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ORIGINAL ARTICLE

Overall survival and progression-free survival in patients with primary brain tumors after treatment: is the outcome of [^{18}F] FDOPA PET a prognostic factor in these patients?

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Abstract

Aim To investigate the progression-free survival (PFS) and the overall survival (OS) in a population affected by primary brain tumors (PBT) evaluated by [^{18}F]-L-dihydroxyphenylalanine ([^{18}F] FDOPA) positron emission tomography/computed tomography (PET/CT).

Materials and methods 133 subjects with PBT (65 women and 68 men, mean age 45 ± 10 years old) underwent ^{18}F FDOPA PET/CT after treatment. Of them, 68 (51.2%) were Grade II, 34 (25.5%) were Grade III and 31 (23.3%) were Grade IV. PET/CT was scored as positive or negative and standardized uptake value ratio (SUVr) was calculated as the ratio between SUVmax of the lesion vs. that of the background. Patients have been observed for a mean of 24 months.

Results The outcome of [^{18}F] FDOPA PET/CT scan was significantly related to the OS and PFS in Grade II gliomas. In Grade II PBT, the OS proportions at 24 months were 100% in subjects with a negative PET/CT scan and 82% in those with a positive scan. Gehan–Breslow–Wilcoxon test showed a significant difference in the OS curves ($P = 0.03$) and the hazard-ratio was equal to 5.1 (95% CI of ratio 1.1–23.88). As for PFS, the proportion at 24 months was 90% in subjects with a negative PET/CT scan and 58% in those with a positive scan. Gehan–Breslow–Wilcoxon test showed a significant difference in the OS curves ($P = 0.007$) and the hazard-ratio was equal to 4.1 (95% CI of ratio 1.3–8). We did not find any significant relationship between PET outcome and OS and PFS in Grade III and IV PBT.

Conclusions A positive [^{18}F] FDOPA PET/CT scan is related to a poor OS and PFS in subjects with low-grade PBT. This imaging modality could be considered as a prognostic factor in these subjects.

Keywords [^{18}F] FDOPA · PET/CT · Prognostic value · Survival · Brain tumors · Tumor relapse

Introduction

The current therapeutic approach to primary brain tumors (PBT) is based on a multidisciplinary intervention combining surgery, radiotherapy and/or chemotherapy and for monitoring and follow-up, actually, magnetic resonance imaging (MRI) is the modality of choice for the detection of tumor recurrence [1]. MRI allows an accurate morphological evaluation of the brain and the possibility to detect areas of pathologic contrast enhancement, an hallmark of recurrence in PBT previously submitted to surgery [2]. However, even with MRI, the appropriate assessment of treatment-induced modifications or possible tumor relapse are not easily recognizable [3, 4]; moreover it has been recently reported that the assessment of PBT with MRI significantly underestimate the tumor volume, especially for low-grade tumors due to the absence of contrast enhancement [5, 6]. Positron emission tomography/computed tomography (PET/CT) with amino [^{18}F]-L-dihydroxyphenylalanine ([^{18}F] FDOPA) has proved as a promising diagnostic tool in the evaluation of PBT recurrence with the detection in vivo of amino acid

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metabolism and an higher sensitivity and specificity as compared to MRI [7].

The classification of PBT has been significantly revised in 2016, with the uses molecular parameters and the histology to define the main tumor categories [1, 8]. For the first time, genetically defined entities are now included in the classification of diffuse gliomas, medulloblastomas, embryonal tumors as for other histological variants of PBT [1, 9]. Nevertheless, tumor grade as defined by world health organization (WHO) still remain an hallmark in tumor classification representing together with younger age, performance status and the extent of resection one of the most important prognostic factors in PBT [8]. In particular, a lower age at diagnosis (< 50 years) is associated with a better prognosis [10] while higher functional impairment—as expressed by Karnofsky Performance Status (KPS)—and the residual tumor volume are significant negative prognostic factors [11].

The aim of our study was to investigate the potential predictive role of [^{18}F] FDOPA PET/CT in a cohort of patients previously treated for PBT, including II, III and IV WHO.

Materials and methods

Patients

The present study was conceived as a retrospective cohort study. The final protocol has been approved by the local institutional review board (Comitato Etico, IRCCS Neuromed, Pozzilli, Italy). For the purpose of the present study, we retrospectively reviewed clinical records of all patients with a histological diagnosis of PBT during a 5-year period who underwent [^{18}F] FDOPA brain PET/CT and MRI at the recruiting center. Inclusion criteria were adult age (≥ 18 years), a KPS ≥ 60 and willingness to participate in the present study as demonstrated by providing written informed consent. Exclusion criteria were predefined as follows: currently pregnant or breastfeeding, current or past diagnosis of other neoplastic diseases, or neurological/psychiatric conditions. The final cohort comprised 133 patients. All study-related procedures have been performed according to the declaration of Helsinki [12].

Clinical and demographic characteristic were collected at study enrolment. A general overview of the population examined is shown in Table 1. Of the 133 patients examined, 55 (41%) were affected by astrocytoma, 32 (24%) by oligodendroglioma, 14 (10%) by oligoastrocytoma and 32 (24%) by glioblastoma. Regarding tumor grade, 68 (51.2%) were Grade II, 34 (25.5%) were Grade III and 31(23.3%) were Grade IV. All patients received treatment with neurosurgery, chemotherapy (CHT) and/or radiotherapy (RT) according to the latest guidelines [1]. Neurosurgery was considered as complete in 40% of the subjects examined (54/133).

MRI scan

MRI scans were performed with a 1.5-T superconductive system (OptimaTM MR450w; GE Medical System, Waukesha, WI, USA). We used a head-coil. All patients were scanned with the following sequences: fast spin-echo (FSE) T2 on coronal plane, FSE T1, T2 and fluid attenuated inversion recovery images (FLAIR) in axial plane. After gadolinium infusion (Gd-DTPA; 0.1 mmol/kg), T1 sequences were acquired.

[^{18}F] FDOPA injection and PET/CT scan

The PET/CT system Discovery ST (GE Medical Systems, Tennessee, USA) has been used to assess [^{18}F] FDOPA brain distribution in all patients by means of a 3D-mode standard technique in a 256 × 256 matrix as reported previously in other reports from our group in this field [13,

Table 1 General overview of the population examined

	SUVmax (mean ± SD)	SUVmax occ (mean ± SD)	SUV ratio (mean ± SD)	PET/CT outcome	OS in months; (mean ± SD)	PFS in months; (mean ± SD)
Whole population (n = 133; males = 72; females = 61; age = 46 ± 14 years old)	2.25 ± 2.75	2 ± 2.84	1.42 ± 0.43	Positive = 93 Negative = 41	24 ± 12	17 ± 12
Grade II WHO (n = 68; males = 39; females = 29; age = 44 ± 14 years old)	2.4 ± 3.52	2.1 ± 1.61	1.4 ± 0.44	Positive = 42 Negative = 26	27 ± 10	18 ± 12
Grade III WHO (n = 34; males = 11; females = 23; age = 44 ± 14 years old)	2.1 ± 1.61	1.6 ± 1.32	1.45 ± 0.47	Positive = 25 Negative = 9	21.7 ± 10	17 ± 12
Grade IV WHO (n = 31; males = 22, females = 9; age = 53 ± 13 years old)	2.1 ± 2.01	2.1 ± 3.02	1.44 ± 0.30	Positive = 26 Negative = 5	21 ± 17	18 ± 16

14]. Reconstruction was performed using the 3-dimensional reconstruction method of ordered-subsets expectation maximization (OSEM) with 20 subsets and with 4 iterations. A low-ampere CT scan of the head for attenuation correction (40 mA; 120 kV) was performed before PET image acquisition. All the patients fasted for at least 5 h before intravenous injection of [^{18}F] FDOPA; the dose administered was 185–210 MBq. PET/CT acquisition started at least 15 min after [^{18}F] FDOPA injection and lasted 12 min in all the subjects.

SUVmax and SUV ratio and image evaluation

The PET CT images were interpreted as positive by an experienced nuclear medicine physician (A.C.) when the lesion definitely showed an increased [^{18}F] FDOPA accumulation (over the background). The background and the contralateral site were considered as well. From the volume of interest (VOI), the standardized uptake value (SUV) was calculated using standard body weight method. Values for maximum SUV for the site of recurrence (SUVmax) were calculated by A.C. on a dedicated workstation (ADVANTAGE WORKSTATION 4.4. GE MEDICAL SYSTEMS) for all the PET/CT examinations (semi-quantitative analysis). A volume of interest (VOI) was traced on the site of recurrence starting from the slice that showed the highest tracer uptake with the aid of co-registered MRI images for a correct VOI placement [14]. Since no one of the patients examined did have PBT in the occipital regions as detectable by both PET/CT and MRI data, this site has been selected for SUVmax calculation for the background (SUVmax occ) that were measured with a standard VOI of $1.5 \times 1.5 \times 1.5$ cm (for a total volume of 3.375 cm^3) placed on the occipital region (occ) as proposed previously [14].

SUV ratio (SUVr) was calculated with the following formula: SUVr = SUVmax/SUVmax occ [15].

Statistical analysis

We calculated the means and standard deviation for age and the results of the semi-quantitative analysis for SUVr, SUVmax and SUVocc in different tumor grades (Table 1) and in different histological types (Table 2). Differences in SUVr values for patients with a positive or a negative PET/CT scan and in different histological types have been examined with Kolmogorov–Smirnov test. PFS was calculated from the date of surgery until the date of documented tumor recurrence or further growth of residual tumor and defined as ''tumor regrowth''. Overall survival was defined from the day of surgery until death of the patient while disease progression was assessed according to RANO criteria [16]. For patients who had not experienced recurrence or death at the time of last follow-up, PFS and OS were censored at the date of last follow-up. In case of inability to contact a patient, the last date visit was taken as provisional endpoint to allow statistical analysis. The association between PFS or OS and the results of PET/CT scan was evaluated using Gehan–Breslow–Wilcoxon test and presented as Kaplan–Meier plots. Hazard ratios (HR) and their corresponding 95% confidence intervals (95% CI) were computed to provide quantitative information about the relevance of results of the statistical analysis. Receiver operator characteristics (ROC) curves have been built to evaluate the performance of SUVr in predicting OS or PFS; optimal threshold for SUVr was determined using the Youden's index on the basis of the combination between sensitivity and specificity. Finally, agreement between MRI and PET findings were evaluated with Cohen's *k*.

Results

A general overview of the study population is provided in Table 1. SUVr was 2.20 ± 0.26 in patients with a negative scan and 2.90 ± 0.42 in patients with a positive scan ($P < 0.001$).

In MRI, 71% ($n = 48$) of patients with Grade II gliomas did not show any area of contrast enhancement while 29% ($n = 20$) patients had residual disease with areas of contrast enhancement. MRI did not show any area of contrast enhancement in 24% of patients with high-grade gliomas ($n = 16$) while the remaining 76% ($n = 49$) had residual disease with areas of contrast enhancement.

There was no agreement between PET and MRI findings in low-grade PBT (Cohen's $k = -0.1$; % of agreement = 42%).There was a moderate agreement between

Table 2 SUV ratio (SUVr) values in each histological type of the population examined

	Oligodendroglioma ($n = 32$); SUVr ± SD	Astrocytoma ($n = 55$); SUVr ± SD	Oligoastrocytoma ($n = 14$); SUVr ± SD	Glioblastoma	*P* value
PET/CT positive	1.59 (±0.55)	1.57 (±0.37)	1.55 (±0.43)	1.50 (±0.40)	> 0.05 (in all the comparisons)
PET/CT negative	0.87 (±0.12)	1.03 (±0.24)	1.02 (±0.33)	1.03 (±0.28)	> 0.05 (in all the comparisons)
P value (positive vs. negative scans SUVr values)	< 0.0001	< 0.0001	< 0.0001	< 0.0001	

PET and MRI in 77% of the observations in high-grade PBT (Kappa = 0.538).

Qualitative analysis of PET/CT data: OS and PFS in the whole population examined

In the whole population, the results of [^{18}F] FDOPA PET/CT scan were significantly related to OS and PFS. In particular, none of the 41 subjects with a negative PET/CT scan died during the follow-up while 20 of the 93 (21.5%) subjects with a positive PET/CT scan died. The OS proportions at 24 months were 100% in subjects with a negative PET/CT scan and 75% in those with a positive scan. Gehan–Breslow–Wilcoxon test showed a significant difference in OS curves ($P = 0.003$) with an HR of 4.4 (95% CI of ratio 1.7–11.3). Regarding PFS, 5 out of the 41 (12%) subjects with a negative PET/CT scan and 37 out of the 93 (40%) subjects with a positive PET/CT scan showed disease progression. The PFS proportions at 24 months were 84% in subjects with a negative PET/CT scan and 60% in those with a positive scan. Gehan–Breslow–Wilcoxon test showed a significant difference in PFS curves ($P = 0.006$) with an HR of 3.3 (95% CI of ratio 1.3–5). PFS and OS curves for the whole population are presented in Fig. 2. Cox proportional hazards regression analysis performed on the whole population demonstrated no significant association between OS and age (HR: 1.01, 95% CI 0.99–1.03) or sex (HR: 1.38, 95% CI 0.90–2.11) and between PFS and age (HR: 1.00, 95% CI 0.98–1.02) or sex (HR: 1.20, 95% CI 0.92–1.98).

Qualitative analysis of PET/CT data: OS and PFS in different PBT grades

Grade II WHO

In the 68 subjects with Grade II PBT, the results of [^{18}F] FDOPA PET/CT scan were significantly related to OS and PFS. In particular, none of the 26 subjects with a negative PET/CT scan died until the end of the study while 7 of the 42 subjects (16%) with a positive PET/CT scan died. The OS proportions at 24 months were 100% in subjects with a negative PET/CT scan and 82% in those with a positive scan. Gehan–Breslow–Wilcoxon test showed a significant difference in the OS curves ($P = 0.03$) and the hazard-ratio was equal to 5.1 (95% CI of ratio 1.1–23.88).

As for PFS, 3 of the 25 subjects (12%) with a negative PET/CT scan showed disease progression until the end of the study while 16 of the 42 (38%) subjects with a positive PET/CT scan showed disease progression. The PFS proportions at 24 months were 90% in subjects with a negative PET/CT scan and 58% in those with a positive scan. Gehan–Breslow–Wilcoxon test showed a significant difference in the PFS curves ($P = 0.007$) and the hazard-ratio resulted equal to 4.1 (95% CI of ratio 1.3–8). PFS and OS curves are presented in Fig. 3a, b.

Grade III WHO

In the 34 subjects with Grade III PBT, the results of [^{18}F] FDOPA PET/CT scan were not significantly related to OS and PFS. In particular, none of the 9 subjects with a negative PET/CT scan died until the end of the study while 8 of the 25 subjects (32%) subjects with a positive PET/CT scan died. The OS proportions at 24 months were 100% in subjects with a negative PET/CT scan and 60% in those with a positive scan. Nevertheless, Gehan–Breslow–Wilcoxon test did not show a significant difference in the OS curves ($P = 0.11$).

As for PFS, 4 of the 9 subjects with a negative PET/CT scan (44%) showed disease progression until the end of the study while 9 of the 25 (36%) subjects with a positive PET/CT scan showed disease progression. The OS proportions at 24 months were 40% in subjects with a negative PET/CT scan and 66% in those with a positive scan. Gehan–Breslow–Wilcoxon test did not show a significant difference in the OS curves ($P = 0.13$). PFS and OS curves are presented in Fig. 3c, d.

Grade IV WHO

In the 34 subjects with Grade IV PBT, the results of [^{18}F] FDOPA PET/CT scan were not significantly related to the OS and PFS. In particular, none of the 5 subjects with a negative PET/CT scan died until the end of the study while 5 of the 26 subjects (19%) with a positive PET/CT scan died. The OS proportions at 24 months were 100% in subjects with a negative PET/CT scan and 80% in those with a positive scan. Nevertheless, Gehan–Breslow–Wilcoxon test did not show a significant difference in the OS curves ($P = 0.24$).

As for PFS, 3 of the 5 subjects (60%) with a negative PET/CT scan showed disease progression until the end of the study while 12 of the 26 subjects (46%) with a positive PET/CT scan showed disease progression. The PFS proportions at 24 months were 40% in subjects with a negative PET/CT scan and 60% in those with a positive scan. Gehan–Breslow–Wilcoxon test did not show a significant difference in the PFS curves ($P = 0.85$) and the hazard-ratio resulted equal to 0.9 (95% CI of ratio 0.23–3.3). PFS and OS curves are presented in Fig. 3e, f.

Semi-quantitative analysis of PET/CT data: OS and PFS in the whole population examined

ROC curve analysis performed on the whole population demonstrated that SUVr of [^{18}F] FDOPA PET/CT scan was significantly related to OS with (AUC = 0.68, $P = 0.01$). In details, SUVr was equal to 1.60 ± 0.41 in the 20 patients who

died during the follow-up vs. 1.40 ± 0.30 in the remaining 113 subjects. The optimal SUVr threshold for discriminating patients who survived was 1.37 with a sensitivity of 80% and specificity of 61%. In particular, 4 out of the 73 subjects with a SUVr < 1.37 died until the end of the study (5.5%) while 16 out of the of the 61 subjects with SUVr ≥ 1.37 died (26%). On the other hand, we did not find significant differences when comparing SUVr of subjects with and without disease progression after PET/CT examination. In particular, SUVr was equal to 1.48 ± 0.35 in the 47 subjects showing disease progression and 1.39 ± 0.43 in the remaining 87 subjects (AUC = 0.57, $P = 0.18$). Graphs of ROC analyses are presented in Fig. 1.

Discussion

In the whole population examined in our study (133 subjects), [^{18}F] FDOPA uptake appears to be a good prognostic factor when the metabolic pattern is assessed both

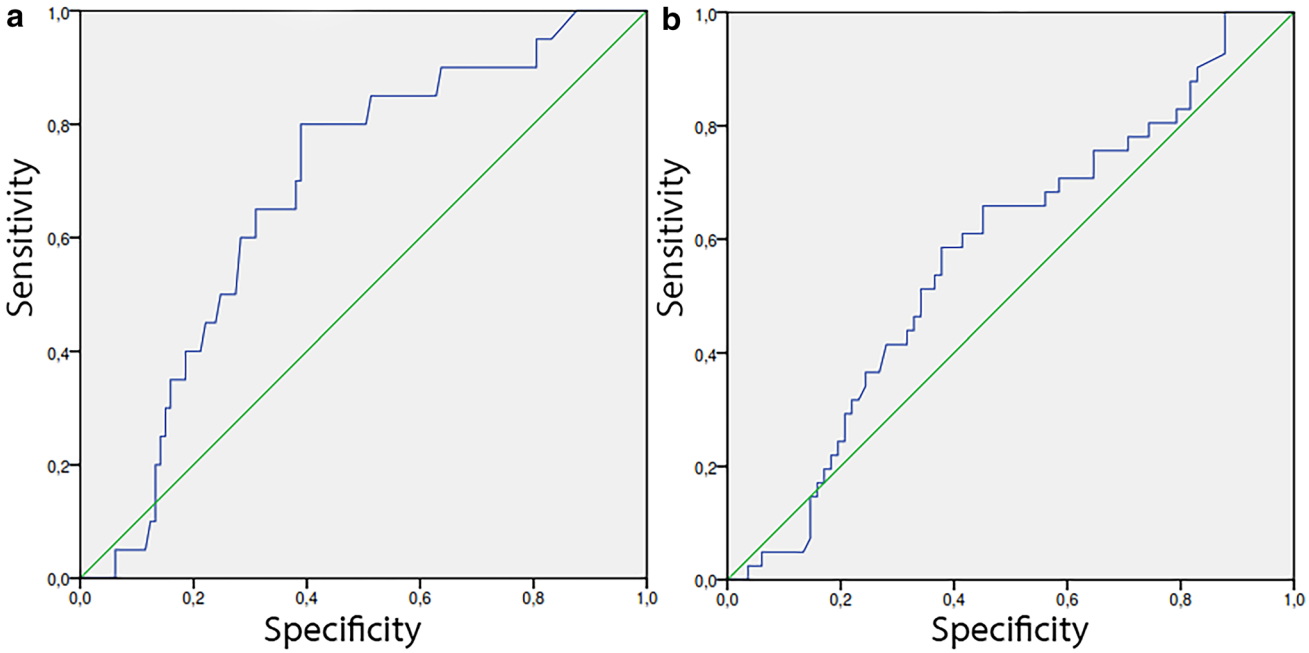

Fig. 1 Receiver operator characteristics (ROC) curves show the performance of SUVr in predicting OS (**a**) and PFS (**b**). SUVr of [^{18}F] FDOPA PET/CT scan was significantly related to OS (AUC = 0.68, $P = 0.01$) (**a**) while SUVr was not related to PFS (AUC = 0.57, $P = 0.18$) (**b**)

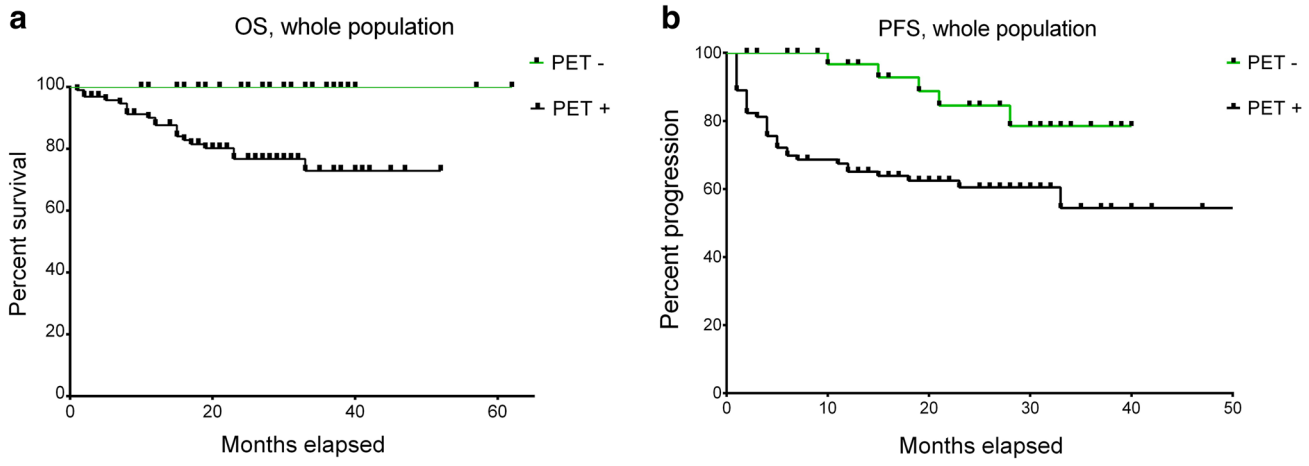

Fig. 2 Overall survival (**a**) and progression-free survival (**b**) in the whole population. In green a negative PET/CT scan and in black a positive PET/CT scan according to visual analysis

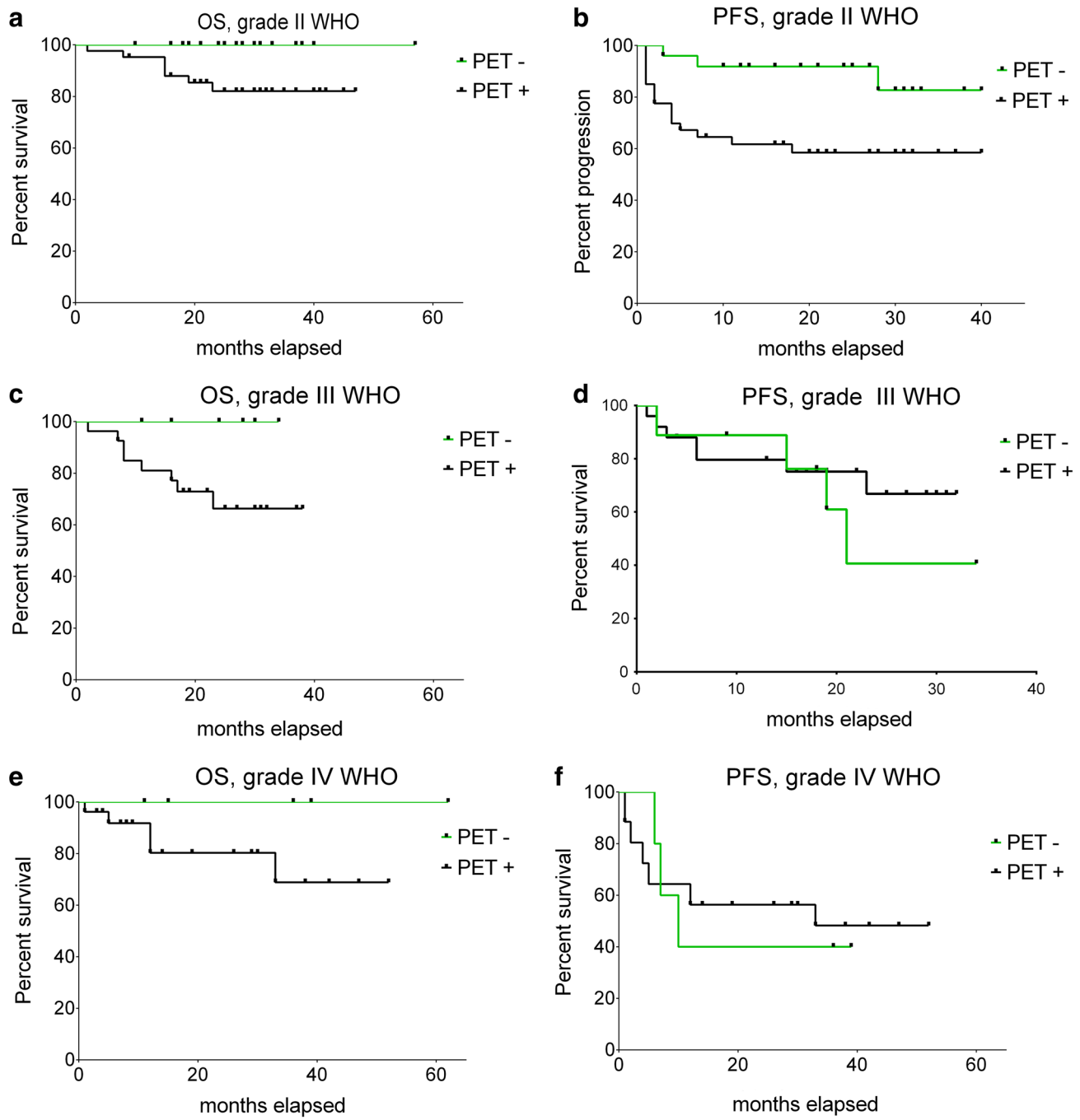

Fig. 3 Overall survival and progression-free survival per tumor grade. In green a negative PET/CT scan; in black a positive PET/CT scan. Glioma Grade II: **a**, **b**; glioma Grade III: **c**, **d**; glioma Grade IV: **e**, **f**

qualitatively (visual analysis) (Figs. 2, 3) when considering the data concerning OS and PFS. In particular, the OS and PFS proportions at 24 months were 100% and 90%, respectively, in subjects with a negative PET/CT scan. On the other hand, semi-quantitative (SUV ratio) analysis appears as a good prognostic factor for PFS only. To the best of our knowledge, few studies have been carried out to date in order to investigate the predictive value of [^{18}F] FDOPA in brain tumors. One of the most cited papers in this field report that patient previously treated with radiation, surgery and chemotherapy for secondary brain lesions (mostly breast cancer) and with a positive PET finding resulted into a significant difference in mean time to progression and survival in comparison with patients with negative PET findings [17].

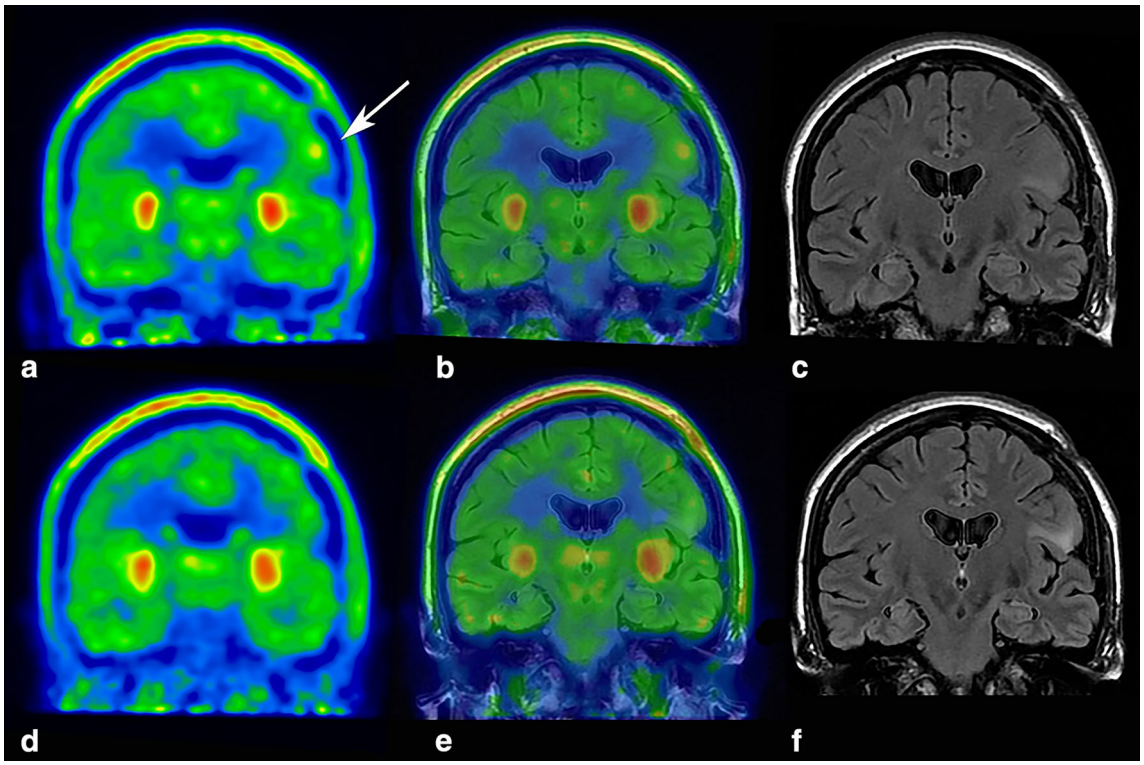

Fig. 4 Coronal view in **a** of a [^{18}F] FDOPA scan in a subject with Grade II primary brain tumor showing a focal area (arrow) of increased uptake of the radiolabeled compound in the left frontal lobe on the surgical resection margins. SUVr was equal to 1.17. In **b** we report the PET/MRI fusion imaging and in **c** the T2-weighted MRI. Follow-up scan performed after 19 months showed a normal uptake of the radiolabeled compound in the same site (**d**). No additional treatments have been performed in the interval between the scans. In **e** we report the PET/MRI fusion imaging and in **f** the T2-weighted MRI

Moreover, in agreement with our findings, semi-quantitative analysis with lesion-to-normal brain tissue ratio or visual score represented a good discriminator in this study [13, 17, 18]. We found that a SUVr (derived from the ratio between [^{18}F] FDOPA uptake in pathological tissue and normal cortex) higher than 1.37 performed well as cut-off in discriminating those patients with a worse prognosis in terms of OS and PFS. Interestingly, at a similar threshold of sensitivity, the value of SUVr in our study was significantly lower as compared to that reported by Lizarraga [17] in secondary brain tumors (2.02, sensitivity 81%). On the other hand, Karunanithi et al. [18] reported that a threshold of 1.51 in PBT led to a better sensitivity (94%). Differences between SUVr values could be easily explained if one considers that tumor biology between PBT and secondary brain tumors is significantly different, reflecting also different strategies in their management and treatment [1, 19]. On the other hand, the significant difference in the number of subjects examined (133 vs. 33) and the different repartition in tumor grades of our case studies as compared to that of Karunanithi could partially explain these discrepancies (see Table 1) [18]. In particular, 51.2% of the patients examined in our study were affected by Grade II gliomas, which is a significantly higher percentage as compared to the report of Karunanithi [18]. Moreover, no Grade I was included in our study. Once again, differences in amino acid metabolism in different types of tumors could explain the discrepancies observed in the identification of an optimal SUVr value. ROC analysis in our study show a major limitation: the different follow-up period for each patient may represent a confounding factor. The standard approach of ROC curve analysis considers event (death or disease progression in our study) as fixed over time and this is not the case of our study cohort as in the most of clinical studies. A ROC curve as a function of time is more appropriate. To date, several models have been proposed, but a general consensus on the best methodology is still matter of debate. Future studies, possibly using the same time point on the study cohort should be performed to obtain a better evaluation of semi-quantitative parameters on OS and PFS.

The normalization of SUV (i.e., ratio between pathological and normal tissue) represent, in any case, the optimal strategy when evaluating PET scan for PBT with [^{18}F] FDOPA. SUV, in fact may vary significantly when using different scanners, reconstruction parameters and dose [20]. Nevertheless, the use of a ratio tumor/background could partially limit the biases due to different kinetics of [^{18}F]

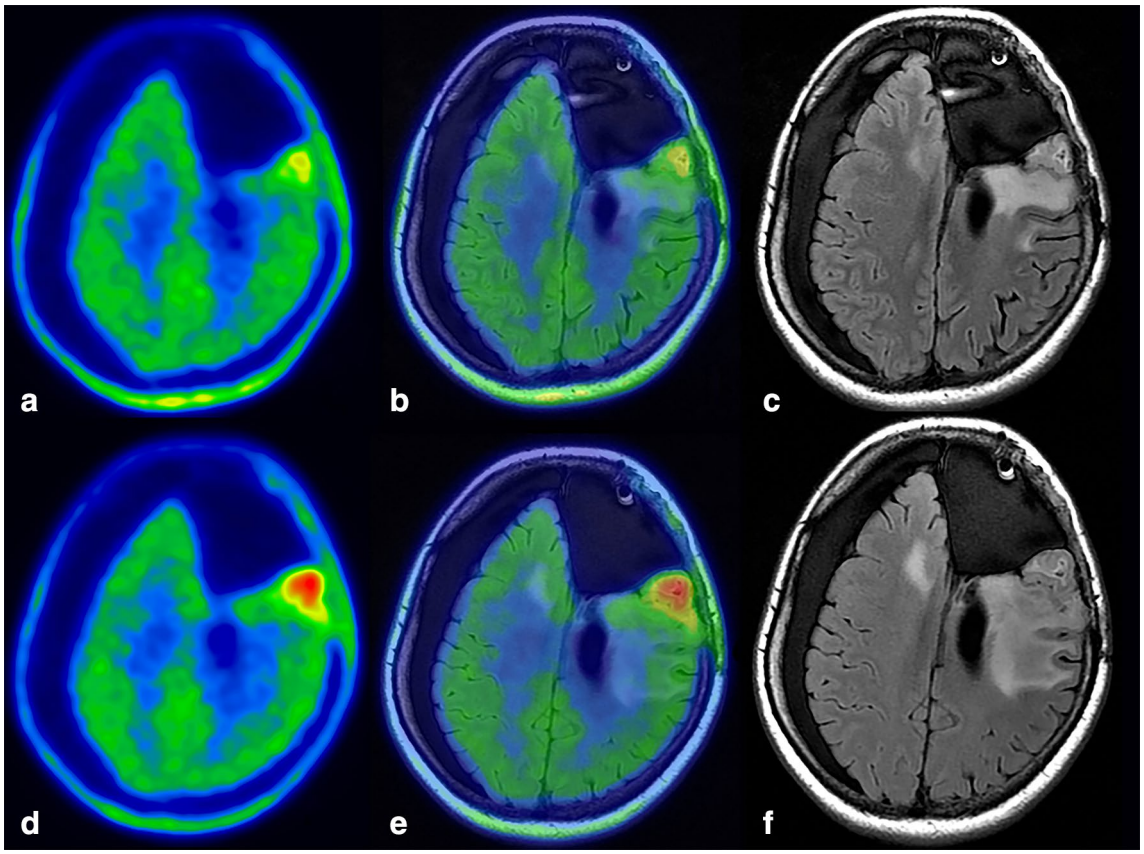

Fig. 5 Axial slice in **a** showing an increased [^{18}F] FDOPA uptake in the residual part of frontal lobe after surgery in a patient with Grade III glioma 6 months after surgery (SUVr = 1.45). In **b** we report the PET/MRI fusion imaging and in **c** the T2-weighted MRI. Thirteen months follow-up in **d** showing a disease progression with a further increase of [^{18}F] FDOPA uptake (SUVr = 1.7). In **e** we report the PET/MRI fusion imaging and in **f** the T2-weighted MRI

FDOPA in PBT according to their grade of malignancy. While the wash out of [^{18}F] FDOPA in normal tissues is relatively slow (with the concentration of [^{18}F] FDOPA over time being quietly constant), high-grade tumors are usually characterized by a rapid wash out as compared to low grades [21, 22]. Another possible explanation of the differences in SUVr values could be sought in the different timings in the acquisition of PET scans in our study (15 min) as compared to that of Karunanithi (15–30 min) [18].

Despite the results mentioned above seems promising and, generally, in partial agreement with the literature published to date, the analyses performed per-grade depict a different scenario. When considering high-grade gliomas (Grade III e IV) only, the uptake in [^{18}F] FDOPA do not show any significant relationship with OS and PFS. In other words, PET with [^{18}F] FDOPA appear as an important prognostic factor in low-grade PBT (as already described by another previous report of our group in this field [13]) but not in high-grade PBT (Fig. 3). This finding is remarkable if one considers the huge discrepancy between PET and MRI findings in our study in low-grade PBT. Examples of case studies are provided in Figs. 4 and 5. In the first EANO guidelines recently published, the use of PET imaging in PBT has been well established after treatment [23]. Soon after treatment (12 weeks after radio-chemotherapy) or during maintenance PET could be used in both low-grade and high-grade PBT to discriminate (a) treatment-induced changes as pseudoprogression vs. treatment relapse; (b) monitoring of radio-chemotherapy or (c) delineating the tumor extent for resection planning [23]. In this scenario, amino acid PET could be reserved for the identification of those patients with a high risk of malignant transformation lo low-grade PBT.

Although providing novel data regarding the predictive role of [^{18}F] FDOPA in prognostic stratification, our study has some limitations. First, despite our sample size was relatively high, the heterogeneity of the cases examined, the small number of subjects with glioblastoma and of individuals with negative PET/CT scan hamper the generalizability of the results. Furthermore, another significant limitation of our study is represented by the large interval between surgical intervention and the execution of [^{18}F] FDOPA

PET/CT (> 1 year in some cases). During this time frame, low-grade glioma could have switched in a more malignant grade as already described [24], thus biasing our analysis. In this recent published study, Murphy et al. [24] estimated a conversion rate up to 21% with a median time to malignant transformation of 56 months. The switch to a more malignant phenotype could explain the absence of significant differences in SUVr among different histological types of PBT as reported in Table 2. In the last decade, genetic characterization is covering a predominant role in tumor identification and classification. In particular, it has been reported that the 1p36 and 19q13.3 regions are codeleted in 11% of astrocytomas and 64% of oligodendrogliomas. These parameters could possibly explain tumor behavior, by providing information about prognosis and/or expected response to treatment [25]. Future studies on this topic are required possibly on a selected population with a shorter interval between diagnosis, first line treatment and PET and considering the genetic characterization of PBT.

Conclusions

In conclusion, the results of our study suggest that [^{18}F] FDOPA PET/CT may have a role in identifying PBT and predicting OS and PFS in patients with low-grade but not in high-grade PBT.

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