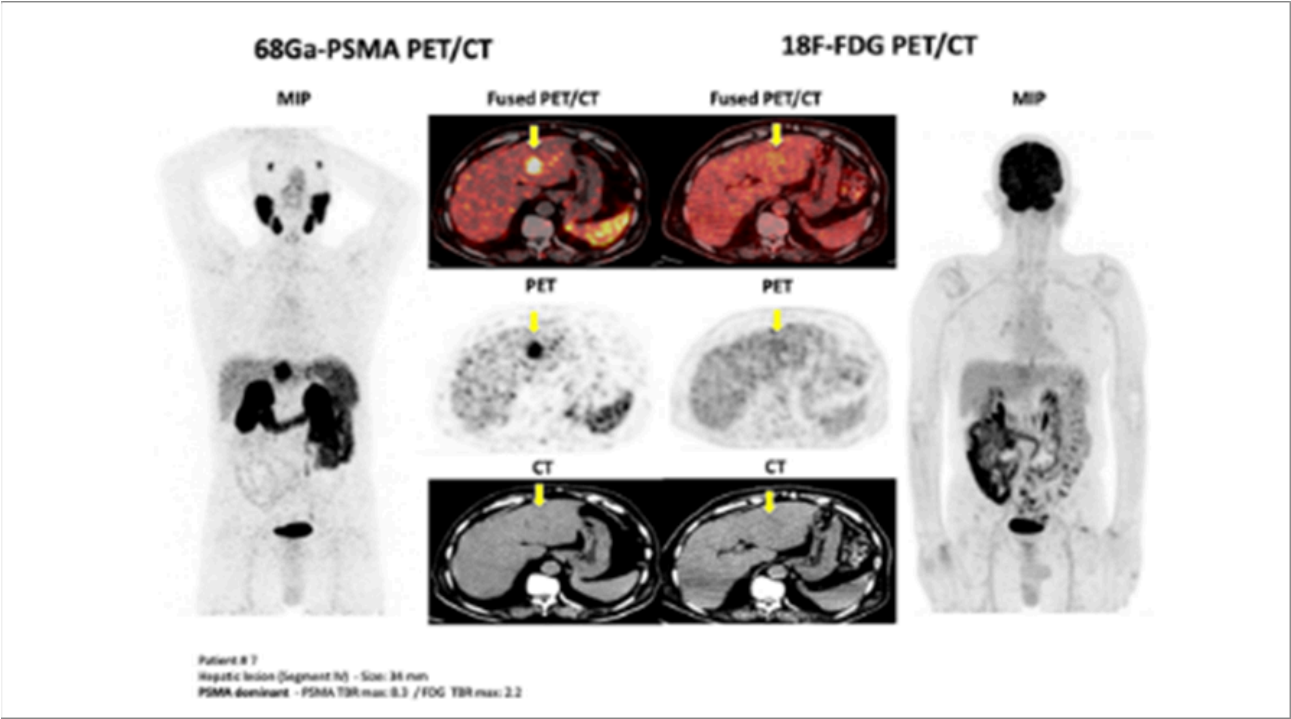


Figure 2
Representative PET/CT images of patient 7 with PSMA-dominant disease, showing higher PSMA uptake than FDG uptake in the hepatic lesion.

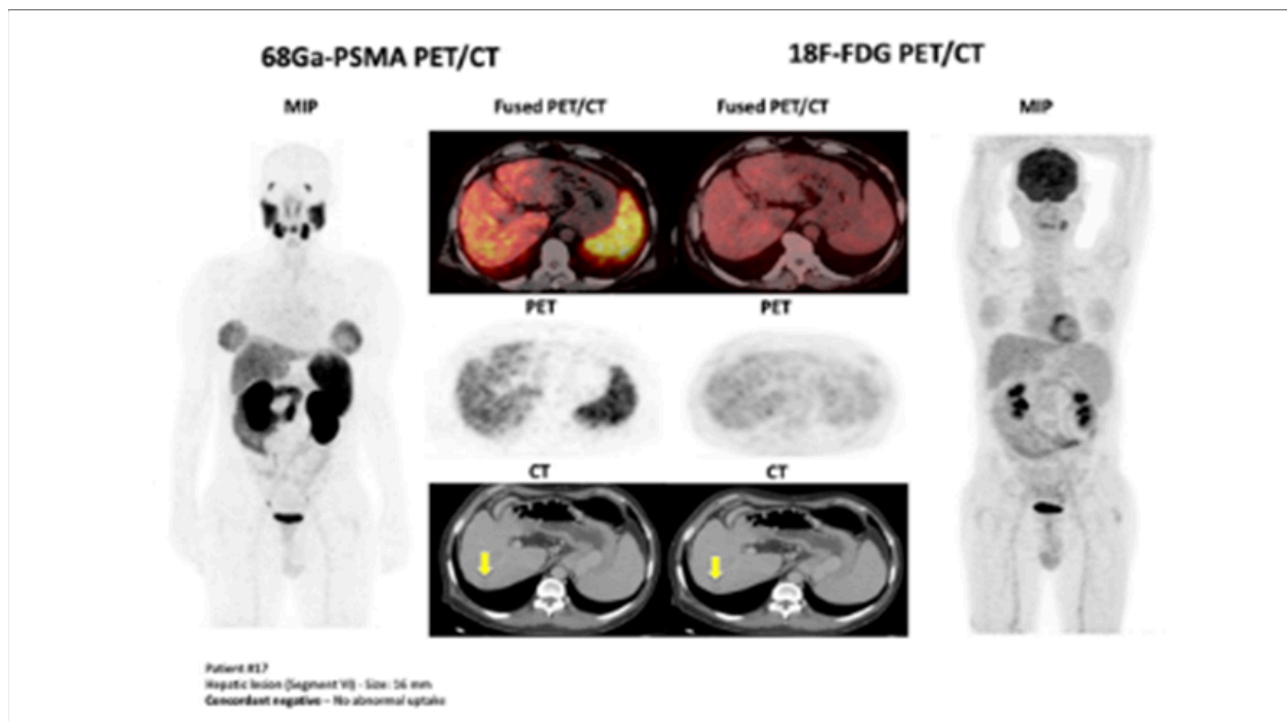


Figure 3

Representative PET/CT images of patient 17 with non-PSMA-dominant disease, showing no abnormal uptake on either PSMA or FDG PET/CT.

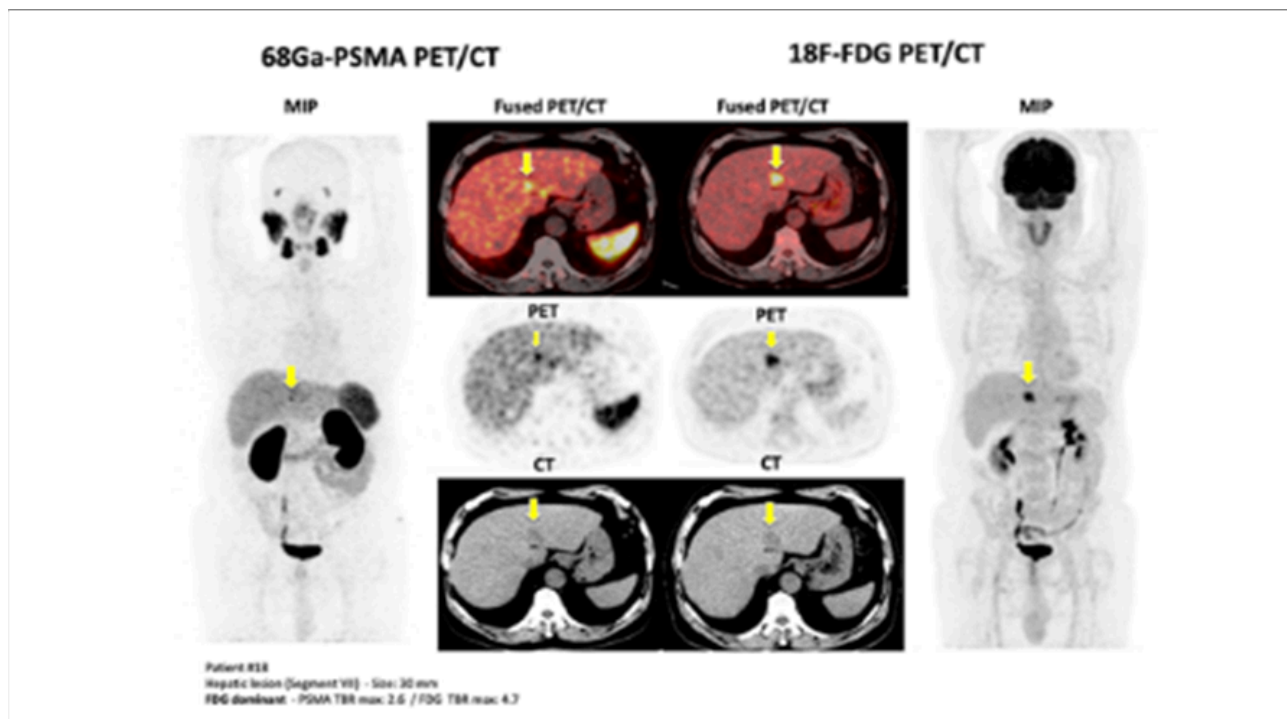


Figure 4

Representative PET/CT images of patient 18 with FDG-dominant disease, showing higher FDG uptake than PSMA uptake in hepatic lesion.

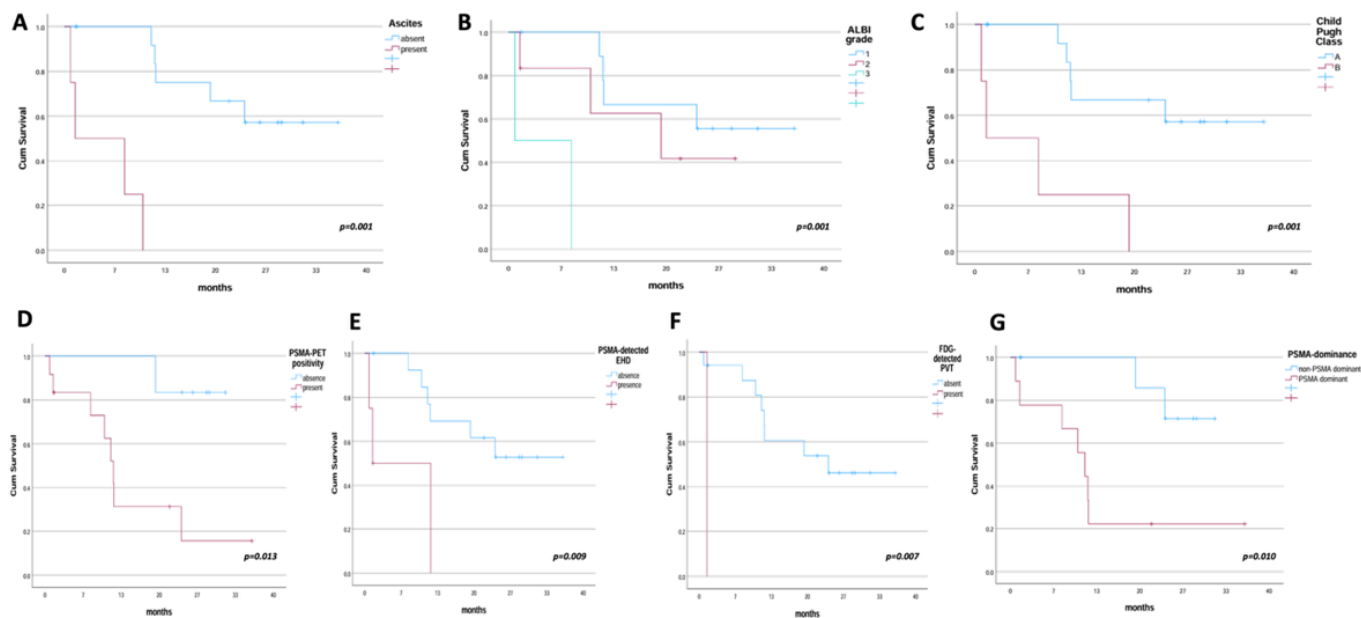


Figure 5

Kaplan–Meier curves for overall survival (OS) according to significant clinical and imaging variables. Overall survival was significantly associated with the presence of (A) ascites, (B) ALBI grade, (C) Child–Pugh class, (D) PSMA-PET positivity, (E) PSMA-detected extrahepatic disease (EHD), (F) FDG-detected portal vein thrombosis (PVT), and (G) PSMA dominance.

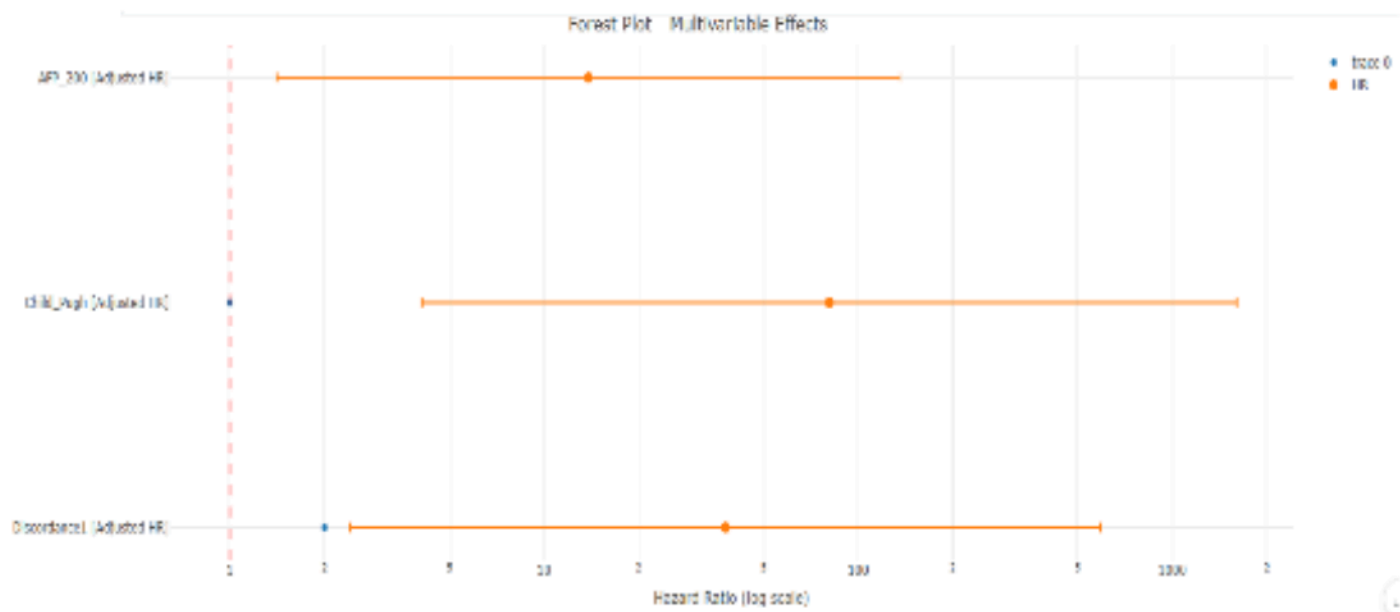


Figure 6

Forest plot showing the multivariable Cox proportional hazards analysis for overall survival. Child–Pugh class, AFP ≥ 200 ng/mL, and PSMA dominance remained independent predictors of overall survival. Hazard ratios (HRs) are presented with 95% confidence intervals.

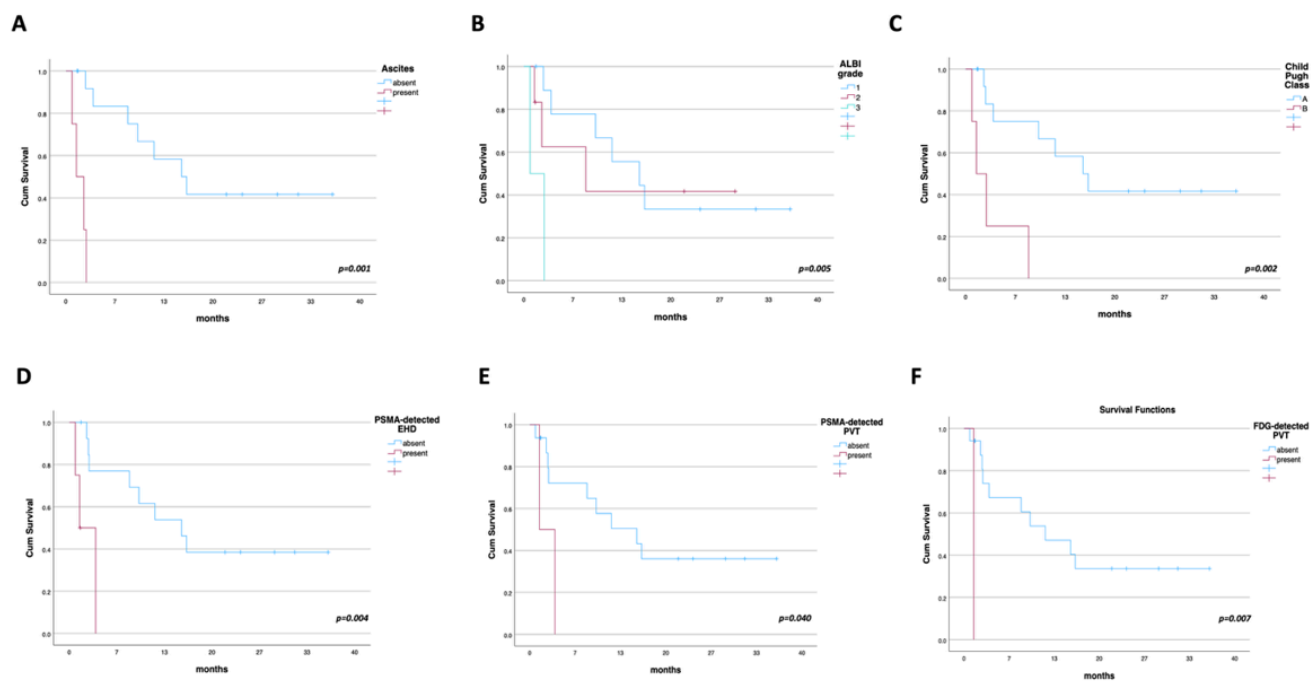


Figure 7

Kaplan–Meier curves for time to progression (TTP) according to significant clinical and imaging variables. Shorter TTP was significantly associated with the presence of (A) ascites, (B) ALBI grade, (C) Child–Pugh class, (D) PSMA-detected extrahepatic disease (EHD), and portal vein thrombosis (PVT) detected by both (E) PSMA PET and (F) FDG PET.