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Disproportionate Mass Effect as a Conventional MRI Marker of High-Grade Glioma

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Abstract

Introduction

Tumor size and mass effect are commonly considered together on conventional magnetic resonance imaging (MRI), although they may represent different aspects of glioma behavior. This study compared the association of absolute mass effect, size-normalized mass effect, and estimated tumor volume with histopathological grade.

Methods

This single-center cross-sectional study included 30 adults with histopathologically confirmed gliomas who underwent preoperative MRI. Ellipsoid tumor volume and equivalent tumor diameter were calculated from three orthogonal dimensions. Mass effect was defined as maximum linear displacement of midline structures in millimeters. A mass-effect index (MEI) was defined as mass effect divided by equivalent tumor diameter. The World Health Organization (WHO) grade 2 tumors were categorized as low grade and grades 3-4 as high grade. Group comparisons, grade-wise trends, receiver operating characteristic analysis, logistic regression, and leave-one-out cross-validation were performed.

Results

The cohort included eight grade 2, seven grade 3, and 15 grade 4 tumors. Tumor volume did not differ between low- and high-grade groups (median: 34.9 vs 54.7 cm^3; p = 0.622). High-grade tumors demonstrated greater mass effect (7.54 vs 3.33 mm; p = 0.009) and MEI (0.149 vs 0.075; p = 0.024). Absolute mass effect had the highest observed area under the curve (AUC: 0.821), compared with 0.776 for the index and 0.563 for volume. Its volume-adjusted association was imprecise (OR: 4.32; 95% CI: 0.95-19.75).

Conclusion

Greater absolute and size-normalized mass effect was associated with high-grade histology. Absolute mass effect had the highest observed AUC, but an independent contribution beyond volume was not established. These exploratory findings and thresholds require external validation.

Categories: Radiology, Medical Education, Neurosurgery
Keywords: conventional mri, glioma grading, high grade glioma, mass effect, tumor volume

Introduction

Gliomas are a heterogeneous group of primary central nervous system tumors with considerable variation in biological behavior, treatment response, and prognosis. The fifth edition of the World Health Organization (WHO) Classification of Tumors of the Central Nervous System emphasizes an integrated histomolecular approach and categorizes adult-type diffuse gliomas into astrocytoma, isocitrate dehydrogenase (IDH)-mutant; oligodendroglioma, IDH-mutant and 1p/19q-codeleted; and glioblastoma, IDH-wildtype [1]. Despite the central role of molecular characterization, preoperative estimation of tumor aggressiveness remains clinically important for surgical planning, selection of biopsy targets, patient counseling, and prioritization of treatment.

Conventional magnetic resonance imaging (MRI) is the principal imaging modality for the initial evaluation of gliomas. It provides information regarding tumor location, dimensions, enhancement, hemorrhage, necrosis, edema, contralateral extension, and mass effect [2]. Features such as heterogeneous or rim-like enhancement, necrosis, hemorrhage, extensive edema, and substantial mass effect are traditionally associated with high-grade tumors. Nevertheless, considerable overlap exists: some high-grade gliomas demonstrate limited enhancement or necrosis, while some lower-grade tumors show apparently aggressive characteristics [2,3]. Consequently, qualitative conventional MRI grading has variable diagnostic performance.

Advanced techniques including diffusion-weighted imaging, perfusion imaging, and proton magnetic resonance spectroscopy can improve biological characterization by evaluating cellularity, vascularity, and metabolism [4,5]. However, these methods require additional acquisition, post-processing, expertise, and adequate technical quality. Their availability may be limited in resource-constrained institutions. Carefully assessed conventional MRI features may retain substantial discriminatory value and, in some settings, perform comparably with more complex measurements [3,6].

Tumor size is commonly interpreted as disease burden, but it may not adequately represent the mechanical and biological effects of a glioma on the surrounding brain. Slowly growing or infiltrative tumors may attain considerable volume with relatively little displacement, whereas more aggressive tumors may generate substantial mass effect despite comparable size. Mass effect reflects the combined consequences of expansion, edema, tissue compression, and intracranial compliance. It is an established conventional imaging feature, and previous studies have examined its grading, prognostic, and functional associations [6,7]. The present study focuses on quantitatively comparing displacement with estimated tumor size rather than introducing mass effect itself as a new marker.

A size-normalized assessment may help characterize displacement relative to tumor size using routine conventional MRI. This study therefore evaluated estimated tumor volume, absolute mass effect, and a derived mass-effect index (MEI) across histopathological grades. We hypothesized that high-grade gliomas would demonstrate greater absolute and size-normalized mass effect. We also compared the observed diagnostic discrimination of these measurements with that of volume alone.

Materials And Methods

Study design and setting

This single-center cross-sectional observational study was conducted over a period of one year. Consecutive patients with a radiological diagnosis of glioma underwent conventional and multiparametric MRI before surgical resection or biopsy. Histopathological examination was the reference standard. The study was conducted after Institutional Ethics Committee approval (Ref. 262/Cert./IEC/UPUMS/2025-26 dated March 30, 2026). Written informed consent was obtained from all participants.

Patient selection

Adult patients with a presumptive diagnosis of glioma on computed tomography or conventional MRI were eligible. Inclusion required completion of the prescribed MRI protocol, technically adequate images, and histopathological confirmation. Exclusion criteria were previous tumor-directed treatment before the index MRI; final nonglial or nonneoplastic diagnosis; active intracranial infection; contraindication to MRI or gadolinium; or artifacts preventing reliable interpretation.

MRI acquisition

MRI was performed using a 1.5-T SIGNA Explorer system (GE Healthcare, Milwaukee, Wisconsin, United States) with a 16-channel neurovascular array coil. Sequences included axial T1-weighted, T2-weighted, and T2-fluid-attenuated inversion recovery imaging; sagittal and coronal T2-weighted imaging; susceptibility-weighted imaging; three-dimensional brain volume imaging; diffusion-weighted imaging with apparent diffusion coefficient mapping; and postcontrast fat-suppressed T1-weighted imaging.

Clinical and conventional MRI assessment

Demographic and clinical variables included age, sex, symptom duration, headache, seizure, hemiparesis, and altered sensorium. MRI was assessed for location, three orthogonal dimensions, hemorrhage, calcification, necrosis, edema, enhancement, contralateral extension, multiplicity, and mass effect. Definite and rim-like enhancement were combined as positive enhancement. Moderate and gross edema were combined for inferential analysis. For this analysis, mass effect was operationally defined as the maximum linear displacement of midline structures in millimeters; it did not represent an aggregate score of all space-occupying imaging features.

Tumor-volume calculation and mass-effect index (MEI)

Tumor volume was estimated from the three orthogonal tumor dimensions measured on imaging. The maximum tumor diameter was designated as a, with the remaining two perpendicular dimensions designated as b and c. Assuming ellipsoidal tumor geometry, the estimated tumor volume was calculated using the following formula: $V = \frac{\pi}{6}abc$, where V represents tumor volume and a, b, and c represent the three orthogonal tumor dimensions. With a, b, and c expressed in millimeters, V was obtained in cubic millimeters and divided by 1,000 for reporting in cubic centimeters (cm^3).

To provide a single standardized measure of tumor size, an equivalent tumor diameter was subsequently

calculated from the estimated volume using: $d = \left(\frac{6V}{\pi}\right)^{1/3}$, where d represents the equivalent tumor diameter. This value corresponds to the diameter of a sphere with the same volume as the estimated tumor. For d to be expressed in millimeters, V in this equation must be expressed in cubic millimeters. Because the tumor volume was derived from three orthogonal dimensions, the equivalent diameter is mathematically equivalent to the geometric mean of these dimensions: $d = (abc)^{1/3}$.

The same maximum linear displacement of midline structures was used as the numerator throughout the analysis. To account for differences in tumor size, a dimensionless MEI was calculated by dividing mass effect by equivalent tumor diameter, with both measurements expressed in millimeters: MEI = mass effect (mm)/d (mm). A higher MEI indicates greater midline displacement relative to equivalent tumor diameter. This ratio is an exploratory size-normalized measurement and does not quantify edema, intracranial pressure, or all forms of tissue compression.

Histopathological classification and outcomes

The final diagnosis and WHO grade were obtained from the biopsy or resection specimen. The cohort comprised eight grade 2, seven grade 3, and 15 grade 4 tumors. Grade 2 tumors were classified as low grade and grades 3-4 as high grade. The primary outcome was the association of absolute mass effect and the MEI with high-grade histology. Secondary outcomes included grade-wise differences, diagnostic performance, and associations of clinical and conventional MRI characteristics with grade group. Because molecular characterization was incomplete for some tumors, these analyses concern the recorded histopathological grades rather than a uniformly established integrated WHO CNS5 classification. The study evaluated grade association and discrimination, not longitudinal survival or treatment response.

Statistical analysis

Continuous variables were summarized as median and interquartile range and compared using the Mann-Whitney U test. Categorical variables were reported as n (%) and compared using Fisher's exact test with odds ratios. Grade-wise comparisons used the Kruskal-Wallis H test, and ordinal trends were assessed using Spearman correlation. Receiver operating characteristic (ROC) area under the curve (AUC) and 95% confidence intervals were calculated using DeLong's method; cutoffs were optimized to maximize the Youden index. The reported ROC P-values test each AUC against 0.50; they do not establish differences between the AUCs of competing measurements. Standardized predictors were evaluated by logistic regression, with Wald z-statistics and odds ratios per one-standard-deviation increase. A restricted model containing log-transformed volume and mass effect assessed size-adjusted association. Leave-one-out cross-validation used L2-penalized logistic regression. All tests were two-sided; $p < 0.05$ was significant, and secondary analyses were exploratory without multiplicity adjustment. Cutoffs were derived in the same cohort and were not externally validated.

Results

Study population and conventional MRI characteristics

Thirty patients were included: eight with WHO grade 2, seven with grade 3, and 15 with grade 4 gliomas. Twenty-two tumors were classified as high-grade. The median age was 46.0 years, and 17 patients (56.7%) were male. Age, sex, symptom duration, seizure, hemiparesis, altered sensorium, and estimated volume did not differ significantly between groups. High-grade tumors demonstrated greater absolute mass effect and a higher MEI. Hemorrhage and definite or rim-like enhancement were more frequent in high-grade tumors (Table *1*).

Characteristic	Overall (n = 30)	Low grade (n = 8)	High grade (n = 22)	Test statistic	p-value
Age, years	**46.0 (39.0-53.3)**	**46.5 (34.0-50.0)**	**45.5 (39.8-54.0)**	**U = 78.5**	**0.672**
Symptom duration (months)	5.0 (4.0-6.8)	6.5 (5.0-7.3)	5.0 (3.3-6.0)	U = 125.0	0.083
Seizure	19 (63.3)	6 (75.0)	13 (59.1)	OR = 0.48	0.672
Hemiparesis	9 (30.0)	1 (12.5)	8 (36.4)	OR = 4.00	0.374
Altered sensorium	7 (23.3)	1 (12.5)	6 (27.3)	OR = 2.63	0.638
Estimated tumor volume (cm^3)	49.1 (26.1-67.6)	34.9 (15.4-74.8)	54.7 (31.8-66.8)	U = 77.0	0.622
Mass effect (mm)	5.97 (3.47-8.10)	3.33 (2.38-4.08)	7.54 (4.39-8.28)	U = 31.5	0.009*
Mass-effect index	0.137 (0.079-0.163)	0.075 (0.049-0.117)	0.149 (0.092-0.191)	U = 39.5	0.024*
Hemorrhage	21 (70.0)	2 (25.0)	19 (86.4)	OR = 19.00	0.003*
Necrosis	27 (90.0)	6 (75.0)	21 (95.5)	OR = 7.00	0.166
Definite/rim enhancement	26 (86.7)	4 (50.0)	22 (100.0)	OR = infinite	0.003*
Moderate/gross edema	13 (43.3)	3 (37.5)	10 (45.5)	OR = 1.39	1.000
Contralateral extension	3 (10.0)	0	3 (13.6)	OR = infinite	0.545

TABLE 1: Clinical and conventional MRI characteristics according to tumor-grade group

OR: odds ratio

Values are median (interquartile range) or n (%). Continuous variables were compared using the two-sided Mann-Whitney U test; U corresponds to the low-grade group. Categorical variables were compared using the two-sided Fisher exact test, with the conditional OR shown as the effect estimate. High grade includes WHO grades 3 and 4. A p-value < 0.05 was considered statistically significant. * denotes a statistically significant p-value (p < 0.05), including values reported as p < 0.001

Grade-wise tumor volume and mass effect

Tumor volume did not differ significantly across individual grades. Absolute mass effect demonstrated a significant across-grade difference and a moderate positive correlation with grade. The MEI increased from grade 2 to grades 3 and 4; its overall three-group comparison was marginal, although the ordinal correlation was significant (Table *2*).

Parameter	Grade 2 (n = 8)	Grade 3 (n = 7)	Grade 4 (n = 15)	Kruskal-Wallis H	p-value	Spearman rho	Trend p-value
Tumor volume (cm^3)	**34.9 (15.4-74.8)**	**29.2 (24.9-54.6)**	**62.3 (45.7-66.1)**	**H = 1.459**	**0.482**	**rho = 0.192**	**0.310**
Mass effect, mm	3.33 (2.38-4.08)	7.48 (2.87-7.88)	7.80 (5.09-9.15)	H = 8.272	0.016*	rho = 0.525	0.003*
Mass-effect index	0.075 (0.049-0.117)	0.148 (0.071-0.175)	0.154 (0.117-0.203)	H = 5.779	0.056	rho = 0.432	0.017*

TABLE 2: Grade-wise tumor volume and mass effect

Values are median (interquartile range). Across-grade p-values were calculated using the Kruskal-Wallis test, with H reported. Trend p-values were calculated using Spearman rank correlation, with rho reported as the statistic and effect-size measure. A p-value < 0.05 was considered statistically significant. * denotes a statistically significant p-value (p < 0.05), including values reported as p < 0.001

Diagnostic performance

Absolute mass effect had the highest observed AUC for high-grade histology (0.821; 95% CI: 0.668-0.974), followed by the MEI (0.776) and tumor volume (0.563). The AUCs of mass effect and the index differed from 0.50, whereas that of volume did not. A mass-effect threshold of 4.97 mm provided 72.7% sensitivity and

87.5% specificity in this cohort (Table 3). These results describe numerical discrimination and do not establish a statistically significant difference between competing AUCs. The threshold is exploratory.

Parameter	AUC (95% CI)	DeLong z	p-value vs AUC = 0.50	Exploratory cutoff	Sensitivity, %	Specificity, %
Tumor volume	**0.563 (0.249-0.876)**	**z = 0.391**	**0.696**	**>=39.7 cm3**	**72.7**	**62.5**
Mass effect	0.821 (0.668-0.974)	z = 4.111	<0.001*	>=4.97 mm	72.7	87.5
Mass-effect index	0.776 (0.588-0.963)	z = 2.883	0.004*	>=0.141	63.6	87.5

TABLE 3: ROC performance for identifying high-grade glioma

AUC: area under the curve; CI: confidence interval; ROC: receiver operating characteristic

AUC confidence intervals and p-values were calculated using DeLong's method. The z-statistic tests the null hypothesis AUC = 0.50 for each measurement, not a difference between measurements. Cutoffs maximized the Youden index in the development cohort and require external validation

Logistic regression analysis

In univariable regression, volume was not associated with high-grade histology. Each one-standard-deviation increase in mass effect was associated with approximately 3.8-fold greater odds of high-grade histology, and the MEI showed a similar association. The restricted two-predictor model was significant overall. After adjustment for volume, the mass-effect estimate remained positive but was imprecise (OR: 4.32; 95% CI: 0.95-19.75; p = 0.059). Because its confidence interval included unity, an independent association beyond tumor volume was not established (Table 4).

Model/predictor	OR per 1-SD increase (95% CI)	Wald z	Predictor P	Model LR Chi-square (df)	Model P	Apparent AUC	LOOCV AUC	Brier score
Tumor volume alone	**1.32 (0.58-2.99)**	**0.670**	**0.503**	**0.454 (1)**	**0.500**	**0.563**	**0.318**	**0.222**
Mass effect alone	3.81 (1.17-12.44)	2.218	0.027*	6.950 (1)	0.008*	0.821	0.716	0.179
Mass-effect index alone	3.25 (1.05-10.07)	2.044	0.041*	5.646 (1)	0.017*	0.776	0.699	0.185
Size-adjusted: log volume	0.86 (0.30-2.50)	-0.269	0.788	7.023 (2)	0.030*	0.807	0.670	0.196
Size-adjusted: mass effect	4.32 (0.95-19.75)	1.887	0.059	-	-	-	-	-

TABLE 4: Logistic models

OR: odds ratio; CI: confidence interval; SD: standard deviation; LR: likelihood ratio; AUC: area under the curve; LOOCV: leave-one-out cross-validation

Predictor p-values used Wald tests. Overall model p-values used likelihood-ratio Chi-square tests. LOOCV used L2-penalized logistic regression. The two size-adjusted rows are components of one model. A p-value < 0.05 was considered statistically significant. * denotes a statistically significant p-value (p < 0.05), including values reported as p < 0.001

Discussion

The principal finding was that absolute mass effect and the size-normalized index were greater in high-grade gliomas, whereas estimated volume did not differ between grade groups. Absolute mass effect had the highest observed AUC, and each standard-deviation increase was associated with approximately 3.8-fold greater odds of high-grade histology in univariable analysis. These observations support further evaluation of quantitative displacement as a complementary conventional MRI measurement. They do not establish a biological mechanism, statistically significant superiority over other measurements, or an independent

contribution beyond volume.

Conventional characteristics associated with aggressive biology traditionally include enhancement, necrosis, hemorrhage, edema, heterogeneity, and mass effect [2,3]. Guzmán-De-Villoria et al. found enhancement, necrosis, edema, hemorrhage, and neovascularization more frequently in high-grade tumors; enhancement and necrosis were the most useful conventional predictors [3]. Ellika et al. reported good sensitivity but limited specificity for conventional MRI grading [6].

Definite or rim-like enhancement occurred in all high-grade tumors compared with half of low-grade tumors. Fayed et al. reported that quantitatively assessed enhancement discriminated malignant tumors with an AUC of 0.88 [5]. Lasocki et al. also associated enhancement, necrosis, and hemorrhage with aggressive molecular subtypes [8]. Enhancement should nevertheless remain supportive rather than definitive because nonenhancing high-grade and enhancing lower-grade gliomas are recognized [2,8].

Intratumoral hemorrhage was significantly more frequent in high-grade tumors. This is biologically plausible because abnormal neovascular channels, endothelial disruption, and necrosis predispose to bleeding. The result agrees with previous associations of hemorrhage with high-grade or biologically aggressive glioma [3,8]. Necrosis was frequent in both groups and did not discriminate grade, differing from studies in which it was a strong conventional marker [3,6]. The unusually high recorded prevalence, including six grade 2 tumors, may reflect inclusion of cystic, degenerative, or nonenhancing central components rather than histologically confirmed necrosis. This emphasizes the need for strict imaging definitions.

Moderate or gross edema was not associated with grade. Schoenegger et al. found greater edema independently associated with poorer survival in glioblastoma [9]. Wu et al. reported extensive edema and necrosis as adverse prognostic features [10]. Pope et al. likewise identified edema and multifocality as survival correlates in high-grade glioma [11]. Those studies evaluated prognosis within high-grade populations, whereas ours addressed discrimination between grade groups. Broad ordinal edema categories may also have reduced sensitivity.

The absence of a significant volume difference deserves consideration. Size is influenced by growth rate, symptom-producing location, presentation timing, infiltration, and intracranial accommodation. A slowly growing lower-grade glioma may become large before diagnosis, while a smaller high-grade lesion in a constrained location may present earlier. Pope et al. similarly found tumor size was not an independent imaging correlate of survival in high-grade glioma [11]. Conversely, maximal diameter has shown prognostic importance in selected grade 2 cohorts [12].

Absolute mass effect increased across grades. After adjustment for volume, the OR was 4.32, but the 95% confidence interval was wide and included unity (0.95-19.75). The positive direction of the estimate therefore warrants investigation rather than a claim of independence from tumor size. Dallabona et al. examined relationships between mass effect, location, and cognitive outcomes in high-grade glioma [7]. Experimental biomechanical modelling has also incorporated tumor growth and tissue displacement using longitudinal MRI [13]. Such work provides context for considering size and displacement separately, but does not validate the present index or explain the associations observed in this cohort.

The MEI showed moderate discrimination, with a lower observed AUC than absolute mass effect. Normalization may introduce variability from three independently measured dimensions, while absolute mass effect may reflect a combination of expansion, edema, and compression. These explanations remain hypotheses because the study did not directly measure these mechanisms or compare measurement reliability. Multiparametric MRI studies have evaluated diffusion, perfusion, and spectroscopy measurements for glioma grading [14-16], but their results do not establish the validity of this conventional MRI ratio. The index should therefore be regarded as exploratory.

Cross-validation tempered the apparent strength of the findings. The mass-effect model retained moderate discrimination, the volume model performed poorly, and combining volume with mass effect did not improve cross-validated performance. In this small cohort, these results indicate uncertainty in model generalizability. Internal cross-validation cannot substitute for evaluation in an independent population.

Novelty and clinical relevance

Mass effect is an established conventional MRI feature, and numerous studies have assessed radiological markers of glioma grade and molecular subtype [2,3,6,8]. The specific contribution of this study is the quantitative comparison of absolute midline displacement with ellipsoid tumor volume and a dimensionless index normalized to equivalent tumor diameter. This approach examines displacement relative to estimated tumor size within the same cohort. We do not claim priority for measuring mass effect or propose the MEI as an established diagnostic biomarker. The observation that normalization did not increase the observed AUC is also relevant to evaluating whether this additional calculation offers practical value.

The proposed measurements can be obtained from routine MRI without perfusion, spectroscopy, radiomics, or automated volumetry. This makes their evaluation relevant to settings where advanced imaging and post-processing are limited. However, clinical utility, reproducibility, and incremental value over established conventional features were not established. A single linear measurement is simpler to obtain than a derived ratio, but greater reproducibility cannot be assumed without testing. Future studies should standardize measurement landmarks and tumor-boundary rules, assess interobserver and intraobserver reliability, account for tumor location and edema volume, use integrated WHO CNS5 diagnoses, and validate diagnostic performance and clinical outcomes independently.

Limitations

This single-center study included only 30 patients and eight low-grade tumors, producing wide confidence intervals and limited multivariable power. The cross-sectional design supports associations with recorded grade but cannot establish causality, temporal progression, survival prediction, or treatment benefit. Requiring completion of the MRI protocol, technically adequate images, and histopathological confirmation may introduce selection bias and limit generalizability. Volume was estimated using an ellipsoid approximation, which may be inaccurate for irregular or infiltrative tumors. Mass effect and edema were not assessed by automated segmentation or interobserver testing. The reporting does not specify sequence-specific acquisition parameters, a fixed anatomical displacement landmark and reference line, tumor-boundary rules for edema and cystic or necrotic components, or reader-level measurement procedures; this limits exact replication. ROC comparisons were descriptive, and an independent contribution beyond volume was not established. Multiple exploratory analyses and cohort-derived cutoffs increase the risk of optimistic findings.

Conclusions

High-grade gliomas demonstrated greater midline displacement and greater displacement relative to tumor size than low-grade gliomas, despite overlapping tumor volumes. Absolute mass effect showed the highest observed discrimination of high-grade histology, while normalization to equivalent tumor diameter offered no improvement. These findings highlight the value of assessing the displacement produced by a glioma alongside its size. Quantitative measurement of midline displacement on routine MRI may provide complementary information for preoperative assessment of tumor grade and should be interpreted together with other imaging features and the final histomolecular diagnosis.

Additional Information

Author Contributions

All authors have reviewed the final version to be published and agreed to be accountable for all aspects of the work.

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Disclosures

Human subjects: Informed consent for treatment and open access publication was obtained or waived by all participants in this study. Uttar Pradesh University of Medical Sciences (UPUMS) issued approval 262/Cert./IEC/UPUMS/2025-26. **Animal subjects:** All authors have confirmed that this study did not involve animal subjects or tissue. **Conflicts of interest:** In compliance with the ICMJE uniform disclosure form, all authors declare the following: **Payment/services info:** All authors have declared that no financial support was received from any organization for the submitted work. **Financial relationships:** All authors have declared that they have no financial relationships at present or within the previous three years with any organizations that might have an interest in the submitted work. **Other relationships:** All authors have declared that there are no other relationships or activities that could appear to have influenced the submitted work.

References

1. Louis DN, Perry A, Wesseling P, et al.: The 2021 WHO classification of tumors of the central nervous system: a summary. Neuro Oncol. 2021, 23:1231-51. 10.1093/neuonc/noab106

2. Upadhyay N, Waldman AD: Conventional MRI evaluation of gliomas. Br J Radiol. 2011, 84:S107-11. 10.1259/bjr/65711810
3. Guzmán-De-Villoria JA, Mateos-Pérez JM, Fernández-García P, Castro E, Desco M: Added value of advanced over conventional magnetic resonance imaging in grading gliomas and other primary brain tumors. Cancer Imaging. 2014, 14:35. 10.1186/s40644-014-0035-8
4. Law M, Yang S, Wang H, et al.: Glioma grading: sensitivity, specificity, and predictive values of perfusion MR imaging and proton MR spectroscopic imaging compared with conventional MR imaging. AJNR Am J Neuroradiol. 2003, 24:1989-98.
5. Fayed N, Morales H, Modrego PJ, Pina MA: Contrast/noise ratio on conventional MRI and choline/creatine ratio on proton MRI spectroscopy accurately discriminate low-grade from high-grade cerebral gliomas. Acad Radiol. 2006, 13:728-37. 10.1016/j.acra.2006.01.047
6. Ellika SK, Jain R, Patel SC, Scarpace L, Schultz LR, Rock JP, Mikkelsen T: Role of perfusion CT in glioma grading and comparison with conventional MR imaging features. AJNR Am J Neuroradiol. 2007, 28:1981-7. 10.3174/ajnr.A0688
7. Dallabona M, Sarubbo S, Merler S, et al.: Impact of mass effect, tumor location, age, and surgery on the cognitive outcome of patients with high-grade gliomas: a longitudinal study. Neurooncol Pract. 2017, 4:229-40. 10.1093/nop/npw030
8. Lasocki A, Buckland ME, Drummond KJ, et al.: Conventional MRI features can predict the molecular subtype of adult grade 2-3 intracranial diffuse gliomas. Neuroradiology. 2022, 64:2295-305. 10.1007/s00234-022-02975-0
9. Schoenegger K, Oberndorfer S, Wuschitz B, et al.: Peritumoral edema on MRI at initial diagnosis: an independent prognostic factor for glioblastoma?. Eur J Neurol. 2009, 16:874-8. 10.1111/j.1468-1331.2009.02613.x
10. Wu CX, Lin GS, Lin ZX, Zhang JD, Liu SY, Zhou CF: Peritumoral edema shown by MRI predicts poor clinical outcome in glioblastoma. World J Surg Oncol. 2015, 13:97. 10.1186/s12957-015-0496-7
11. Pope WB, Sayre J, Perlina A, Villablanca JP, Mischel PS, Cloughesy TF: MR imaging correlates of survival in patients with high-grade gliomas. AJNR Am J Neuroradiol. 2005, 26:2466-74.
12. Liu H, Shen L, Huang X, Zhang G: Maximal tumor diameter in the preoperative tumor magnetic resonance imaging (MRI) T2 image is associated with prognosis of grade II Glioma. Medicine (Baltimore). 2021, 100:e24850. 10.1097/MD.0000000000024850
13. Tunc B, Hormuth D, Biros G, Yankeelov TE: Modeling of glioma growth with mass effect by longitudinal magnetic resonance imaging. IEEE Trans Biomed Eng. 2021, 68:3713-24. 10.1109/TBME.2021.3085523
14. Seo M, Choi Y, Soo Lee Y, Ahn KJ, Kim BS, Park JS, Jeon SS: Glioma grading using multiparametric MRI: head-to-head comparison among dynamic susceptibility contrast, dynamic contrast-enhancement, diffusion-weighted images, and MR spectroscopy. Eur J Radiol. 2023, 165:110888. 10.1016/j.ejrad.2023.110888
15. Hilario A, Ramos A, Perez-Nuñez A, et al.: The added value of apparent diffusion coefficient to cerebral blood volume in the preoperative grading of diffuse gliomas. AJNR Am J Neuroradiol. 2012, 33:701-7. 10.3174/ajnr.A2846
16. Zonari P, Baraldi P, Crisi G: Multimodal MRI in the characterization of glial neoplasms: the combined role of single-voxel MR spectroscopy, diffusion imaging and echo-planar perfusion imaging. Neuroradiology. 2007, 49:795-803. 10.1007/s00234-007-0253-x