A new diagnostic marker for differentiating multicentric gliomas from multiple intracranial diffuse large B-cell lymphomas on $^{18}$F-FDG PET images

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Abstract

Intracranial gliomas and lymphomas may share similar radiological manifestations, while the treatment strategies for them are different. The aim of the study was to investigate the diagnostic value of fluorine-18-fluoro-2-deoxy-D-glucose ($^{18}$F-FDG) positron emission computed tomography (PET) for differentiation of multicentric gliomas and intracranial multiple diffuse large B-cell lymphomas (DLBCLs) as a study of diagnostic accuracy.

A total of 32 patients with multiple intracranial tumors visualized on contrast-enhanced magnetic resonance imaging (MRI) were retrospectively evaluated. Histopathological findings confirmed multicentric gliomas and multiple DLBCLs in 17 and 15 patients, respectively. All patients underwent $^{18}$F-FDG PET with or without $^{11}$C-methionine PET. Maximum standardized uptake values (SUV$_{max}$) and tumor-to-normal tissue (T/N) ratios were compared between the 2 tumors. The diagnostic value of $^{18}$F-FDG PET for differentiating multicentric gliomas from multiple DLBCLs was evaluated by receiver operating characteristic (ROC) analysis.

The SUV$_{max}$ of multiple DLBCLs was significantly higher than that of multicentric gliomas ($P<.001$). However, the percentage of maximum difference-value of SUV$_{max}$ (or T/N ratio) of multiple DLBCLs was significantly lower than that of multicentric gliomas ($P<.001$). The ROC curve demonstrated that the percentage of maximum difference-value of SUV$_{max}$ (or T/N ratio) on $^{18}$F-FDG PET images could effectively differentiate multicentric gliomas from multiple DLBCLs, with a cut-off value of 44.4%, sensitivity of 64.7%, and specificity of 100% ($P<.001$).

Percentage of maximum difference-value of SUV$_{max}$ (or T/N ratio) on $^{18}$F-FDG PET images might be a potential indicator for distinguishing multicentric gliomas from intracranial multiple DLBCLs, which might help determine the treatment strategy.

Keywords: $^{18}$F-FDG, differentiation, glioma, lymphoma, PET

1. Introduction

High-grade gliomas, including anaplastic gliomas and glioblastomas, primary central nervous system lymphomas (PCNSLs), and metastases are common malignant brain tumors in adults. These tumors may exhibit similar appearances on magnetic resonance (MR) imaging, which makes differential diagnosis challenging.[1,2] Although the standard treatment for patients with high-grade gliomas is maximal resection followed by radiation therapy and chemotherapy, in certain cases—for example in PCNSL—biopsy with the least invasive approach is recommended.[3,4] Therefore, accurate diagnosis is crucial because the treatment approach and prognoses of these tumors vary substantially.

As it is sometimes difficult to distinguish these tumors by MRI, fluorine-18-fluoro-2-deoxy-D-glucose ($^{18}$F-FDG) or $^{11}$C-methionine ($^{11}$C-MET) positron emission computed tomography (PET) has been used to acquire additional information to assist differential diagnosis.[5] In brain metastases, whole-body $^{18}$F-FDG PET might reveal the systemic site of the primary malignant lesion.[6] Consequently, it is often necessary to distinguish high-grade gliomas from lymphomas, especially diffuse large B-cell lymphomas (DLBCLs), in clinical practice. Previous studies have demonstrated that maximum standardized uptake value
PET images are appropriate for distinguishing DLBCLs from glioblastomas and other malignant brain tumors.\textsuperscript{[15,7]} In addition, \( \Delta \text{SUV}_{\text{max}} \) on \(^{11}\text{C}-\text{MET} \) PET images could be potentially useful for differential diagnosis of intracranial DLBCL and glioblastoma.\textsuperscript{[5]}

Patients with brain tumors of glial origin often exhibit 2 or more brain lesions. Multicentric gliomas are widely separated lesions located in different lobes, which do not grow through dissemination along an established route. The most common pathologic type of PCNSL is DLBCL, which usually originates deep within the cerebral hemisphere. However, intracranial lymphomas could also present as multiple lesions separated from each other.\textsuperscript{[18]} The similarities in conventional MRI features, including obvious edema, mass effect, and marked contrast enhancement, render differential diagnosis of multicentric gliomas and multiple DLBCLs challenging. \(^{18}\text{F}-\text{FDG} \) and \(^{11}\text{C}-\text{MET} \) are commonly used radiotracers that could help acquire additional information and improve the diagnostic accuracy of PET for distinguishing between these 2 tumors.\textsuperscript{[9]} Although some previously reported indicators, such as SUV\textsubscript{max} and T/N ratio, have been shown to be effective in differentiating solitary gliomas and lymphomas,\textsuperscript{[15–17]} the diagnostic value of \(^{18}\text{F}-\text{FDG} \) PET for distinguishing multicentric gliomas from multiple DLBCLs has not been well evaluated.

In the present study, we aimed to investigate the value of \(^{18}\text{F}-\text{FDG} \) PET in differential diagnosis of multicentric gliomas and multiple DLBCLs and to establish a new and alternative PET marker for discriminating of these 2 malignant tumors, which might aid therapeutic decision making.

2. Methods

2.1. Participants

Fifth-three patients initially diagnosed with multiple intracranial tumors at our department between July 2014 and September 2016 were retrospectively enrolled. Patients were included if they met the following criteria: multiple intracranial tumors—supratentorial, infratentorial, or both, confirmed by contrast-enhanced T1-weighted MRI; histopathological diagnosis of multicentric gliomas or DLBCLs by neurosurgery or stereotactic biopsy according to the World Health Organization grading system for central nervous system tumors;\textsuperscript{[11]} and presurgical \(^{18}\text{F}-\text{FDG} \) PET data, with or without \(^{11}\text{C}-\text{MET} \) PET, available for analysis. Patients were excluded if they had previously undergone neurosurgical resection or received radiotherapy or chemotherapy or exhibited blood sugar levels >150 mg/dL at the time of \(^{18}\text{F}-\text{FDG} \) or \(^{11}\text{C}-\text{MET} \) PET. The study has been approved by the institutional review board of Beijing Tiantan Hospital, and the need for written informed consent was waived due to the retrospective nature of the present study.

2.2. PET protocol

\(^{18}\text{F}-\text{FDG} \) and \(^{11}\text{C}-\text{MET} \) PET images were acquired using a PET/CT scanner (Elite Discovery; GE Health Care, Fairfield, Connecticut), with a 5 mm axial resolution and 4 mm full-width half-maximum at the center of the field of view. Imaging data were reconstructed into 30 transaxial planes with 5 mm slice thickness and 256 \( \times \) 256 image matrix.

All patients underwent \(^{18}\text{F}-\text{FDG} \) or \(^{11}\text{C}-\text{MET} \) PET according to the same protocol. \(^{18}\text{F}-\text{FDG} \) was intravenously injected at a dose of 3.7 MBq/kg, and whole-brain image acquisition was started 60 minutes later. For \(^{11}\text{C}-\text{MET} \) PET, 555 to 740 MBq of \(^{11}\text{C}-\text{MET} \) was intravenously injected, and whole-brain imaging was started 10 minutes later. Subjects were positioned supine and instructed to remain absolutely quiet throughout the scanning procedure. Scanning times for both \(^{18}\text{F}-\text{FDG} \) and \(^{11}\text{C}-\text{MET} \) PET were maintained between 8 and 10 minutes.

The time interval between \(^{18}\text{F}-\text{FDG} \) and \(^{11}\text{C}-\text{MET} \) PET was at least 24 hours but less than a week. Patients were not administered any intervention between the 2 imaging sessions.

2.3. Analysis of PET images

Regional uptakes of \(^{18}\text{F}-\text{FDG} \) and \(^{11}\text{C}-\text{MET} \) were expressed as SUV\textsubscript{max}, calculated according to the following equation: \( [\text{tissue activity (Bq/mL)} \times (\text{body weight, g})] / [\text{injected radioisotope activity (Bq)}] \).\textsuperscript{[7]} The SUV\textsubscript{max} of a tumor was sampled from a single pixel exhibiting the highest \(^{18}\text{F}-\text{FDG} \) or \(^{11}\text{C}-\text{MET} \) accumulation. The T/N ratio of \(^{18}\text{F}-\text{FDG} \) PET images was defined as the ratio of SUV\textsubscript{max} of the lesion to the contralateral normal white matter. The T/N ratio of \(^{11}\text{C}-\text{MET} \) PET images was defined as the ratio of SUV\textsubscript{max} of the lesion to the contralateral normal gray matter. For lesions located along the midline, such as the thalamus or brain stem, the average value of SUV\textsubscript{max} of both sides of the gray (or white) matter was considered.

As all included patients exhibited multiple lesions in the brain, the following uptake features for \(^{18}\text{F}-\text{FDG} \) and \(^{11}\text{C}-\text{MET} \) in multicentric gliomas and multiple DLBCLs were evaluated. To be specific, the highest SUV\textsubscript{max} among all lesions in multicentric gliomas (or multiple DLBCLs) was considered as the actual SUV\textsubscript{max}. The maximum difference-value (D-value) of SUV\textsubscript{max} among lesions in multicentric gliomas (or multiple DLBCLs) was calculated as the difference between the highest SUV\textsubscript{max} and the corresponding lowest SUV\textsubscript{max} among the tumors. A similar analysis method was applied for T/N ratios. The T/N ratio\textsubscript{max} was defined as the ratio of the highest SUV\textsubscript{max} to the SUV\textsubscript{max} of the contralateral white (or gray) matter in \(^{18}\text{F}-\text{FDG} \) (or \(^{11}\text{C}-\text{MET} \) PET) images. The maximum D-value of T/N ratio among lesions in multicentric gliomas (or multiple DLBCLs) was calculated as the difference between the highest T/N ratio and the corresponding lowest T/N ratio among the lesions. The percentage of maximum D-value of SUV\textsubscript{max} among lesions in multicentric gliomas (or multiple DLBCLs) for each patient was calculated as follows:

\[
\text{Maximum D-value of SUV}_{\text{max}} = \frac{\text{highest SUV}_{\text{max}} - \text{lowest SUV}_{\text{max}}}{\text{highest SUV}_{\text{max}}} \times 100\%
\]

The percentage of maximum D-value of T/N ratio among lesions in multicentric gliomas (or multiple DLBCLs) was calculated according to the same formula. The uptake features mentioned above were assessed by 2 experienced nuclear medicine physicians (XBZ and QC, who have 8 and 10 years of experience, respectively) blinded to the patient clinical information.

2.4. Statistical analysis

All statistical analyses were performed using the SPSS Window version 16.0 (IBM, Armonk, NY) and Prism version 6.0 software (GraphPad Software, San Diego, CA). Patient age, SUV\textsubscript{max} maximum D-value of SUV\textsubscript{max} T/N ratio\textsubscript{max}, maximum D-value of T/N ratio, and percentages of maximum D-values of SUV\textsubscript{max}
The mean age of patients with multicentric gliomas was lower than that of patients with multiple DLBCLs; however, the difference was not statistically significant (P=.21). The gender ratio between the 2 groups did not exhibit a significant difference either (P=.94).

The SUVmax of 18F-FDG in patients with multiple DLBCLs (26.2±10.5) was significantly higher than that in patients with multicentric gliomas (16.1±10.0; P=.009). The difference in T/N ratio of 18F-FDG between multicentric gliomas and multiple DLBCLs was not significant (5.8±2.9 vs 8.3±4.0; P=.06). There were no statistically significant differences in maximum D-values of SUVmax or T/N ratio of 18F-FDG between the 2 groups (P=.39 and P=.18, respectively). Notably, the percentage of maximum D-value of SUVmax (and T/N ratio) of 18F-FDG in multicentric gliomas was significantly higher than that in multiple DLBCLs (45.8±12.0% vs 22.6±12.7%; P=.001; Table 3).

The SUVmax, T/N ratio, maximum D-values of SUVmax and T/N ratio, and percentages of maximum D-values of SUVmax and T/N ratio of 11C-MET in patients with multicentric gliomas were all higher than those in patients with multiple DLBCLs (Table 3).

For 18F-FDG PET data, receiver operating characteristic analysis demonstrated that percentages of maximum D-values of SUVmax and T/N ratio might be suitable markers for differentiating between multicentric gliomas and multiple DLBCLs (Fig. 3). The cut-off value, sensitivity, specificity, and area under the curve of 18F-FDG PET for differential diagnosis between the 2 tumors were 44.4%, 64.7%, 100%, and 0.912, respectively. In other words, patients with multiple intracranial tumors exhibiting percentages of maximum D-values of SUVmax or T/N 18F-FDG PET can be diagnosed with multicentric gliomas with a high degree of certainty. At percentages less than 44.4%, tumors may not be diagnosed as multicentric gliomas; instead, intracranial multiple DLBCL should be considered as a possible diagnosis after excluding metastasis by whole-body PET.
4. Discussion

The present findings demonstrated that \(^{18}\)F-FDG uptake in DLBCL is significantly higher than that in gliomas. Moreover, percentages of maximum D-values of SUV\(_{\text{max}}\) and T/N ratio of \(^{18}\)F-FDG might be useful parameters for differentiating multicentric gliomas from multiple DLBCLs.

As the most widely used radiotracer for central nervous system lesions, \(^{18}\)F-FDG has been employed for detection of brain tumors in clinical practice. \(^{18}\)F-FDG uptake in gliomas is associated with tumor cell density and activity.\[12,13\] Specifically, increased tumor cellularity and decreased extracellular matrix are correlated with increased cell proliferation and glucose accumulation on \(^{18}\)F-FDG PET images. In contrast,

### Table 2
**Clinical characteristics and PET data of patients with multiple diffuse large B-cell lymphomas.**

| Gender | Age, y | Pathologic diagnosis | FDG PET | | Max D-value of SUV\(_{\text{max}}\) (or T/N) (%) | MET PET | | Max D-value of SUV\(_{\text{max}}\) (or T/N) (%) |
|--------|--------|----------------------|---------|--------|---|---------|--------|---|
| M      | 24     | DLBCLs               | Homogeneous | 33.4 | 7.8 | 12.3 | --- | --- |
| F      | 73     | DLBCLs               | Homogeneous | 20.7 | 6.9 | 21.7 | --- | --- |
| M      | 56     | DLBCLs               | Homogeneous | 21.6 | 7.0 | 8.8  | --- | --- |
| M      | 40     | DLBCLs               | Homogeneous | 33.3 | 11.1| 42.6 | --- | --- |
| F      | 66     | DLBCLs               | Homogeneous | 21.3 | 7.3 | 19.2 | --- | --- |
| M      | 72     | DLBCLs               | Homogeneous | 43.8 | 19.9| 18.5 | --- | --- |
| M      | 50     | DLBCLs               | Homogeneous | 30.2 | 7.7 | 41.4 | --- | --- |
| F      | 65     | DLBCLs               | Homogeneous | 43.0 | 9.6 | 20.2 | --- | --- |
| M      | 63     | DLBCLs               | Heterogeneous | 11.7 | 3.2 | 13.7 | Heterogeneous | 2.1 | 1.75 | 14.3 |
| F      | 61     | DLBCLs               | Homogeneous | 29.9 | 8.5 | 3.3  | --- | --- |
| M      | 52     | DLBCLs               | Homogeneous | 16.9 | 5.3 | 9.5  | --- | --- |
| M      | 29     | DLBCLs               | Homogeneous | 24.9 | 9.6 | 43.4 | --- | --- |
| F      | 65     | DLBCLs               | Homogeneous | 21.4 | 5.9 | 27.1 | --- | --- |
| M      | 58     | DLBCLs               | Homogeneous | 33.2 | 10.7| 28.0 | --- | --- |
| F      | 74     | DLBCLs               | Homogeneous | 7.0  | 3.3 | 30.0 | --- | --- |

DLBCLs = diffuse large B-cell lymphomas; D-value = Difference value; FDG = fluorodeoxy-D-glucose; MET = methionine; PET = positron emission computed tomography; SUV = standardized uptake value; T/N = tumor to normal tissue ratio.

Figure 1. Multicentric gliomas. A lesion (white arrow) located at the junction of the right frontal and parietal lobes exhibited higher metabolism on \(^{18}\)F-FDG PET findings than normal gray matter. The lesion exhibited hyperintensity on T2-weighted MR images and obvious inhomogeneous contrast enhancement and restricted diffusion on diffusion-weighted MR images (upper row). Another lesion in the mid-brain (black arrow) exhibited much lower metabolism than the above lesion on \(^{18}\)F-FDG PET findings and similar manifestation on MR images (lower row).
scant cellularity and abundant extracellular matrix in gliomas correspond with decreased cell proliferation and low SUV of 18F-FDG. Therefore, SUV possibly indicates cellularity and tumor grading. Gliomas are generally heterogeneous and can present different histologic features and grades even within the same tumor. Patients with 2 or more gliomas in the brain are generally diagnosed with multiple or multicentric gliomas, which originate from different locations on the unilateral or bilateral cerebral hemisphere. Because of the heterogeneity of origin of gliomas, 18F-FDG accumulation may vary among lesions or even within the same tumor. Therefore, differences in SUVmax as well as T/N ratio are relatively prominent, as 18F-FDG uptake in the gray matter is generally constant.

Although PCNSL was previously regarded as a rare tumor, its incidence has been increasing over the past 2 decades. Histologically, a majority of PCNSLs are DLBCLs. They consist of abundant tumor cells, which present as hyper-intensities on diffusion-weighted images, suggesting high tumor cell density. Homogeneous and intense contrast enhancement is common, as intratumoral necrosis and hemorrhage rarely occur in DLBCL. Previous studies have reported that DLBCLs exhibit high 18F-FDG uptake and can be detected by 18F-FDG PET with relatively high sensitivity. Besides, the mean T/N ratio of 18F-FDG in lymphomas has been shown to be significantly higher than that in high-grade gliomas (2.0 vs 1.6). The higher T/N ratio of 18F-FDG in DLBCLs in comparison with that in gliomas may partially be due to the high cellularity and consumption rate of tumor cells in DLBCLs. In addition to being solitary lesions in the brain, DLBCLs could also present as multiple lesions that could invade various anatomic structures of the brain, including the cerebral lobes, corpus callosum, and ventricles, in which case, some lesions may not be located deep within the cerebral hemisphere and, consequently, may not exhibit as high an 18F-FDG uptake as typical DLBCLs. Although 18F-FDG PET is regarded as a useful tool for diagnosing PCNSL, the overall 18F-FDG accumulation characteristics of multiple lymphomas have not been described well.

Table 3
Comparison of clinical data and positron emission computed tomography characteristics between patients with multicentric gliomas and multiple diffuse large B-cell lymphomas.

|                      | Multicentric glioma (n = 17) | Multiple DLBCLs (n = 15) | P   |
|----------------------|------------------------------|--------------------------|-----|
| Age (y, mean ± SD)   | 49.2 ± 16.6                  | 56.5 ± 15.3              | .21 |
| Gender (male/female) | 10/7                         | 9/6                      | .94 |
| FDG PET (n = 32)     | n = 17                       | n = 15                   |     |
| SUVmax               | 16.1 ± 10.0                  | 26.2 ± 10.5              | .009|
| Maximum D-value of SUVmax | 7.7 ± 6.2               | 6.0 ± 4.3               | .39 |
| T/N ratio max        | 5.8 ± 2.9                    | 8.3 ± 4.0                | .06 |
| Maximum D-value of T/N ratio | 2.8 ± 1.8                  | 1.9 ± 1.5               | .18 |
| Maximum D-value of SUVmax (or T/N ratio) (%) | 45.8 ± 12.0% | 22.6 ± 12.7%       | <.001|
| MET PET (n = 9)      | n = 8                        | n = 1                    |     |
| SUVmax               | 5.4 ± 2.9                    | 2.1                      |     |
| Maximum D-value of SUVmax | 2.5 ± 1.5                 | 0.3                      |     |
| T/N ratio max        | 3.6 ± 0.9                    | 1.75                     |     |
| Maximum D-value of T/N ratio | 1.6 ± 0.6                 | 0.25                     |     |
| Maximum D-value of SUVmax (or T/N ratio) (%) | 44.3 ± 10.5% | 14.3%                   |     |

Data are presented as mean ± standard deviation.

DLBCLs = diffuse Large B-cell lymphomas; D-value = difference value; FDG = fluoro-2-deoxy-D-glucose; MET = methionine; PET = positron emission computed tomography; SD = standard deviation; SUV = standardized uptake value; T/N = tumor to normal tissue.
Several studies have reported 18F-FDG PET as sometimes demonstrating hypo or iso-metabolism in high-grade gliomas or lymphomas, which could be a limitation of this technique. Other radioisotopes, such as 11C-MET, have been proposed to overcome this limitation. High-grade gliomas and PCNSLs exhibit increased 11C-MET uptake and good contrast, which might help locate PCNSLs.

As the MR and 18F-FDG and 11C-MET PET features of multicentric gliomas and multiple DLBCLs might be similar, accurate differentiation of the 2 types of tumors is important for identifying the appropriate therapeutic strategy. In previous studies, the values of all 18F-FDG PET parameters, including SUVmax and T/N ratio, in PCNSLs were found to be significantly higher than those in high-grade gliomas. According to previous findings of receiver operating characteristic analysis, a SUVmax cutoff threshold of 12 (or 15) may be reliable for differentiation of PCNSLs and high-grade gliomas. In addition, several studies have reported the cutoff thresholds of SUVmax for diagnosis of PCNSLs on FDG PET images. However, SUVs of brain tumors may be influenced by various factors, including plasma glucose levels and steroid treatment. In order to eliminate the effects of these confounding factors, previous studies have employed T/N ratio as a diagnostic indicator and have reported its superior accuracy in comparison with that of SUVmax. The mean T/N ratio of 18F-FDG for distinguishing PCNSLs ranges from 2.36 to 2.79. In 11C-MET PET, the rate of 11C-MET uptake—defined as ΔSUVmax (the ratio of SUVmax in the late and early phases of PET)—could enable clinicians to distinguish glioblastomas and DLBCLs.

Although SUVmax and T/N ratio have been demonstrated to be useful for differential diagnosis of PCNSL and glioma, the targeted lesions in previous studies were confined to single tumors. In case of multiple lesions, however, previously established markers for differentiating multicentric gliomas and multiple DLBCLs might not be reliable. In the present study, we focused on a new indicator that could better distinguish these 2 types of multiple tumors. The present findings demonstrated that SUVmax and T/N ratio of 18F-FDG are useful for differentiating multicentric gliomas from multiple DLBCLs, with the former exhibiting better performance than the latter in terms of the area under the curve [0.789 (P = .006) vs 0.706 (P = .04)]. Irrespective of the type of tumor, accumulation of radioisotopes in each lesion was found to vary, which may be attributed to the heterogeneity of lesions, especially in multicentric gliomas; however, the same might also be true for multiple DLBCLs. In order to take greater advantage of the uptake data of each lesion, we compared the maximum D-values of SUVmax and T/N ratio of 18F-FDG between lesions in multicentric gliomas and multiple DLBCLs. However, the diagnostic power of these 2 markers was inadequate for differentiating between the 2 types of tumors, which might possibly be because the absolute maximum D-values of SUVmax and T/N ratio of 18F-FDG might not represent the actual degree of variation in radioisotope uptake among lesions in multicentric gliomas or multiple DLBCLs. Therefore, percentages of maximum D-values of SUVmax and T/N ratio among lesions in multicentric gliomas or multiple DLBCLs were evaluated and found to be more appropriate and accurate for distinguishing these 2 types of tumors than absolute maximum D-values (area under the curve, 0.912; P < .001). These new 18F-FDG PET markers could better reflect the actual degree of variation in radioisotope uptake among lesions in multicentric gliomas or multiple DLBCLs than existing markers. Despite a cut-off value of 44.4% and specificity of 100%, the sensitivity of maximum D-value of SUVmax for diagnosing multicentric gliomas was only 64.7%, which might not be adequate for differential diagnosis. This suggests that the degree of radioisotope uptake varies substantially among lesions in multicentric gliomas, possibly because of their heterogeneity, including differences in histopathologic origin and tumor composition. In comparison, heterogeneity among lesions in multiple DLBCLs was relatively obscure.

Figure 3. Receiver operating characteristic curves of different diagnostic markers for differentiating multicentric gliomas from multiple diffuse large B-cell lymphomas. In comparison with the other 4 diagnostic parameters, percentage of maximum difference-value of maximum standardized uptake value (or tumor to normal ratio) could better distinguish multicentric gliomas from diffuse large B-cell lymphomas (sensitivity and specificity, 64.7% and 100%, respectively).
Previous studies have reported that PET sometimes fails to detect atypical PCNSLs because of low $^{18}$F-FDG or $^{11}$C-MET uptake. $^{10,26,27}$ In the present study, only 1 patient (1/15) with multiple DLBCls did not exhibit typical $^{18}$F-FDG and $^{11}$C-MET uptake; in addition, the SUV$_{max}$ and T/N ratio in this patient were not as high as those among other patients. Although this atypical case was included for data analysis, it had no obvious effect on the present results. Therefore, in $^{18}$F-FDG PET, the percentages of maximum D-values of SUV$_{max}$ and T/N ratio among lesions might actually reflect the biological features of multicentric gliomas and multiple DLBCls and thus exhibit better diagnostic performance than conventional markers such as SUV$_{max}$ and T/N ratio.

There are some limitations to the present study. First, we retrospectively enrolled a limited number of patients from a single institution. Second, not all patients included in the present study underwent both $^{18}$F-FDG and $^{11}$C-MET PET. The diagnostic values of the new markers established in our study need to be validated in future prospective studies.

5. Conclusion

The percentage of maximum D-values of SUV$_{max}$ and T/N ratio on $^{18}$F-FDG PET images might reflect the actual degree of variation among lesions in multicentric gliomas and multiple DLBCls. These markers could potentially be used for further differentiation of these 2 tumors.

Acknowledgment

We would like to thank Dr Y.Z. Zhang for the efforts of radiopharmaceuticals synthesis, and Dr X.J. Ru for the assistance in the statistical work.

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