Review

Mol Imaging Radionucl Ther ***DOI:****10.4274/mirt.galenos.2026.84704*

[Epub Ahead of Print]

Comparative Insights into ^{18}F-FDG and ^{68}Ga-FAPI PET Imaging in Glioma: Diagnostic Value, Tumor Grading, and Clinical Implications

Gliomada ^{18}F-FDG ve ^{68}Ga-FAPI PET Görüntülemeye İlişkin Karşılaştırmalı Bilgiler: Tanısal Değer, Tümör Derecelendirmesi ve Klinik Çıkarımlar

Raydel BrianKwee Amalo, Hendra Budiawan, Budi Darmawan

Universitas Padjajaran, Hasan Sadikin General Hospital,Faculty of Medicine, Department of Nuclear Medicine and Theranostic Molecular, Bandung, Indonesia

Abstract

Gliomas are the most common primary malignant brain tumors and are characterized by heterogeneous growth and complex biology, which complicate accurate diagnosis and management. While magnetic resonance imaging (MRI) remains the clinical standard, its limitations in delineating tumor margins and distinguishing recurrence from treatment-induced changes highlight the need for complementary molecular imaging. ^{18}F-fluorodeoxyglucose (^{18}F-FDG) positron emission tomography (PET) has been extensively studied, providing valuable prognostic information by reflecting tumor glycolytic activity. However, its diagnostic utility is hampered by high cortical background uptake and by poor sensitivity in detecting low-grade gliomas. Conversely, glioma-68 fibroblast activation protein inhibitor (FAPI) PET targets cancer-associated fibroblasts, offering superior tumor-to-background contrast and improved visualization of infiltrative margins. Comparative studies suggest that FAPI PET better discriminates between low- and high-grade gliomas, correlates with tumor stromal activity, and aids in therapy planning by differentiating true progression from post-treatment changes. Despite these advantages, the evidence base for FAPI remains limited, largely derived from small cohorts and pilot studies. Standardized imaging protocols and larger prospective trials are necessary to validate its role. Overall, ^{18}F-FDG and FAPI PET provide complementary insights into glioma biology, and their integration with MRI and amino acid tracers may refine diagnostic accuracy, therapeutic planning, and prognostic assessment in clinical neuro-oncology.

Keywords: Glioma, ^{18}F-FDG, PET, FAPI, tumor grading, molecular imaging

Öz

Gliomalar, en sık görülen primer malign beyin tümörleridir ve heterojen büyüme ile karmaşık biyoloji göstermeleri nedeniyle doğru tanı ve yönetimi güçleştirir. Manyetik rezonans görüntüleme (MRG), klinik standart olmaya devam etse de tümör sınırlarını belirlemedeki ve nüksü tedaviye bağlı değişikliklerden ayırt etmedeki sınırlılıkları, tamamlayıcı moleküler görüntüleme yöntemlerine olan gereksinimi ortaya koymaktadır. ^{18}F-florodeoksiglukoz (^{18}F-FDG) pozitron emisyon tomografisi (PET), tümörün glikolitik aktivitesini yansıtarak değerli prognostik bilgiler sağlaması nedeniyle kapsamlı biçimde araştırılmıştır. Ancak tanısal yararlılığı, kortekste yüksek arka plan tutulumu ve düşük dereceli gliomaları saptamadaki

Address for Correspondence: Raydel BrianKwee Amalo, Universitas Padjajaran, Hasan Sadikin General Hospital,Faculty of Medicine, Department of Nuclear Medicine and Theranostic Molecular, Bandung, Indonesia
E-mail: ray_amalo@hotmail.com **ORCID ID:** orcid.org/0009-0008-9224-8965
Received: 01.10.2025 **Accepted:** 23.01.2026 **Epub:** 24.03.2026

Cite this article as: BrianKwee Amalo R, Budiawan AH, Darmawan B. Comparative insights into ^{18}F-FDG and ^{68}Ga-FAPI PET imaging in glioma: diagnostic value, tumor grading, and clinical implications. Mol Imaging Radionucl Ther. [Epub Ahead of Print]

düşük duyarlılık nedeniyle sınırlanmaktadır. Buna karşılık, galyum-68 fibroblast aktivasyon proteini inhibitörü (FAPI) PET, kansere ilişkili fibroblastları hedef alarak daha üstün tümör-arka plan kontrastı ve infiltratif sınırların daha iyi görüntülenmesini sağlar. Karşılaştırmalı çalışmalar, FAPI PET'in düşük ve yüksek dereceli gliomaları ayırt etmede daha başarılı olduğunu, tümör stromal aktivitesi ile korelasyon gösterdiğini ve gerçek progresyonu tedavi sonrası değişikliklerden ayırarak tedavi planlamasına katkı sağladığını düşündürmektedir. Bununla birlikte, bu avantajlara rağmen FAPI'ye ilişkin kanıt temeli halen sınırlıdır ve büyük ölçüde küçük kohortlar ile pilot çalışmalara dayanmaktadır. Rolünün doğrulanabilmesi için standartlaştırılmış görüntüleme protokollerine ve daha büyük, prospektif çalışmalara ihtiyaç vardır. Genel olarak, ^{18}F-FDG ve FAPI PET, glioma biyolojisine ilişkin birbirini tamamlayıcı bilgiler sunmakta; MRG ve amino asit belirteçleri ile birlikte kullanımları, klinik nöro-onkolojide tanısal doğruluğu, tedavi planlamasını ve prognostik değerlendirmeyi geliştirebilir.

Anahtar kelimeler: Glioma, ^{18}F-FDG, PET, FAPI, tümör derecelendirmesi, moleküler görüntüleme

Introduction

Gliomas are the most common primary malignant brain tumors, characterized by heterogeneous and infiltrative growth. Magnetic resonance imaging (MRI) is the standard imaging modality but has limitations in delineating tumor margins and distinguishing tumor progression from post-treatment changes. Molecular imaging with positron emission tomography (PET) provides complementary information. ^{18}F-florodeoksiglukoz (^{18}F-FDG) PET measures glucose metabolism and is useful for high-grade gliomas (HGG), with uptake correlating with tumor aggressiveness and overall survival, but is limited by high cortical background and reduced sensitivity to low-grade or small lesions (1,2).

Fibroblast activation protein inhibitor (FAPI) PET targets FAP in cancer-associated fibroblasts (CAF), offering high tumor-to-background contrast and better visualization of infiltrative margins. Pilot studies indicate FAPI PET may improve detection of residual or recurrent gliomas and provide prognostic information related to tumor stromal aggressiveness (3,4,5). Combining FDG and FAPI PET with MRI and advanced analysis may enhance diagnostic accuracy, treatment planning, and prognostic assessment in glioma patients.

Mechanism of Uptake

Molecular imaging with PET provides complementary information to MRI in glioma evaluation. ^{18}F-FDG PET measures glucose metabolism in tumor cells, reflecting the Warburg effect, and is widely used to assess tumor aggressiveness and to grade tumors. However, its clinical utility is limited by high cortical background, reduced sensitivity for low-grade or small lesions, and potential uptake confounded by inflammation or therapy Kawada et al. (6). Glucose loading prior to ^{18}F-FDG PET can enhance tumor-to-background contrast, improving delineation and characterization of gliomas Kim et al. (7).

FAPI-PET, targeting FAP expressed in CAFs, highlights stromal components and infiltrative tumor margins that are often underrepresented on MRI or ^{18}F-FDG PET. This modality offers high tumor-to-background contrast, aiding detection of residual or recurrent gliomas and potentially providing prognostic information related to stromal aggressiveness Mori et al. (4), Djekidel et al. (8). FAPI PET is particularly promising for visualizing infiltrative gliomas and complementing anatomical imaging, although current evidence is limited to pilot studies and small patient cohorts.

Overall, ^{18}F-FDG PET and FAPI PET provide complementary insights into glioma biology, with FDG reflecting metabolic activity and FAPI delineating stromal and infiltrative regions, supporting improved diagnosis, treatment planning, and prognostic assessment.

Diagnostic Value of ^{18}F-FDG PET in Glioma

^{18}F-FDG PET has been widely applied in glioma imaging due to its ability to reflect the glycolytic activity of tumor cells. Early studies, such as Padma et al. (9), demonstrated that higher FDG uptake strongly correlated with tumor grade and poorer survival outcomes, highlighting its prognostic significance. Subsequent work confirmed this trend, showing that standardized uptake values (SUVs) are generally higher in HGG than in low-grade gliomas (LGG) Takahashi et al. (10). This underscores the utility of ^{18}F-FDG PET in assessing tumor aggressiveness and predicting clinical outcomes.

However, the diagnostic accuracy of ^{18}F-FDG PET is limited by the intrinsically high glucose metabolism in normal cortical tissue, which reduces the lesion-to-background contrast, particularly in LGG. Meta-analyses by Nihashi et al. (11) and Zhao et al. (12) consistently showed that while ^{18}F-FDG PET has moderate sensitivity and specificity, amino acid tracers such as ^{11}C-methionine (MET) or ^{18}F-FDG in detecting recurrent gliomas and differentiating tumor tissue from treatment-related changes. Sharma et al. (13) further confirmed this in a direct comparison in which MET-PET was superior to ^{18}F-FDG PET in distinguishing tumor recurrence from post-treatment necrosis or pseudoprogression.

The role of ^{18}F-FDG PET has therefore shifted from primary diagnosis to prognostic evaluation. Treglia et al. (14), in a systematic review of meta-analyses, concluded that ^{18}F-FDG

provides meaningful information in predicting patient outcomes but is less effective than amino acid tracers for lesion detection. Similarly, Wang et al. (15) highlighted that PET, particularly with MET or fluoroethyltyrosine (FET), was more accurate than MRI spectroscopy in detecting recurrence, whereas ^{18}F-FDG was less reliable as a stand-alone tool. An earlier receiver-operating characteristic analysis of irradiated low-grade astrocytomas, Henze et al. (16), also found ^{18}F-FDG PET useful but inferior to MET-PET in distinguishing tumor progression from radiation-induced changes.

Advantages of FAPI PET in Glioma

The diagnostic evaluation of cancer of unknown primary (CUP) has long relied on ^{18}F-FDG PET/computed tomography (CT) as a functional imaging tool, given its ability to detect tumors based on glycolytic activity. However, several studies have consistently demonstrated the limitations of ^{18}F-FDG, particularly in tumors with low glucose metabolism or in anatomical regions with intrinsically high background uptake, such as the brain.

The introduction of FAPI has opened new avenues in molecular imaging. FAP, expressed predominantly in CAFs, is widely present in the stroma of multiple solid tumors but minimally expressed in normal tissues, including the brain. This biological property forms the basis for the high tumor-to-background contrast of glioma-68 (^{68}Ga)-FAPI PET/CT. Kratochwil et al. (17) highlighted the molecular rationale for targeting FAP, emphasizing its role in tumor proliferation, invasion, and stromal remodeling study by Giesel et al. (18) showed that ^{68}Ga-FAPI PET/CT has markedly lower background uptake in normal brain tissue compared to the high physiological uptake of ^{18}F-FDG, resulting in a much higher tumor-to-background ratio (TBR). This feature is particularly important for brain tumors, where ^{18}F-FDG often struggles due to high baseline glucose metabolism, making lesion detection and delineation difficult.

A broader perspective on the application of FAPI imaging was provided by Dendl et al. (19), who described the "perfect symbiosis" between FAP biology and FAPI imaging. While the high uptake in malignant stroma offers a powerful diagnostic advantage, the authors cautioned that FAP expression is not exclusively tumor-specific and may also occur in conditions such as fibrosis, chronic inflammation, or tissue repair, thereby posing a risk of false positives. This consideration is particularly important in neuro-oncology, where reactive gliosis and post-treatment changes are common.

The superiority of FAPI over ^{18}F-FDG in the CUP setting was further supported by the prospective trial by Gu et al. (20) in head and neck CUP. In this study, ^{68}Ga-FAPI PET/CT identified primary tumors in 51% of patients compared to only 25% with FDG PET/CT, with significant improvements in sensitivity, positive predictive value, and overall diagnostic accuracy. Importantly, the implementation of FAPI imaging altered clinical management in nearly one-quarter of patients, underscoring its real-world clinical impact. Although this study focused on head and neck malignancies, the results are directly translatable to CUP in the brain, where the detection of occult primary lesions remains a major diagnostic challenge.

FDG vs FAPI for Tumor Grading and diagnostic

Recent evidence highlights important differences between^{18}F-FDG and FAPI PET in the assessment of glioma grading. Ruan et al. (21) demonstrated that ^{68}Ga-FAPI-46 uptake increases with glioma grade, with grade IV tumors showing a mean maximum standard uptake value (SUV_{max}) of 5.03 compared to only 1.14 in grade I-II (p=0.02), and exhibiting significantly higher TBR. This reflects the biological reality that FAP expression rises with tumor aggressiveness. In contrast, ^{18}F-FDG PET, as reported by Valentini et al. (22), shows higher uptake in HGG due to increased proliferation, angiogenesis, reflected by higher Ki-67 indices. However, its clinical utility is hampered by the intrinsically high glucose metabolism of normal cortex, resulting in low TBR and making the distinction between LGG and normal brain tissue unclear. A direct head-to-head study by Liu et al. (23) confirmed these limitations: although FAPI SUV_{max} values were generally lower than those of ^{18}F-FDG, the TBR of FAPI was markedly superior because normal brain tissue shows negligible uptake. This allows clearer discrimination between high- and LGG compared with FDG. Supporting these imaging findings, Oster et al. (24) demonstrated that FAPI uptake strongly correlates with FAP expression in tumor tissue, with gliosarcoma showing particularly high tracer accumulation in line with its stromal biology.

Lyu et al. (25) conducted a preliminary study on 25 patients using ^{18}F-FAPI-42 PET/CT. They found significantly higher SUV_{max} and TBR values in HGG compared with LGG. With cut-off values of SUV_{max} 1.20 and TBR 9.09, the diagnostic accuracy was high [area under the curve (AUC) 0.812-0.850]. The strength of FAPI lies in its low background uptake in the normal brain, providing superior contrast compared with FDG. No significant difference was observed between isocitrate dehydrogenase-mutant and wild-type gliomas, suggesting FAPI uptake reflects tumor grade rather than molecular subtype. Study Dev et al. (26), among six high-grade glioma patients, one grade IV lesion demonstrated ^{68}Ga-FAPI-04 uptake with SUV_{max}=2.8, corresponding to MRI enhancing regions and FET PET uptake. While the study primarily classified lesions

as FAPI-positive vs. FAPI-negative (based on uptake above background), it did not provide detailed per-grade averages or TBR values. Study by Kosaka et al. (27) reported that HGG (World Health Organization grade III-IV) showed an average SUV_{avg} of 8.6±2.7 and SUV_{max} of 11.6±3.7, higher than brain metastases, but with significant overlap that reduces discriminatory value. Dunet et al. (28) confirmed that ^{18}F-FDG reflects tumor aggressiveness. However, in (grade I-II), ^{18}F-FDG uptake is low and often indistinguishable from normal cortex, yielding only 38% sensitivity and a poor AUC (0.40). In contrast, HGG typically present with higher SUV_{max} values, yet specificity remains limited (86%) due to overlap with other enhancing lesions. This trend was reinforced by Pietrzak et al. (29), who retrospectively analyzed over 14,000 ^{18}F-FDG PET/CT scans and found that primary brain tumors had a mean SUV_{max} of 9.2±4.7, metastases were even higher at 12.4±5.6, while benign lesions remained low at ~1.0. Importantly, the range of uptake in primary tumors was broad (1.2-25.0), indicating that although HGG are generally more hypermetabolic than LGG, the absolute differences are often obscured by overlapping values. Katsanos et al. (30) performed a meta-analysis of 23 studies (994 patients) comparing ^{18}F-FDG with amino-acid tracers. ^{18}F-FDG had lower sensitivity (63%) but higher specificity (89%) than ^{11}C-MET (94% sensitivity, 55% specificity) and ^{18}F-FET (88% sensitivity, 57% specificity). Thus, high ^{18}F-FDG uptake is specific for high-grade glioma, but many high-grade cases may be missed because ^{18}F-FDG uptake has low sensitivity, highlighting the need for complementary tracers such as FAPI. Quartuccio et al. (31) reviewed 22 studies on ^{18}F-FDG PET combined with MRI. The combined approach consistently outperformed either modality alone, particularly in distinguishing HGG and in differentiating tumor recurrence from radionecrosis. The integration of PET metabolic parameters (SUV, T/N ratio) with MRI functional markers (apparent diffusion coefficient, cerebral blood volume, Cho/Cr) yielded AUC values >0.90. This shows that ^{18}F-FDG PET, despite its limitations, remains valuable when combined with advanced MRI, offering complementary metabolic information. Overall, ^{18}F-FDG PET demonstrates a clear trend of increased uptake with higher glioma grade, but its main limitations are poor contrast in LGG and considerable overlap with metastatic lesions and normal brain tissue. The comparison summary is shown in Table 1.

Implications for Therapy Planning and Monitoring

Accurate delineation of tumor extent is critical for effective neurosurgical intervention and radiotherapy planning in glioma patients. Conventional MRI often fails to precisely define tumor margins, particularly in infiltrative gliomas, and cannot reliably distinguish treatment-related changes from true tumor progression. Molecular imaging with PET provides complementary functional information that can address these limitations.

^{18}F-FDG PET, which measures glucose metabolism, has been widely used to assess tumor aggressiveness and guide therapy. However, its high uptake in normal cortical tissue can obscure tumor margins, limiting sensitivity for low-grade lesions and complicating early assessment of treatment response Kim et al (5). PET tracers with higher tumor specificity, such as FAPI, target FAP expressed in CAFs within the tumor stroma, offering high tumor-to-background contrast and enabling visualization of infiltrative tumor regions that may not enhance on MRI Yao et al. (3), Dev et al. (26).

Studies have demonstrated that FAPI PET can effectively differentiate tumor recurrence from post-treatment changes, which is essential for determining whether additional therapy or biopsy is needed Dev et al. (26). Furthermore, pilot studies suggest that pre-radiotherapy FAPI PET can improve delineation of radiation target volumes, ensuring that infiltrative areas are included while minimizing exposure to normal tissue Yao et al. (3). The PET/RANO report by Galldiks et al. (32) emphasizes that PET imaging contributes to more precise radiotherapy planning and monitoring, allowing early detection of nonresponding tumor regions and informing adaptive treatment strategies to enhance therapeutic efficacy while reducing toxicity.

Limitations and Future Perspectives

Despite promising results, the clinical adoption of FAPI PET in glioma remains limited. Current evidence primarily derives from case series or pilot studies with small cohorts, thereby restricting the generalizability of the findings (8,26,33,34). While FAPI PET demonstrates high tumor-to-background contrast and the ability to visualize infiltrative tumor regions, standardized imaging protocols are lacking and diagnostic thresholds have not yet been validated.

Preliminary studies suggest that FAPI PET can differentiate tumor recurrence from post-treatment changes and may provide prognostic information related to stromal activity and aggressiveness Dev et al. (26), Hua et al. (34). Furthermore, combining FAPI PET with other tracers, such as amino acid PET (^{11}C-MET, ^{18}F-FET), could offer complementary information, potentially improving clinical decision-making and therapy planning Chandekar et al. (33), Djekidel et al. (8). To establish its clinical utility, larger prospective trials are required to assess reproducibility, diagnostic accuracy, and prognostic value in glioma patients.

Table 1. Comparison of ^{18}F-FDG and FAPI PET in glioma grading and diagnostic performance across key studies

Study	Tracer/method	Key findings	Implications for glioma grading
Ruan et al. (21), (2024)	^{68}Ga-FAPI-46 PET/CT	SUV_{max} ↑ with grade (grade IV = 5.03 vs. grade I-II=1.14, p=0.02); TBR significantly higher.	FAPI uptake reflects tumor aggressiveness; superior contrast vs. FDG.
Valentini et al. (22), 2017	^{18}F-FDG PET	Higher uptake in high-grade gliomas linked to proliferation, angiogenesis, Ki-67.	Confirms metabolic aggressiveness, but limited by high cortical background (low TBR).
Liu et al. (23), 2024	^{18}F-FDG vs. FAPI PET/CT	FDG SUV_{max} > FAPI SUV_{max}, but FAPI TBR > FDG (normal brain negligible uptake).	FAPI allows clearer discrimination of glioma grade.
Oster et al. (24), 2024	^{68}Ga-FAPI-46 PET + tissue	FAPI uptake strongly correlates with FAP expression; gliosarcoma shows very high uptake.	Validates biological basis of FAPI PET, esp. in stromal-rich tumors.
Lyu et al. (25), 2022	^{18}F-FAPI-42 PET/CT (25 pts)	HGG had higher SUV_{max} and TBR than LGG; cutoff SUV_{max} 1.20 (AUC 0.812), TBR 9.09 (AUC 0.850).	FAPI provides high diagnostic accuracy, independent of IDH status.
Dev et al. (26), 2024	^{68}Ga-FAPI-04 PET/CT vs. FET (6 patients)	5/6 recurrences detected by both FAPI and FET; 1 negative consistent with treatment change. example grade IV lesion SUV_{max}=2.8	Shows FAPI highlights recurrent high-grade gliomas with high contrast; useful in differentiating recurrence vs. treatment effects.
Kosaka et al. (27), 2008	^{18}F-FDG PET	HGG: SUV_{avg} 8.6±2.7, SUV_{max} 11.6±3.7; higher than brain metastases, but overlapping values.	Uptake higher in HGG, but overlap reduces specificity.
Dunet et al. (28), 2015	^{18}F-FDG PET	In LGG, FDG uptake often indistinguishable from cortex; sensitivity only 38%, AUC 0.40.	FDG unreliable in LGG detection; better in HGG.
Pietrzak et al. (29), 2021	^{18}F-FDG PET/CT (14,000 scans)	Primary brain tumors SUV_{max}=9.2±4.7; metastases=12.4±5.6; benign ~1.0; wide range (1.2-25.0).	Confirms trend of ↑ uptake with grade, but overlap with metastases.
Katsanos et al. (30), 2019	Meta-analysis FDG vs. MET/FET	FDG: sensitivity 63%, specificity 89%; MET/FET: higher sensitivity but lower specificity.	FDG highly specific for HGG, but low sensitivity → many missed cases.
Quartuccio et al. (31), 2020	^{18}F-FDG PET + MRI (22 studies)	PET+MRI > PET or MRI alone; AUC >0.90 for grading and recurrence detection.	Multimodal imaging maximizes accuracy; FDG retains complementary value.

^{18}F-FDG: ^{18}F-fluorodeoxyglucose, FAPI: Fibroblast activation protein inhibitor, PET/CT: Positron emission tomography/computed tomography, SUV_{max}: Maximum standardized uptake value, SUV_{avg}: Average standardized uptake value, TBR: Tumor-to-background ratio, FAP: Fibroblast activation protein, HGG: High-grade gliomas, LGG: Low-grade glioma, AUC: Area under the curve, IDH: Isocitrate dehydrogenase, FET: Fluoroethyltyrosine, MRI: Magnetic resonance imaging

Conclusion

^{18}F-FDG PET and FAPI PET each offer distinct and complementary contributions to glioma imaging. ^{18}F-FDG remains a well-established modality for evaluating tumor aggressiveness and predicting outcomes, although its diagnostic accuracy is limited by physiological cortical uptake and by poor sensitivity for low-grade lesions. In contrast, FAPI PET demonstrates superior lesion-to-background contrast, enabling improved delineation of tumor margins, tumor grading, and differentiation of recurrence from post-treatment effects. These properties make FAPI a promising tool for enhancing neurosurgical and radiotherapy planning. Nevertheless, clinical application is still constrained by the paucity of large-scale, standardized studies. Future research should focus on multicenter prospective trials, protocol harmonization, and the integration of FAPI with other tracers to maximize diagnostic and therapeutic impact. Ultimately, a multimodal imaging strategy that combines MRI, FDG, FAPI, and amino acid PET may represent the most effective approach to optimize glioma diagnosis, treatment monitoring, and patient outcomes.

Footnotes

Authorship Contributions

Surgical and Medical Practices: R.B.A., H.B., B.D., Concept: R.B.A., H.B., B.D., Design: R.B.A., H.B., Data Collection or Processing: R.B.A., B.D., Analysis or Interpretation: R.B.A., B.D., Literature Search: R.B.A., H.B., B.D., Writing: R.B.A.

Conflict of Interest: No conflict of interest was declared by the authors.

Financial Disclosure: The authors declared that this study received no financial support.

References

1. Cui M, Zorrilla-Veloz RI, Hu J, Guan B, Ma X. Diagnostic accuracy of PET for differentiating true glioma progression from post treatment-related changes: a systematic review and meta-analysis. Front Neurol. 2021;12:671867.
2. Shahriari A, Ghazanafar Ahari S, Mousavi A, Sadeghi M, Abbasi M, Hosseinpour M, Mir A, Zohouri Zanganeh D, Gharedaghi H, Ezati S, Sareminia A, Seyedi D, Shokouhfar M, Darzi A, Ghaedamini A, Zamani S, Khosravi F, Asadi Anar M. Machine learning-driven radiomics on 18 F-FDG PET for glioma diagnosis: a systematic review and meta-analysis. Cancer Imaging. 2025;25:106.
3. Yao Y, Tan X, Yin W, Kou Y, Wang X, Jiang X, Chen S, Liu Y, Dang J, Yin J, Cheng Z. Performance of 18 F-FAPI PET/CT in assessing glioblastoma before radiotherapy: a pilot study. BMC Med Imaging. 2022;22:226.
4. Mori Y, Dendl K, Cardinale J, Kratochwil C, Giesel FL, Haberkorn U. FAPI PET: fibroblast activation protein inhibitor use in oncologic and nononcologic disease. Radiology. 2023;306:e220749.
5. Kim D, Lee SH, Hwang HS, Kim SJ, Yun M. Recent update on PET/CT radiotracers for imaging cerebral glioma. Nucl Med Mol Imaging. 2024;58:237-245.
6. Kawada K, Iwamoto M, Sakai Y. Mechanisms underlying ^{18}F-fluorodeoxyglucose accumulation in colorectal cancer. World J Radiol. 2016;8:880-886.
7. Kim D, Ko HY, Lee S, Lee YH, Ryu S, Kim SY, Chung JI, Lee M, Moon JH, Chang JH, Yun M. Glucose loading enhances the value of ^{18}F-FDG PET/CT for the characterization and delineation of cerebral gliomas. Cancers (Basel). 2020;12:1977.
8. Djekidel M, Alsadi R, Abi Akl M, Bouhali O, O'Doherty J. Tumor microenvironment and fibroblast activation protein inhibitor (FAPI) PET: developments toward brain imaging. Front Nucl Med. 2023;3:1183471.
9. Padma MV, Said S, Jacobs M, Hwang DR, Dunigan K, Satter M, Christian B, Ruppert J, Bernstein T, Kraus G, Mantil JC. Prediction of pathology and survival by FDG PET in gliomas. J Neurooncol. 2003;64:227-237.
10. Takahashi M, Soma T, Mukasa A, Tanaka S, Yanagisawa S, Momose T. Pattern of FDG and MET distribution in high- and low-grade gliomas on PET images. Clin Nucl Med. 2019;44:265-271.
11. Nihashi T, Dahabreh IJ, Terasawa T. Diagnostic accuracy of PET for recurrent glioma diagnosis: a meta-analysis. AJNR Am J Neuroradiol. 2013;34:944-950, S1-S11.
12. Zhao C, Zhang Y, Wang J. A meta-analysis on the diagnostic performance of (18)F-FDG and (11)C-methionine PET for differentiating brain tumors. AJNR Am J Neuroradiol. 2014;35:1058-1065.
13. Sharma R, D'Souza M, Jaimini A, Hazari PP, Saw S, Pandey S, Singh D, Solanki Y, Kumar N, Mishra AK, Mondal A. A comparison study of (11)C-methionine and (18)F-fluorodeoxyglucose positron emission tomography-computed tomography scans in evaluation of patients with recurrent brain tumors. Indian J Nucl Med. 2016;31:93-102.
14. Treglia G, Muoio B, Trevisi G, Mattoli MV, Albano D, Bertagna F, Giovanella L. Diagnostic performance and prognostic value of PET/CT with different tracers for brain tumors: a systematic review of published meta-analyses. Int J Mol Sci. 2019;20:4669.
15. Wang X, Hu X, Xie P, Li W, Li X, Ma L. Comparison of magnetic resonance spectroscopy and positron emission tomography in detection of tumor recurrence in posttreatment of glioma: a diagnostic meta-analysis. Asia Pac J Clin Oncol. 2015;11:97-105.
16. Henze M, Mohammed A, Schlemmer HP, Herfarth KK, Hoffner S, Haufe S, Mier W, Eisenhut M, Debus J, Haberkorn U. PET and SPECT for detection of tumor progression in irradiated low-grade astrocytoma: a receiver-operating-characteristic analysis. J Nucl Med. 2004;45:579-586.
17. Kratochwil C, Flechsig P, Lindner T, Abderrahim L, Altmann A, Mier W, Adeberg S, Rathke H, Röhrich M, Winter H, Plinkert PK, Marme F, Lang M, Kauczor HU, Jäger D, Debus J, Haberkorn U, Giesel FL. ^{68}Ga-FAPI PET/CT: tracer uptake in 28 different kinds of cancer. J Nucl Med. 2019;60:801-805.
18. Giesel FL, Kratochwil C, Schlittenhardt J, Dendl K, Eiber M, Staudinger F, Kessler L, Fendler WP, Lindner T, Koerber SA, Cardinale J, Sennung D, Roehrich M, Debus J, Sathekge M, Haberkorn U, Calais J, Serfling S, Buck AL. Head-to-head intra-individual comparison of biodistribution and tumor uptake of ^{68}Ga-FAPI and ^{18}F-FDG PET/CT in cancer patients. Eur J Nucl Med Mol Imaging. 2021;48:4377-4385.
19. Dendl K, Koerber SA, Kratochwil C, Cardinale J, Finck R, Dabir M, Novruzov E, Watabe T, Kramer V, Choyke PL, Haberkorn U, Giesel FL. FAP and FAPI-PET/CT in malignant and non-malignant diseases: a perfect symbiosis? Cancers (Basel). 2021;13:4946.
20. Gu B, Yang Z, Du X, Xu X, Ou X, Xia Z, Guan Q, Hu S, Yang Z, Song S. Imaging of tumor stroma using ^{68}Ga-FAPI PET/CT to improve diagnostic accuracy of primary tumors in head and neck cancer of unknown primary: a comparative imaging trial. J Nucl Med. 2024;65:365-371.
21. Ruan D, Sun J, Han C, Cai J, Yu L, Zhao L, Pang Y, Zuo C, Sun L, Wang Z, Tan G, Qu X, Chen H. ^{68}Ga-FAPI-46 PET/CT in the evaluation of gliomas: comparison with ^{18}F-FDG PET/CT and contrast-enhanced MRI. Theranostics. 2024;14:6935-6946.
22. Valentini MC, Mellai M, Annovazzi L, Melcarne A, Denysenko T, Cassoni P, Casalone C, Maurella C, Grifoni S, Fania P, Cistaro A, Schiffer D. Comparison among conventional and advanced MRI, ^{18}F-FDG PET/CT, phenotype and genotype in glioblastoma. Oncotarget. 2017;8:91636-91653.
23. Liu Y, Ding H, Cao J, Liu G, Chen Y, Huang Z. [^{68}Ga]Ga-FAPI PET/CT in brain tumors: comparison with [^{18}F]F-FDG PET/CT. Front Oncol. 2024;14:1436009.
24. Oster C, Kessler L, Blau T, Keyvani K, Pabst KM, Fendler WP, Fragoso Costa P, Lazaridis L, Schmidt T, Feldheim J, Pierscianek D, Schildhaus HU, Sure U, Ahmadipour Y, Kleinschnitz C, Guberina N, Stuschke M, Deuschl C, Scheffler B, Herrmann K, Kebir S, Glas M. The role of fibroblast activation protein in glioblastoma and gliosarcoma: a comparison of tissue, ^{68}Ga-FAPI-46 PET data, and survival data. J Nucl Med. 2024;65:1217-1223.
25. Lyu J, Lin T, Hou P, Liu S, Lai M, Li H, Shan C, Cheng L, Wen X, Cai L, Wang X. The preliminary study for gliomas grading by 18 F-FAPI-42 PET/CT. Oncoradiology. 2022:380-387.
26. Dev ID, Puranik AD, Rangarajan V, Patra S, Purandare N, Sahu A, Choudhary A, Bhattacharya K, Gupta T, Chatterjee A, Dasgupta A, Moiyadi A, Shetty P, Singh V, Sridhar E, Sahay A, Shah A, Ghosh S, Choudhury S, Shah S, Agrawal A. Preliminary evaluation of FAPI-04-PET/CT for differentiating recurrence and post-treatment changes in high-grade gliomas. Explor Target Antitumor Ther. 2024;5:1289-1296.
27. Kosaka N, Tsuchida T, Uematsu H, Kimura H, Okazawa H, Itoh H. ^{18}F-FDG PET of common enhancing malignant brain tumors. AJR Am J Roentgenol. 2008;190:W365-W369.
28. Dunet V, Pomoni A, Hottinger A, Nicod-Lalonde M, Prior JO. Performance of ^{18}F-FET versus ^{18}F-FDG-PET for the diagnosis and grading of brain tumors: systematic review and meta-analysis. Neuro Oncol. 2016;18:426-434.
29. Pietrzak A, Marszałek A, Piotrowski T, Medak A, Pietrasz K, Wojtowicz J, Szweda H, Matuszewski K, Cholewi ski W. Primary and metastatic brain tumours assessed with the brain and torso [^{18}F]FDG PET/CT Study protocol-10 years of single-institutional experiences. Pharmaceuticals (Basel). 2021;14:722.
30. Katsanos AH, Alexiou GA, Fotopoulos AD, Jabbour P, Kyritsis AP, Sioka C. Performance of ^{18}F-FDG, 11C-methionine, and ^{18}F-FET PET for glioma grading: a meta-analysis. Clin Nucl Med. 2019;44:864-869.
31. Quartuccio N, Laudicella R, Vento A, Pignata S, Mattoli MV, Filice R, Comis AD, Arnone A, Baldari S, Cabria M, Cistaro A. The additional value of ^{18}F-FDG PET and MRI in patients with glioma: a review of the literature from 2015 to 2020. Diagnostics (Basel). 2020;10:357.

32. Galldiks N, Niyazi M, Grosu AL, Kocher M, Langen KJ, Law I, Minniti G, Kim MM, Tsien C, Dhermain F, Soffietti R, Mehta MP, Weller M, Tonn JC. Contribution of PET imaging to radiotherapy planning and monitoring in glioma patients - a report of the PET/RANO group. Neuro Oncol. 2021;23:881-893.
33. Chandekar KR, Prashanth A, Vinjamuri S, Kumar R. FAPI PET/CT imaging-an updated review. Diagnostics (Basel). 2023;13:2018.
34. Hua T, Huang Q, Zhou Z, Zhou W, Wen J, Xie F, Li M, Guan Y, Zhuang D. Fibroblast activation protein expression in the tumor microenvironment is crucial in survival prediction and differentiation of recurrent gliomas: a head-to-head comparison of ^{68}Ga-FAPI-04 and ^{18}F-FET in PET/CT imaging. EJNMMI Radiopharm Chem. 2025;10:57.