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High-contrast somatostatin receptor imaging of meningiomas with [¹⁸F]SiTATE PET/CT

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Short Report

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Abstract

Purpose

Somatostatin receptor (SSTR)–targeted PET imaging is increasingly used in the management of meningiomas. While gallium-68–labeled tracers are widely used, fluorine-18–labeled compounds may offer logistical and imaging advantages. We evaluated the feasibility and imaging characteristics of the novel SSTR ligand [^{18}F]SiTATE PET/CT in patients with suspected or known meningioma.

Methods

Thirty-seven consecutive patients undergoing [^{18}F]SiTATE PET/CT for suspected or known meningioma were retrospectively analyzed. Lesion detectability, tracer uptake, and tumor-to-background contrast were assessed. Semiquantitative parameters including SUVmax, SUVpeak, somatostatin receptor–expressing tumor volume (SRETV), and total lesion somatostatin receptor expression (TLSRE) were calculated. PET findings were verified by histopathology when available and otherwise by MRI follow-up as part of a composite reference standard.

Results

Focal tracer uptake consistent with meningioma was observed in 32/37 examinations (86.5%), identifying 69 lesions in total. Meningiomas demonstrated intense uptake (SUVmax 20.44 ± 14.54; SUVpeak 12.10 ± 8.04), significantly higher than non-meningioma lesions and reference tissues (all $p < 0.01$ except pituitary gland). Physiological uptake in normal brain parenchyma was minimal (SUVmax 0.11 ± 0.06), resulting in excellent tumor-to-background contrast. Mean SRETV and TLSRE were 9.81 ± 13.64 mm^3 and 98.10 ± 198.70 g/mL × cm^3, respectively. No tracer-related adverse events occurred.

Conclusion

In this retrospective cohort, [^{18}F]SiTATE PET/CT enabled high-contrast visualization of meningiomas with intense tumor uptake and minimal background activity. These findings support the feasibility of [^{18}F]SiTATE as an ^{18}F-labeled SSTR tracer for meningioma imaging and justify prospective comparative evaluation.

Introduction

Meningiomas are the most common primary intracranial tumors in adults and exhibit highly variable growth behavior and recurrence risk [1]. Accurate imaging is essential for diagnosis, treatment selection, surgical planning, and radiotherapy target definition. Magnetic resonance imaging (MRI) remains the standard imaging modality for meningioma evaluation but may be limited in anatomically complex

locations such as the skull base, in tumors with extensive osseous involvement, or after therapy, where treatment-related changes may complicate interpretation [2, 3].

Most meningiomas strongly express somatostatin receptor subtype 2 (SSTR2), which enables targeted molecular imaging with radiolabeled somatostatin analogues. PET imaging with gallium-68–labeled SSTR ligands, particularly [^{68}Ga]Ga-DOTATATE and [^{68}Ga]Ga-DOTATOC, has shown high sensitivity for meningioma detection and is increasingly integrated into clinical practice [2–6].

Fluorine-18–labeled SSTR tracers may offer practical advantages over ^{68}Ga-labeled compounds, including a longer physical half-life, larger-scale production, and potentially improved image resolution related to the lower positron energy of fluorine-18 [7]. [^{18}F]SiTATE ([^{18}F]SiFAlin-TATE) is a novel fluorine-18-labeled SSTR2 ligand with encouraging initial results in patients with neuroendocrine tumors and, more recently, in meningioma imaging [7–11]. The aim of the present study was to assess the clinical feasibility and imaging characteristics of [^{18}F]SiTATE PET/CT in a consecutive cohort of patients with suspected or known meningioma.

Materials and Methods

Patients

This retrospective study included 37 consecutive patients who underwent [^{18}F]SiTATE PET/CT for evaluation of suspected or known meningioma. Clinical indications comprised suspected meningioma/unclear lesion (n = 5), histologically confirmed untreated meningioma (n = 2), radiotherapy planning for primary tumor or postoperative residual disease (n = 22), and suspected recurrence after surgery and/or radiotherapy (n = 8). Patients with optic nerve sheath meningioma were excluded. Histopathology was available in 29/37 patients (78.4%). For lesions without histological verification, MRI follow-up served as part of a composite reference standard, in line with previous recommendations for meningioma imaging studies [12]. At least one follow-up MRI examination was available in all patients. The retrospective study was approved by the Cypriot National Bioethics Committee (ΕΕΒΚ ΕΠ 2026.01.159) and was conducted in accordance with the Declaration of Helsinki.

PET/CT acquisition

Patients received intravenous [^{18}F]SiTATE (2.22 MBq/kg body weight). PET acquisition was performed 45–60 min after injection using a GE Discovery IQ PET/CT system with a 10-min acquisition time. A low-dose CT was acquired for attenuation correction and anatomical co-registration. The PET/CT system was accredited according to EARL Standards, including Brain PET/CT accreditation.

Image analysis

Images were interpreted in consensus by two experienced nuclear medicine physicians with correlation to MRI and the clinical record. Focal tracer uptake above adjacent background activity, in a pattern and anatomical location compatible with meningioma, was considered suggestive of disease. Semiquantitative analysis was performed using volumes of interest placed over lesions and reference tissues, including healthy brain parenchyma, dura mater, pituitary gland, parotid gland, and nasal mucosa. SUVmean, SUVmax, and SUVpeak were recorded. Lesions were delineated using a 40% isocontour, manually adjusted when needed. Volumetric parameters including somatostatin receptor-expressing tumor volume (SRETV) and total lesion somatostatin receptor expression (TLSRE = SUVmean × SRETV) [13] were calculated.

Statistical analysis

Continuous variables are reported as mean ± standard deviation. Group comparisons were performed using the Wilcoxon rank-sum test. A two-sided p-value < 0.05 was considered statistically significant. Because several patients had more than one lesion, lesion-level analyses should be interpreted descriptively.

Results

Patient cohort

The cohort included 37 patients (10 men, 27 women) with a mean age of 60.5 ± 11.7 years. Histopathological confirmation of meningioma was available in 29 patients (78.4%). Among these, 24 tumors were CNS WHO grade 1, two were grade 2, and three were grade 3 (Table 1).

Table 1
Patient characteristics.

Parameters	
Patients (*n* = 37)	
Age	60.5 ± 11.7 years
Sex	
Male	10
Female	27
Indications for PET/CT	
Initial diagnosis of meningioma	2
Suspected meningioma/unclear lesion	5
Suspected recurrence after therapy	8
Radiotherapy planning of primary tumor at initial diagnosis or of remnant after surgery	22
Histology available	29/37 (78.4%)
CNS WHO grade 1 meningioma	24
CNS WHO grade 2 meningioma	2
CNS WHO grade 3 meningioma	3
Administered [^{18}F]SiTATE activity, MBq	159 ± 41

PET/CT examinations

All 37 [^{18}F]SiTATE PET/CT examinations were evaluable. The mean administered activity was 163 ± 43 MBq. No tracer-related adverse events occurred. The estimated mean radiation exposure from PET/CT was 2.45 ± 0.65 mSv.

PET/CT data analysis

Focal tracer uptake consistent with meningioma was detected in 32/37 PET/CT scans (86.5%). In total, 69 lesions suggestive of meningioma were identified (median, 1 lesion per patient; range, 0–9). According to the composite reference standard, all PET-positive findings were classified as true positive, whereas the five PET-negative examinations (13.5%) were considered true negative on follow-up imaging.

Meningioma lesions demonstrated intense tracer uptake with mean SUVmax and SUVpeak values of 20.44 ± 14.54 of 12.10 ± 8.04, respectively. Mean SRETV was 9.81 ± 13.64 mm^3 and mean TLSRE was 98.10 ± 198.70 g/mL × cm^3. Tracer uptake in meningiomas was significantly higher than in non-meningioma lesions (SUVmax 3.62 ± 1.74; SUVpeak 2.54 ± 1.37; $p < 0.01$). Physiological uptake was lowest in healthy brain parenchyma (SUVmax 0.11 ± 0.06), followed by dura mater, parotid gland, and nasal mucosa, whereas the highest physiological uptake was observed in the pituitary gland (Table 2).

Table 2

[^{18}F]SiTATE uptake (mean ±SD) in meningioma lesions, non-meningioma lesions, and reference organs. The level of statistical significance refers to comparisons between meningioma-indicative lesions and all other evaluated sites and tissues.

Meningioma	**SUVmean**	**p**	**SUVmax**	**p**	**SUVpeak**	**p**
	10.92 ± 6.20	**-**	**20.44 ± 14.54**	**-**	**12.10 ± 8.04**	**-**
Non-meningioma sites	2.30 ± 1.50	0.007*	3.62 ± 1.74	0.007*	2.54 ± 1.37	0.01*
Healthy brain	0.06 ± 0.03	< 0.001*	0.11 ± 0.06	< 0.001*	0.05 ± 0.02	0.002*
Dura mater	1.08 ± 0.49	< 0.001*	1.88 ± 0.87	< 0.001*	1.17 ± 0.46	< 0.001*
Parotid gland	1.59 ± 0.46	< 0.001*	2.39 ± 0.68	< 0.001*	1.98 ± 0.60	< 0.001*
Nasal mucosa	1.95 ± 0.48	< 0.001*	3.15 ± 0.92	< 0.001*	2.62 ± 0.72	< 0.001*
Pituitary gland	14.01 ± 4.58	0.01*	23.19 ± 7.09	0.077	9.69 ± 2.91	0.399

Discussion

This retrospective study demonstrates that [^{18}F]SiTATE PET/CT enables high-contrast visualization of meningiomas, with intense lesion uptake and very low background activity in normal brain tissue. These findings support the feasibility of [^{18}F]SiTATE as an SSTR-targeted tracer for meningioma imaging.

Our results are consistent with the first larger clinical study of [^{18}F]SiTATE PET/CT in meningioma patients reported by Unterrainer et al. [9], which also demonstrated high uptake in meningiomas and minimal physiological uptake in normal brain parenchyma. In the present cohort, meningioma uptake was clearly higher than uptake in non-meningioma lesions and reference tissues, resulting in excellent tumor-to-background contrast and favorable lesion conspicuity.

The very low physiological uptake in healthy brain parenchyma and dura mater is particularly relevant for lesion detection and delineation in anatomically complex regions, including the skull base. This feature

may be clinically useful for radiotherapy planning, where accurate target definition is essential. At the same time, the relatively high physiological uptake observed in the pituitary gland should be considered when interpreting lesions in the sellar or parasellar region.

Compared with [^{68}Ga]-labeled SSTR radiopharmaceuticals currently used in clinical practice, [^{18}F]-labeled tracers may offer practical and technical advantages, including a longer half-life, larger batch production, and potentially improved spatial resolution. These characteristics may facilitate centralized production and wider clinical availability. Although a head-to-head comparison with [^{68}Ga]-labeled tracers was not performed in the present study, previous comparative data in a small patient cohort suggest similar tumor uptake with lower radiation exposure for [^{18}F]SiTATE [9].

Several limitations should be acknowledged. This was a retrospective single-center study with a modest sample size and without direct comparison to [^{68}Ga]-labeled SSTR tracers. Furthermore, not all lesions had histopathological confirmation, and the composite reference standard incorporated imaging follow-up. Finally, lesion-level analyses were descriptive and were not adjusted for intra-patient clustering.

In conclusion, [^{18}F]SiTATE PET/CT provided high-contrast imaging of meningiomas in this consecutive cohort, with intense tumor uptake and minimal brain background. These data support further prospective and comparative evaluation of [^{18}F]SiTATE in meningioma imaging and treatment planning.

Declarations

Authors' contributions: All authors made substantial contributions to the conception and design of the work and interpretation of data.

Material preparation and data collection were performed by KK, KKy, GA, AF and MRP.

Data analyses were performed by CS, PH, IT and AV.

Conceptualization and Methodology: CS and AV.

Formal analysis and investigation: CS, PH and AV.

Writing - original draft preparation: CS and AV.

Writing - review and editing: all authors.

Supervision: AV.

All authors read and approved the final manuscript.

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Competing interests: There are no competing financial interests in relation to the work described. Christos Sachpekidis is an associate editor in this journal.

Data availability: The datasets generated during and/or analysed during the current study are available from the corresponding author on reasonable request.

Ethical approval: All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Consent to participate: Informed consent was obtained from all participants enrolled in the study.

Consent to publish: Consent to publish has been received from all participants.

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Figures

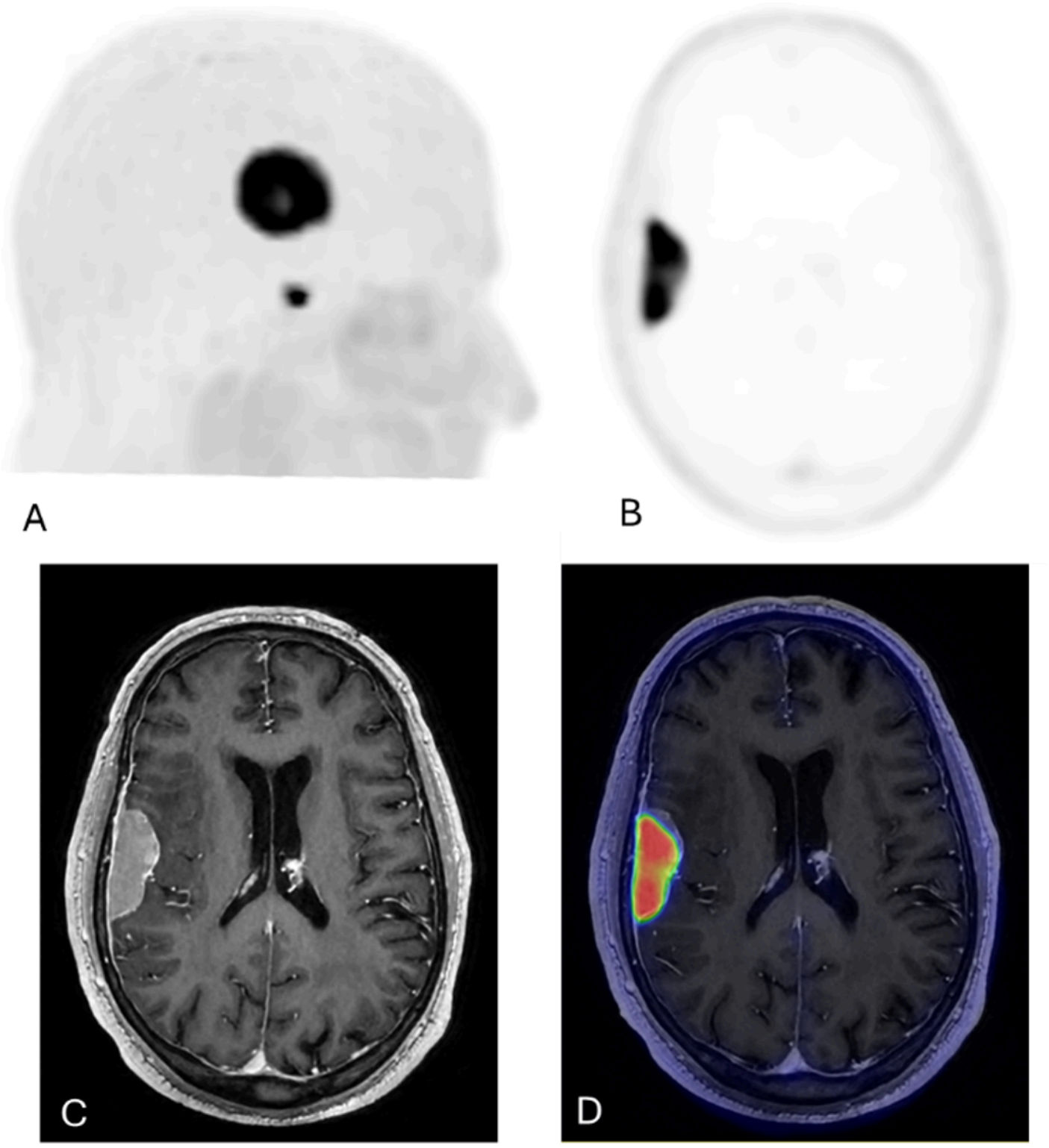


Figure 1

Representative [¹⁸F]SiTATE PET/CT images of a patient with a tracer-avid meningioma in the right parietal lobe, demonstrating intense radiotracer uptake within the lesion and minimal background activity in the normal brain parenchyma. (A) Maximum intensity projection (MIP) image. (B) Axial PET image showing focal intense [¹⁸F]SiTATE uptake in the right parietal lesion. (C) Axial contrast-enhanced T1-weighted MRI obtained 8 days prior to PET imaging, demonstrating the corresponding meningioma. (D) Fused axial PET/MRI image (contrast-enhanced T1-weighted MRI) showing concordant radiotracer uptake and anatomical localization of the lesion.

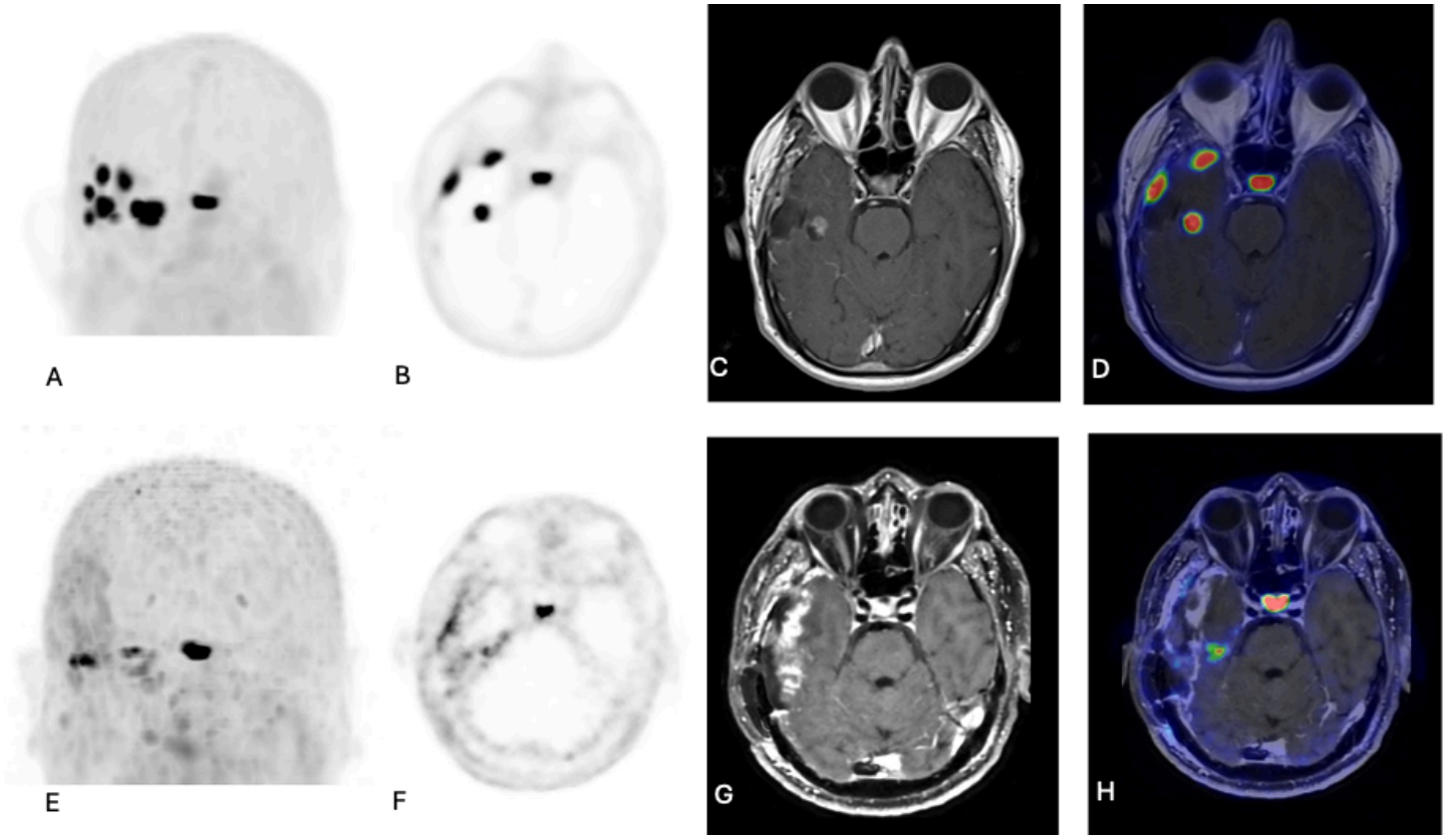


Figure 2

Representative [¹⁸F]SiTATE PET/CT images of a patient with recurrent meningioma before treatment (upper row) and after radiotherapy and surgical resection (lower row). (A) Maximum intensity projection (MIP) image of the pre-treatment PET scan demonstrating multiple [¹⁸F]SiTATE-avid meningioma lesions. (B) Axial PET image obtained before treatment. (C) Axial contrast-enhanced T1-weighted MRI. (D) Axial fused PET/MRI image (contrast-enhanced T1-weighted MRI) demonstrating concordant tracer uptake and anatomical localization of the lesions before treatment. (E) MIP image of the post-treatment PET scan demonstrating partial remission of the meningioma lesions. (F) Axial PET image obtained after treatment. (G) Axial contrast-enhanced T1-weighted MRI. (H) Axial fused PET/MRI image (contrast-enhanced T1-weighted MRI) demonstrating residual tracer-avid disease after treatment. Physiological intense tracer uptake is also observed in the pituitary gland. MRI examinations were performed within 14 days of PET imaging.