Diagnostic Performance of Perfusion MRI in Differentiating Low-Grade and High-Grade Gliomas: Advanced MRI in Glioma, A Siriraj Project

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Background: *To determine the usefulness of the perfusion MRI technique at Siriraj Hospital for differentiating between high- and low-grade gliomas by using pathological results as the gold standard.*
Material and Method: *The authors prospectively investigated 64 consecutive patients who were suspected as cerebral glioma from prior conventional imaging. Cerebral perfusion study was achieved during the first pass of a bolus of gadolinium-based contrast agent. All post-processing MRI images were interpreted by two board-certified neuroradiologists (more than 10-year-experience), one radiology resident and one well-trained technician, who separately performed and blinded from the pathological results.*
Results: *Forty-four patients diagnosed as glioma were included in this study. There were 26 cases of high-grade and 18 cases of low-grade gliomas. The cerebral blood volume and flow and its ratios had a strong association with the grade of glioma. The areas under the ROC curve for CBV, CBV ratio (rCBV), CBF, and CBF ratio (rCBF) are 0.778, 0.769, 0.769, and 0.772, respectively. On the basis of equal misclassification rates, a cutoff value of 6.15 for CBV (sensitivity, 81.5%; specificity, 64.7%), a cutoff value of 2.38 for the rCBV (sensitivity, 88.9%; specificity, 64.7%), a cutoff value of 0.66 for CBF (sensitivity 81.5%; specificity 70.6%), and a cutoff value of 2.6 for the rCBF (sensitivity, 85.2%; specificity, 70.6%) best discriminated the high and low-grade gliomas.*
Conclusion: *Preoperative radiologic grading of gliomas based on conventional MR imaging is sometimes unreliable. The cerebral perfusion measurements can significantly improve the sensitivity and predictive values of radiologic glioma grading. The rCBV measurement is the best parameter for tumor grading due to the highest sensitivity.*

Keywords: *Perfusion MRI, Cerebral blood volume, Cerebral blood flow, Glioma*

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Glioma is the most common primary intra-axial neoplasm of the brain found in adults. The unpublished data collected from Division of Neurosurgery in Siriraj Hospital between 2002 and 2005 included 133 patients with pathologically proven gliomas. Among them, at least 60 cases were high-grade - anaplastic astrocytoma (AA) and glioblastoma (GBM). According to the data of the Division of Radiation Oncology in Siriraj Hospital between 1997 and 2000, the primary brain tumor cases that underwent cranial irradiation and were pathologically confirmed as glioblastoma and anaplastic astrocytoma equaled to 31% and 7%, respectively. The mean survival rate of malignant gliomas remains poor. The two-year survival rate is less than 10%. In cerebral glioma patients, the therapeutic strategies, treatment response, and prognosis seem to differ considerably due to tumor histologic grade. Consequently, discovering the highest grade portion of the biopsied tumor is an important and challenging issue. Furthermore, because of the tumor heterogeneity, an inaccurate biopsy site or inadequate sample may lead to the erroneous interpretation of tumor grade and consequent inappropriate treatment protocol.

Preoperative radiologic grading of cerebral gliomas is difficult to assess, however it is significant for clinical treatment. Conventional MR imaging with

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gadolinium-based contrast agents is an established and beneficial modality in the characterization of tumors. In spite of the optimization of MR protocols, the categorization and grading of gliomas with conventional MR imaging are sometimes unreliable because the sensitivity for glioma grading has a wide range from 55.1% to 83.3%[2-6]. Kondziolka et al[5] demonstrated a 50% false-positive rate in determining supratentorial gliomas. Likewise, Knopp et al[6] reported almost one-fifth of glioblastoma did not show enhancement after intravenous contrast administration. The main obstacles limit conventional MR imaging techniques to distinguish low-grade from high-grade gliomas. This is because conventional MR images may not represent the most malignant tumor areas, although a greater likelihood for contrast enhancement of high-grade portions are generally perceived. Malignant gliomas are able to infiltrate the brain parenchyma and follow the vascular routes of the white matter tracts. This may not be recognized if no signal intensity abnormality or enhancement occurred on conventional MR images.

The benefit of advanced MR imaging techniques in evaluating cerebral gliomas is the capability to examine not only the whole lesion, but also the adjacent brain tissue. Perfusion MR imaging is composed of many recently developed MR techniques to noninvasively evaluate cerebral perfusion by the assessment of diverse hemodynamic measurements, such as cerebral blood volume (CBV), cerebral blood flow (CBF), and mean transit time (MTT). Copious literatures accentuated the advantage of the relative cerebral blood volume for intra-axial cerebral tumors or strokes. CBV and CBF alteration are well correlated: when CBV increases, CBF also increases, and vice versa.

With the advent of novel medical technology, scientists discovered the pathophysiology of various tumors, including brain tumors. Brain tumors can induce angiogenesis or the formation of new blood vessels. Hypoxia can stimulate angiogenic cytokines (these cytokines are responsible for angiogenesis). Tumor vessels that are produced in this manner are histologically abnormal and more permeable than normal vessels. They are also disorganized and tortuous. These vascular abnormalities and altered flow dynamics lead to changes in blood volume and flow.

Many preceding perfusion MRI literatures varied in terms of threshold values for separating low-grade from high-grade groups. Law M et al[7] demonstrated that conventional MRI had 73% sensitivity, 65% specificity and 44% negative predictive value (NPV) as compared to perfusion MRI which achieved 95% sensitivity, 57% specificity and 79% NPV while using rCBV threshold value of 1.75 for differentiating glioma grading.

In Siriraj Hospital, using perfusion MRI technique to determine gliomas is still not regularly performed because of misapprehension about its technical difficulty and result interpretation. However, perfusion MRI technique is now accessible via both of Siriraj's MRI scanners (1.5T machine at HMM cardiac center and 3T machine at Siriraj Imaging Center). In fact, the perfusion MRI technique is not much complicated with a minute additional scan time. Post-processing software is also practical for neuro-radiologists, radiology residents, and technicians. The dilemma of perfusion MRI technique is only the way to translate the outcome. Many literatures have suggested studying perfusion MRI technique in own institute to find the institute's threshold value for differentiating gliomas grading. The presented study was expected to be a guideline to solve the interpretation problems and encourage the utilization of perfusion MRI technique in Siriraj Hospital. This article was also aimed to augment the understanding of perfusion MRI technique and expand its use particularly in Thailand.

The purpose of the presented study was to determine the usefulness of the perfusion MRI technique at Siriraj Hospital for differentiating between high- and low-grade gliomas. The present study was performed in terms of diagnostic performance by using pathological results as the gold standard. Another purpose was to establish the Siriraj's appropriate protocol for brain tumor MRI, especially gliomas. It would be more effective to apply perfusion MRI technique with conventional MRI. The new protocols for routine medical services in brain tumor cases would be established in terms of pre-treatment strategies and post-treatment MRI examination, according to the results of the presented article.

Material and Method

Study group

Between June 2009 and March 2011, the authors prospectively investigated 64 consecutive patients (33 men and 31 women). They were suspected or diagnosed as brain tumor/glioma from prior imaging such as CT brain and needed MRI brain for surgical planning. All patients underwent standard conventional MRI brain and additional perfusion MRI technique at Siriraj Imaging Center, Siriraj hospital. Patients with

any contraindication for performing MRI (i.e. cardiac pacemaker, intracranial aneurismal clip, foreign body in eyes, hypersensitivity to gadolinium (Gd) contrast agents or contraindication for Gd injection) were excluded. Patients younger than seven years were also excluded from the present study because of low prevalence of glioma in this age group. Twenty cases that had pathologically proven as other cell types such as lymphoma, germinoma, meningioma, cysticercosis or metastatic cancer, were excluded as well. Therefore, only 44 cases subsequently identified as having histopathologically confirmed gliomas, were included in the present study. There were 26 high-grade and 18 low-grade gliomas. Twenty-two cases were men and 22 were women. Patient ages ranged from 12 to 74 years (average age, 45.9 years).

Study approval was acquired from the Siriraj Institutional Review Board (SIRB), and written informed consents were obtained from all patients. Permission and informed consents from parents were taken for patients younger than 18 years. Before imaging, the nurses inserted an 18- or 20-gauge intravenous catheter in the antecubital area for contrast agent administration.

Reference standard

For all cases that underwent operation for suspected or diagnosed glioma, histopathology was used as gold standard. A board-certified pathologist evaluated all tumor masses to determine the pathologic diagnosis. The criteria of the WHO classification of brain tumors are internationally recognized and can be utilized for establishing the diagnosis of gliomas.

Imaging system and sequences

All imaging was performed using the same 3T clinical MR system (Philips Achieva, Best, the Netherlands) with a sense head coil. Conventional MRI studies were regularly accomplished, which composed of non-contrast enhancement axial/sagittal T1-weighted, axial FLAIR, axial/coronal T2-weighted, and GEwi/Swi. Post-contrast enhancement T1-weighted sequence was achieved in three orthogonal planes (routine protocol of conventional MRI). In the authors' institute, these images were performed with 3D-T1-weighted and multiplanar reconstructions (MPR) of three orthogonal planes were processed.

Perfusion MRI

Cerebral perfusion study was achieved during the first pass of a bolus of gadobutrol (Gadovist; Bayer Schering, Berlin, Germany) using a 3D Principles of Echo Shifting with a Train of Observations (PRESTO) sequence, effective TR/TE = 16/24 ms, flip angle = 7°, FOV = 230x187 mm, matrix = 64x52, slice thickness 3.5 mm, sense factor = 1.75. A series of 60 volume acquisitions was acquired at 1.2-s intervals. Ten baseline acquisitions were acquired before contrast injection. Then, gadobutrol was injected by using injector at a rate of about 4-5 mL/sec through an 18- or 20-gauge intravenous catheter and was followed immediately by a 10 mL saline flush. The total scan time of perfusion MRI technique was 1.16 minutes.

Subsequently, post-processing of the acquired MRI studies was performed on an independent workstation (Philips, Extended MR Workspace, version 2.6.3.2, Best, The Netherlands) using proprietary analytic software by well-trained technicians at Siriraj Imaging Center.

Unprocessed dynamic susceptibility contrast (DSC) perfusion images were evaluated and compared with co-registered 3D T1-weighted images to ensure that regions of interest (ROIs) were not placed over blood vessels. Intralesional cerebral blood volume (CBV) measurements were obtained from processed CBV maps by manual ROI placement in areas of highest CBV, taking care to avoid uninvolved adjacent grey matter structures. Normal-appearing white matter ROIs (judged as normal on corresponding T2-weighted, FLAIR, and contrast-enhanced T1-weighted images) were placed in the contralateral hemisphere, and a maximum CBV ratio was then calculated for each tumor using the formula: highest average CBV [lesion]/ highest average CBV [contralateral white matter]. Whenever possible, control white matter ROIs were placed in the mirror image location in the contralateral hemisphere (Fig. 1).

Image analysis

All post-processing MRI images were interpreted by two board-certified neuroradiologists (more than 10-year-experience), one radiology resident and one well-trained technician, who separately performed and blinded from the pathological results. Any discrepancy of the results was concluded by consensus.

Statistical analysis

All statistical analyses were performed using commercially available software (SPSS 18, IBM, United States). The Fisher's exact test was performed in order to test the significance of the difference

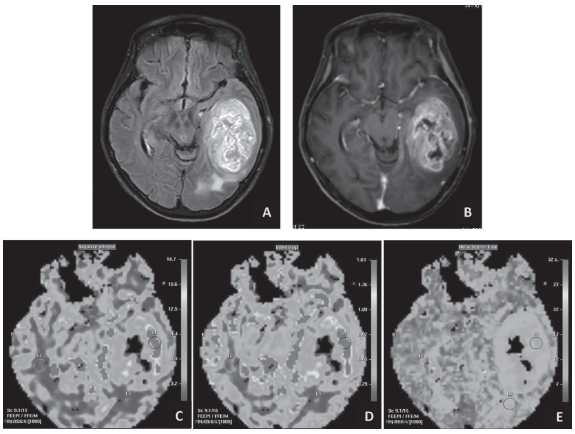

Fig. 1 A 67-year-old woman with glioblastoma at left temporoparietal region.
A, T2-weighted FLAIR image shows peritumoral patchy high signal intensity lesion along subcortical white matter.
B, contrast-enhanced T1-weighted MR image shows irregular strong thick rim enhancement of mass. This lesion has internal cystic portion, could be necrotic part.
C, D and E, on cerebral blood volume (C), cerebral blood flow (D) and mean transit time (E) maps, there are correspondingly high cerebral blood volume and cerebral blood flow values. Note match between perfusion maps (C and D) and contrast-enhanced T1-weighted MR images (B). These perfusion maps show placement of round regions of interest (ROI) for measurement of cerebral blood volume or flow in enhancing tumor portion (L1 appears red on color image) and in contralateral white matter (L2). Note avoid placement of ROI in area of necrosis. Relative cerebral blood volume or flow ratio is cerebral blood volume or flow of tumor divided by that of contralateral white matter. Peritumoral edema is also measured for perfusion by placement of region of interest at area corresponding to peritumoral abnormal high signal intensity on T2-weighted/FLAIR images (L3).

between the peritumoral edema, enhancement pattern and intratumoral hemorrhage in high-grade gliomas and that in low-grade gliomas.

The mean, median and standard deviations of the cerebral blood volume (CBV), cerebral blood flow (CBF) and its ratios (rCBV, rCBF) were computed in each high and low-grade tumors. Receiver operating characteristic (ROC) curve analysis was used to evaluate the intensity of the association between CBV, CBF, rCBV and rCBF and glioma grade. In this instance, the ROC curve was created as follows: the true-positive rate (sensitivity) and the false-positive rate (1-specificity) were paired across all potential cutoff points, permitting discrimination between high and low-grade tumors. In the ROC curve for CBV, CBF, rCBV and rCBF, the size of the area under the ROC curve represented the strength of the association between CBV, CBF, rCBV and rCBF and glioma grade: the closer to 1, the stronger the association; the closer to 0.5, the weaker the association.

Interobserver reliability between radiology resident and technician was also calculated by using intraclass correlation. Diagnostic performance, including sensitivity, specificity, positive predictive value, negative predictive value, accuracy, and likelihood ratio of CBV, CBF, rCBV, and rCBF and parameters of conventional MRI technique were computed. The interobserver reliability and diagnostic performance of both conventional MRI and perfusion MRI techniques in terms of qualitative and quantitative analyses were examined on the basis of pathologic results.

Results

From the 44 patient studies, 26 had high-grade and 18 had low-grade gliomas. Twenty-two cases were men and 22 were women. All patients underwent transcranial tumor resection and received pathologically confirmed grading.

All patients could tolerate the MR protocol without any adverse reaction to contrast agent administration. Magnetic susceptibility artifacts inherent in echoplanar imaging were prominent at bone-air interfaces, such as the petrous temporal bone, skull base, and paranasal sinuses. However, no lesion included in the present study was markedly distorted by these artifacts.

The findings of the conventional MR imaging and cerebral perfusion study from all patients were analyzed. Some findings of conventional MRI showed statistically significant difference between low and high-grade tumors, i.e. peritumoral edema, enhancement pattern and intratumoral hemorrhage with p-value less than 0.05.

All of the low-grade tumors showed no or mild (<50% of lesion size) peritumoral edema, whereas in the high-grade tumors, the edema patterns were diverse from no edema to moderate degree (50-75% of lesion size).

All of the high-grade tumors showed peripheral (8 cases) or heterogeneous (19) enhancement, whereas the low-grade tumors showed various

Table 1. Diagnostic performance of conventional MRI

	Sensitivity	Specificity	Accuracy	NPV	PPV	Positive LR
Edema	37.0%	100.0%	61.4%	50.0%	100.0%	-
Enhancement	100.0%	52.9%	81.8%	100.0%	77.1%	2.12
Hemorrhage	81.5%	52.9%	70.5%	64.3%	73.3%	1.73

MRI = magnetic resonance imaging; NPV = negative predictive value; PPV = positive predictive value; LR = likelihood ratio

characters of enhancement - that is, no enhancement (9), homogeneous (1), peripheral (1) and heterogeneous (6) enhancement.

Diagnostic performance, including sensitivity, specificity, positive predictive value, negative predictive value, accuracy and likelihood ratio of peritumoral edema, enhancement pattern and intratumoral hemorrhage are demonstrated in Table 1.

The authors also collated the data from one radiology resident and one well-trained technician and then calculated the interobserver reliability by using intraclass correlation. The correlation of measured values in enhancement areas in both CBV and CBF were outstanding - the reliabilities of CBV and CBF were 0.967 and 0.854 respectively. This may be described by easily detected enhancement of lesion. On the other hand, the reliabilities of measured values in edematous areas were dissatisfying (0.352 and 0.219 for CBV and CBF, respectively). This pitfall might be explained by misapprehension about the area of peritumoral T2 abnormality. For infiltrative lesion, identifying the tumor margin and peritumoral edema was sometimes arduous.

The CBV in the high-grade gliomas (n = 26) varied from 0.85 to 40.8 with a mean of 16.2±12 (SD), whereas in the low-grade gliomas (n = 18), it varied from 0.51 to 19.6 with a mean of 6.5±5.9. The median of high-grade and low-grade gliomas are 13.5 and 4.95, respectively.

The rCBV in the high-grade gliomas (n = 26) varied from 0.85 to 24 with a mean of 8.9±6.4 (SD), whereas in the low-grade gliomas (n = 18), it varied from 0.25 to 14 with a mean of 3.9±4.1. The median of high-grade and low-grade gliomas are 8.5 and 1.8, respectively.

The CBF in the high-grade gliomas (n = 26) varied from 0.14 to 3.2 with a mean of 1.4±0.87 while in the low-grade gliomas (n = 18), it varied from 0.06 to 2.66 with a mean of 0.7±0.7. The median of high-grade and low-grade gliomas are 1.3 and 0.4, respectively.

The rCBF in the high-grade gliomas (n = 26) varied from 0.7 to 15.0 with a mean of 6.1±4.0, whereas in the low-grade gliomas (n = 18), it varied from 0.3 to 14 with a mean of 3.2±3.5. The median of high-grade and low-grade gliomas are 5.5 and 1.8, respectively.

The cerebral blood volume and flow and its ratios had a strong association with the grade of glioma. The areas under the ROC curve for CBV, rCBV, CBF, and rCBF are 0.778, 0.769, 0.769, and 0.772, respectively (Fig. 2). On the basis of equal misclassification rates, a cutoff value of 6.15 for CBV (sensitivity, 81.5%; specificity, 64.7%), a cutoff value of 2.38 for the rCBV (sensitivity, 88.9%; specificity, 64.7%), a cutoff value of 0.66 for CBF (sensitivity 81.5%; specificity 70.6%) and a cutoff value of 2.6 for the rCBF (sensitivity, 85.2%; specificity, 70.6%) best discriminated the high and low-grade gliomas (Table 2).

Discussion

Precise prospective determination of tumor grade is crucial for planning the optimal treatment approaches for cerebral gliomas. In most histologic grading systems, vascular proliferation is a diagnostic

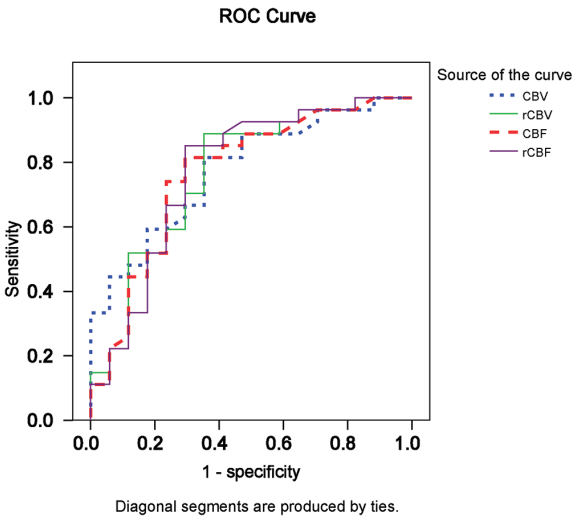

Fig. 2 Receiver operating characteristic curves for CBV, rCBV, CBF and rCBF. Area under curve for CBV, rCBV, CBF and rCBF are 0.778, 0.769, 0.769 and 0.772, respectively.

Table 2. Threshold values for each parameters for differentiation between low and high grade gliomas

	Threshold value	Sensitivity	Specificity	Accuracy	NPV	PPV	Positive LR
CBV	6.15	81.5%	64.7%	75.0%	68.8%	78.6%	2.30
rCBV	2.38	88.9%	64.7%	80.0%	78.6%	80.0%	2.52
CBF	0.66	81.5%	70.6%	77.3%	70.6%	81.5%	2.77
rCBF	2.60	85.2%	70.6%	79.5%	75.0%	82.1%	2.90

NPV = negative predictive value; PPV = positive predictive value; LR = likelihood ratio

criterion for malignancy. The state-of-the-art technology in MR imaging have made it possible to appraise perfusion dynamics alteration in cerebral gliomas, with particular concentrate on rCBV. Knopp et al[6] and Aronen et al[8] exhibited the statistically significant differences in rCBV between high and low-grade gliomas, Knopp et al using gradient echo echoplanar imaging, while Aronen et al using spin echo echoplanar imaging. The rCBV is distinctly correlated to perfusion, and its values can be used to distinguish the grades of gliomas. This reason is based on the fact that angiogenesis, the formation of new blood vessels, is one of the most significant parameters for discriminating the histopathologic grade of gliomas accompanying the degree of cellular or nuclear pleomorphism, and the presence or absence of necrosis. In addition, rCBF can play a role comparable to that of rCBV in the pathologic grading of cerebral gliomas.

The conventional methods of grading gliomas have some limitations. The reference standard of histopathologic grading would be erroneous if the specimens were not biopsied from the most malignant tumor portion. This is a particular dilemma of gliomas since the infiltrative proliferation of the tumor. Precise tumor grading has important implications for treatment planning. Patients with an incorrect diagnosis of high-grade tumor will undergo unnecessary adjuvant treatment, whereas patients with a wrong diagnosis of low-grade tumor will be treated conservatively and more likely to face subsequent concomitant morbidity and mortality.

According to the presented data, rCBV and rCBF were more accurate than CBV and CBF (Table 2), which is 80%, 79.5%, 75%, and 77.3% accuracy for rCBV, rCBF, CBV, and CBF, respectively. This indicated more capability for general utilization of rCBV or rCBF than CBV or CBF.

The outcome of many preceding studies shows that rCBV measurements may improve grading differentiation. Knopp et al[6] exhibited mean rCBV values of 5.07 and 1.44 in high and low-grade tumors, respectively. Aronen et al[8] informed mean rCBV values of 3.64 and 1.11 in high and low-grade tumors, respectively. These previous values are less than the authors' findings, with mean rCBV values of 8.8 and 3.8 for high and low-grade tumors, respectively. This may be explained by a different population, perfusion MRI protocols, MR scanner, and processing software. Lev and Rosen[9] used rCBV threshold value of 1.5 in discriminating among 32 consecutive patients with gliomas. The sensitivity and specificity with use of rCBV of 1.5 as a threshold value were 100% and 69%, respectively. This compares to the authors' results, which is 88.9% sensitivity and 64.7% specificity, by using 2.38 as the threshold value.

The sensitivity of rCBV in the presented article was 88.9%, indicating a high true-positive rate and low false-negative rate. Therefore, if the rCBV is above 2.38, there is a high probability that the tumor will be high-grade. Conversely, when rCBV is below 2.38, the tumor is unlikely to be high-grade. However, the relatively low specificity (64.7%) means that false-positive rates are relatively high and true-negative rates are correspondingly low. In other words, some low-grade tumors will be falsely identified as high-grade. The high NPV (78.6%) is similarly an important finding, as gliomas with low rCBV (<2.38) are unlikely to have high-grade portions. Thus, it is an outstanding tool for excluding the presence of high-grade glioma.

A potential limitation in the presented study is small sample size (n = 44) especially the low-grade group (n = 18). Future studies, including more study subjects and detailed histopathologic correlation of gliomas with the imaging findings, will be necessary to validate these results. Additional studies, such as post-operative MR findings for distinguishing glioma recurrence from posttreatment effects such as radiation necrosis, would be valuable.

The present study demonstrates that cerebral perfusion measurements can enhance preoperative tumor grading. Perfusion MR imaging is beneficial

adjunct to conventional MR imaging in surgical planning. Long-term outcome studies should be required to determine whether cerebral perfusion, other advanced MRI techniques (such as diffusion tensor imaging, and MR spectroscopy), or pathology is the best predictor of patient outcome.

Conclusion

Preoperative radiologic grading of gliomas based on conventional MR imaging is sometimes unreliable. The cerebral perfusion measurements can significantly improve the sensitivity and predictive values of radiologic glioma grading. The rCBV measurement is the best parameter for tumor grading due to the highest sensitivity. This is important for determining the most appropriate treatment protocols and the aggressiveness of post-operative therapy. Perfusion MR imaging can potentially overwhelm the handicap of sampling error because of the ability to sample the entire lesion noninvasively in vivo.

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Potential conflicts of interest

None.

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ความแม่นยำในการวินิจฉัยแยกเนื้องอกสมองชนิด glioma โดยใช้เทคนิคการตรวจเลือดที่หล่อเลี้ยงสมองของการตรวจด้วยคลื่นแม่เหล็กไฟฟ้า

ธันยพร ดิเรกสุนทร, อรสา ชวาลภาฤทธิ์, ตุ้มทิพย์ แสงรุจิ, ธีรพล วิทธิเวช, สิริอร ตริตระการ, ศิริวรรณ ปิยพิทยานันต์, พนิดา ชาญเชาว์วานิช, ประภาพร พรปัญญาวุฒิ, สิทธิ์ สาธรสุเมธี

วัตถุประสงค์: เพื่อศึกษาความแม่นยำในการวินิจฉัยแยกเนื้องอกสมองชนิด glioma โดยใช้เทคนิคการตรวจเลือดที่หล่อเลี้ยงสมองของการตรวจด้วยคลื่นแม่เหล็กไฟฟ้าที่โรงพยาบาลศิริราชโดยใช้ผลการตรวจทางพยาธิเป็นมาตรฐาน

วัสดุและวิธีการ: ได้ทำการศึกษาผู้ป่วยจำนวน 64 ราย ที่มารับการตรวจสมองด้วยคลื่นแม่เหล็กไฟฟ้าด้วยภาวะสงสัยว่ามีก้อนทูมในสมอง และทำการตรวจเพิ่มด้วย MR perfusion ซึ่งเป็นการตรวจภาวะเลือดที่หล่อเลี้ยงสมอง โดยการฉีดสารทึบรังสีที่มีแกดโดลิเนียมเป็นส่วนประกอบ จากนั้นนำข้อมูลมาสร้างภาพและวัดค่า cerebral blood flow และ blood volume ภาพการตรวจคลื่นแม่เหล็กไฟฟ้าที่ได้จะแปลผลโดยรังสีแพทย์ด้านระบบประสาท 2 คน, แพทย์ประจำบ้าน 1 คน และนักรังสีเทคนิค 1 คน โดยแปลผลแยกกัน และไม่ทราบผลทางพยาธิมาก่อน

ผลการศึกษา: จากการศึกษา มีผู้ป่วย 44 ราย ที่ได้รับการวินิจฉัยว่าเป็นเนื้องอกสมองชนิด glioma โดยเป็นชนิด high grade 26 ราย และชนิด low grade 18 ราย ค่า cerebral blood flow และ blood volume มีความสัมพันธ์กับ grading ของเนื้องอกสมองชนิด glioma พื้นที่ใต้กราฟ ROC ของ CBV, CBV ratio (rCBV), CBF และ CBF ratio (rCBF) เท่ากับ 0.778, 0.769, 0.769 และ 0.772 ตามลำดับ ค่าที่ใช้แยกระหว่าง high grade และ low grade ได้ดีที่สุด คือ CBV เท่ากับ 6.15 (ความไว 81.5%; ความจำเพาะ 64.7%), rCBV เท่ากับ 2.38 (ความไว 88.9%; ความจำเพาะ 64.7%), CBF เท่ากับ 0.66 (ความไว 81.5%; ความจำเพาะ 70.6%) และ rCBF เท่ากับ 2.6 (ความไว 85.2%; ความจำเพาะ 70.6%)

สรุป: ภาพทางรังสีก่อนผ่าตัดในการแยกชนิดของเนื้องอกสมอง glioma จากการตรวจด้วยคลื่นแม่เหล็กไฟฟ้า conventional MRI บางครั้งอาจไม่น่าเชื่อถือ การตรวจเลือดที่หล่อเลี้ยงสมองด้วยเทคนิค perfusion MRI ช่วยเพิ่มความไวและค่าพยากรณ์ในการแยกชนิดของเนื้องอกสมอง glioma ค่า rCBV เป็นตัวชี้วัดที่ดีที่สุดเนื่องจากมีความไวสูงที่สุด