



Original Article

Clinicoradiological and Histopathological Correlation of Central Nervous System Tumors: A Retrospective–Prospective Study

Corresponding Author:

Dr. Rutvij Bharatsinh Solanki

MBBS, Gujarat Adani Institute of
Medical Sciences, Bhuj, Gujarat,
India

Email: vrutvij070@gmail.com

Article History:

Received on: Aug 16, 2026

Revised on: Sep 15, 2026

Accepted on: Sep 22, 2026

Published on: Oct 06, 2026

Citation: Dr. Priyanka Nimavat *et al.*
Clinicoradiological and
Histopathological Correlation of
Central Nervous System Tumors: A
Retrospective–Prospective Study.
*Biomedicine and Chemical
Sciences*, 5 (4): 17-23, 2026

Copyright © The Author(s).

Published in [Biomedicine and
Chemical Sciences](#)



This is an Open Access article
published under the Creative
Commons Attribution 4.0
International (CC BY 4.0)

(<https://creativecommons.org/licenses/by/4.0>) Creative
Commons Attribution (CC BY): lets others distribute and copy
the article, to create extracts, abstracts, and other revised
versions, adaptations or derivative works of or from an article
(such as a translation), to include in a collective work (such as
an anthology), to text or data mine the article, even for
commercial purposes, as long as they credit the author(s), do
not represent the author as endorsing their adaptation of the
article, and do not modify the article in such a way as to
damage the author's honour or reputation

Dr. Priyanka Nimavat¹, Dr. Pooja Kagathara², Dr. Rutvij Bharatsinh Solanki^{3*}

¹Third Year Resident, Department of Pathology, GMERS Medical College and Civil Hospital,
Sola, Ahmedabad, Gujarat, India

²Associate Professor, Department of Pathology, Shree M. P. Shah Government Medical
College, Jamnagar, Gujarat, India

³MBBS, Gujarat Adani Institute of Medical Sciences, Bhuj, Gujarat, India.

ABSTRACT

Background: Central nervous system (CNS) tumors are a diverse group of tumors, in
which clinical presentation and neuroimaging are important sources of information
before surgery, while histopathology is the definitive diagnosis.

Objective: To assess the correlation between clinical presentation, radiological
diagnosis and histopathological diagnosis in patients with CNS tumors and to assess
the agreement between the radiological diagnosis and the tissue diagnosis.

Methods: 180 consecutive patients with surgically resected CNS tumors were
included in this retrospective–prospective observational study. Clinical features,
anatomical site, conventional magnetic resonance imaging characteristics, diffusion
findings, radiological impression and histopathological diagnosis were recorded.
Histological classification was done according to current principles of CNS tumor
classification with the use of immunohistochemistry when necessary. The
percentage agreement and Cohen's kappa were used to evaluate the diagnostic
concordance. Imaging features of low- and high-grade gliomas were compared.

Results: The mean age was 43.6 ± 18.2 years; 99 (55.0%) patients were male.
Common presentations included headache (67.8%), vomiting (41.7%), seizures
(32.2%) and focal neurological deficits (27.8%). The supratentorial tumors were
seen in 71.7% of cases. Histopathology showed gliomas in 70 (38.9%), meningiomas
in 47 (26.1%), schwannomas in 16 (8.9%), ependymomas in 10 (5.6%), embryonal
tumors in 9 (5.0%), metastases in 12 (6.7%), and other tumors in 16 (8.9%). There
was substantial to almost perfect agreement between radiological and
histopathological diagnosis ($\kappa = 0.81$, $p < 0.001$) in 153/180 cases (85.0%). The
highest rates of concordance were for meningioma (95.7%) and schwannoma
(93.8%). Higher ADC values, heterogeneous enhancement, necrosis, marked
edema, and lower ADC values were significantly correlated with high-grade histology
(all $p \leq 0.003$) in 70 gliomas.

Conclusions: There was a high degree of agreement between the pre-operative
neuroimaging and the final histopathology, especially for extra-axial tumours.
However, there is overlap in imaging appearances, particularly between infiltrative
gliomas and rare lesions, which underscores the importance of histopathological

diagnosis for definitive classification and grading. The integrated clinicroadiological and pathological evaluation enhances the precision of the diagnosis and assists in the multidisciplinary treatment planning.

Keywords: central nervous system tumors; magnetic resonance imaging; histopathology; radiology–pathology correlation; glioma; meningioma.

INTRODUCTION

Centrally located tumors of the central nervous system are a heterogeneous group of benign and malignant tumors of neuroepithelial, meningeal, nerve sheath, embryonal, hematolymphoid, germ cell and other tissues. They make up a smaller percentage of all human neoplasms than do cancers of several other organ systems, but their anatomic location makes them clinically significant because even histologically benign lesions can cause significant neurologic morbidity. Population-based statistics have shown that meningioma is the most common mostly benign primary CNS tumor, whereas glioblastoma is the most common malignant primary brain tumor and has a poor prognosis [1].

The diagnostic approach to CNS tumors has undergone significant evolution with the fifth edition of the World Health Organization (WHO) classification, which incorporates histomorphology, immunophenotypic and molecular data, and emphasizes biologically defined entities [2]. However, in routine practice the diagnostic process starts much earlier than the examination of the tissues. The pre-operative differential diagnosis is determined by age, symptom pattern, tumor location, relationship to the meninges and ventricles, signal characteristics, diffusion behavior, edema, hemorrhage, calcification and contrast enhancement. Radiological categorization is clinically relevant as it affects surgical approach, extent of resection, the need for image-guided biopsy, perioperative counseling and multidisciplinary planning.

Most intracranial and spinal tumors are best diagnosed with magnetic resonance imaging (MRI). A location-based diagnostic approach can significantly reduce the differential diagnosis, and a previous clinicopathological correlation study has shown that there is high radiology–histology agreement in several common categories of CNS tumor, with lower agreement in selected low-grade gliomas and ventricular lesions [3]. Indian hospital-based tumor series have also revealed significant differences in the age, location, and histopathology of CNS tumors [4–7]. Multiple pediatric tertiary centers in India also show a distinct spectrum with astrocytic tumors, embryonal tumors, craniopharyngioma and ependymal tumors being the predominant types [8].

Advanced MRI has enhanced the ability to estimate tumor biology prior to surgery. In addition to conventional sequences, perfusion MRI and proton MR spectroscopy provide additional diagnostic information for grading gliomas [9]. Tumor cellularity is also reflected by diffusion-weighted imaging and apparent diffusion coefficient (ADC) measurements, which have proven to be useful correlations with glioma grade [10]. In meningiomas, diffusion parameters have been assessed as grade and proliferative activity markers, but the results are not completely consistent in the literature [11–13]. MR spectroscopy has also been shown to provide direct spatial relationships between metabolite abnormalities and histological evidence of viable tumor in image-guided biopsy specimens [14]. These observations highlight the importance of imaging as a biological surrogate and also the fact that imaging cannot completely replace tissue diagnosis.

In the modern era of neuro-oncology, therefore, clinicroadiological–histopathological correlation is still relevant, particularly in centers where sophisticated molecular analysis is not routinely performed for every patient. These studies can help characterize the types of tumors that can be reliably radiologically predicted, can identify patterns that explain diagnostic discordance, and can offer local epidemiological data that can enhance the preoperative reasoning. The aim of the present study was to assess the clinical profile and radiological features of CNS tumors, to establish their histopathological spectrum, to quantify radiology–histopathology concordance, and to evaluate imaging features associated with histological grade of gliomas.

MATERIALS AND METHODS

Study design and setting

The study was designed as a retrospective–prospective observational study in the departments of Radiodiagnosis, Pathology, and Neurosurgery of a tertiary care teaching hospital. All patients who had undergone biopsy or surgical resection for a radiologically suspected CNS neoplasm were screened. The study was designed to mimic the clinical routine and encompass intracranial and spinal tumors for which both imaging and pathological specimens were available.

Sample size

There were 180 patients who fulfilled the inclusion criteria, of which 120 patients were from the retrospective period and 60 patients were from the prospective period. Cases were evaluated on an individual patient basis and repeat procedures for the same tumor were not considered as separate primary observations.

Eligibility criteria

Patients of any age and sex with a radiologically identified CNS mass, who had available tissue samples and an interpretable pre-operative computed tomography (CT) and/or magnetic resonance imaging (MRI) scan were eligible. Histological material was insufficient to diagnose the case, the final diagnosis was non-neoplastic, imaging was not available or technically non-diagnostic, or the lesion had been significantly changed by previous surgery or treatment before imaging–pathology comparison. The primary concordance analysis excluded recurrent tumors to avoid imaging confounding due to treatment.

Evaluation by clinical and radiological means

Demographic data and presenting symptoms were obtained from clinical files and case forms. Imaging evaluation included anatomical compartment (supratentorial, infratentorial, or spinal), intra-axial or extra-axial location, margins, T1- and T2-weighted signal, FLAIR characteristics, hemorrhage, calcification (if available on CT), cystic or necrotic change, peritumoral edema, mass effect, diffusion restriction, ADC values (where measurable), and pattern of contrast enhancement. The final radiological impression before surgery and, in the case of gliomas, the suspected low- versus high-grade category was noted, but not based on the subsequent pathological report.

Histopathological assessment

Specimens that were resected and biopsy specimens were fixed in 10% neutral buffered formalin, processed routinely, embedded in paraffin and stained with hematoxylin and eosin. The tumors were classified according to the modern WHO diagnostic principles of CNS. When indicated, immunohistochemistry was performed and may have included glial fibrillary acidic protein, OLIG2, epithelial membrane antigen, S100 protein, synaptophysin, IDH1 R132H, ATRX, p53, and Ki-67, and other markers were selected based on morphology. When molecular data were available in routine records, this was combined with morphology; cases in which molecular data was not available were reported based on the highest defensible diagnostic level. Histopathology was used as the reference standard for correlation.

Outcome measures

The main outcome was the agreement between the initial radiological diagnosis and the final histopathological diagnosis. Secondary outcomes included tumor-wise concordance, Cohen's kappa for overall agreement, the clinical and anatomical distribution of tumor categories, and associations between selected MRI features and histological grade of gliomas.

Statistical analysis

IBM SPSS Statistics version 26.0 was used for data analysis. Continuous variables were presented as mean $\pm$ SD or median (IQR) as appropriate. Categorical variables were presented as frequencies and percentages. Normally distributed continuous variables were analyzed using independent-samples t test, and categorical comparisons were analyzed using the chi-square test or Fisher's exact test. Agreement between the two diagnoses was reported as percentage concordance and Cohen's kappa (κ). The sensitivity, specificity, positive predictive value, negative predictive value, and overall accuracy were determined for radiological classification of high-grade glioma against histopathology. A two-sided p value <0.05 was considered statistically significant.

RESULTS

The study included 180 patients with histologically confirmed CNS tumors. The mean age was 43.6 ± 18.2 years (range 4–79 years); 99 (55.0%) were male and 81 (45.0%) were female. The largest age group was 41–60 years (68 patients, 37.8%). Headache was the most frequent presenting symptom, occurring in 122 (67.8%) patients, followed by vomiting in 75 (41.7%), seizures in 58 (32.2%), focal neurological deficit in 50 (27.8%), and visual symptoms in 25 (13.9%). Symptoms overlapped in many patients. Most tumors were supratentorial (129, 71.7%), followed by infratentorial (39, 21.7%) and spinal (12, 6.7%) lesions. Intra-axial tumors constituted 104 (57.8%) cases and extra-axial tumors 76 (42.2%). Baseline clinicoradiological characteristics are summarized in Table 1.

Histopathology identified gliomas as the largest group (70/180, 38.9%), followed by meningiomas (47/180, 26.1%). Schwannomas accounted for 16 (8.9%), metastatic tumors 12 (6.7%), ependymomas 10 (5.6%), embryonal tumors 9 (5.0%), and other tumors 16 (8.9%). Overall, the principal radiological diagnosis agreed with final histopathology in 153 of 180 cases, yielding 85.0% concordance. Cohen's kappa was 0.81 (95% CI 0.75–0.87; $p < 0.001$), indicating strong agreement beyond chance. Concordance was highest for meningioma (95.7%) and schwannoma (93.8%), while the heterogeneous 'other' category showed the lowest agreement (50.0%). Tumor-wise findings are presented in Table 2.

Among the 70 gliomas, 31 were classified histologically as low grade and 39 as high grade. High-grade tumors more frequently had ill-defined or infiltrative margins (79.5% vs 45.2%, $p = 0.003$), heterogeneous contrast enhancement (79.5% vs 29.0%, $p < 0.001$), necrosis (69.2% vs 9.7%, $p < 0.001$), restricted diffusion (64.1% vs 22.6%, $p = 0.001$), and moderate-to-severe peritumoral edema (71.8% vs 25.8%, $p < 0.001$). Mean tumor ADC was lower in high-grade gliomas ($0.86 \pm 0.16 \times 10^{-3} \text{ mm}^2/\text{s}$) than in low-grade gliomas ($1.21 \pm 0.18 \times 10^{-3} \text{ mm}^2/\text{s}$; $p < 0.001$). Using the radiological low- versus high-grade impression, 28 of 39 high-grade tumors were correctly identified and 27 of 31 low-grade tumors were correctly classified. This corresponded to a sensitivity of 71.8%, specificity of 87.1%, positive predictive value of 87.5%, negative predictive value of 71.1%, and overall grading accuracy of 78.6%. Detailed imaging–grade associations are shown in Table 3.

The 27 discordant cases were reviewed descriptively. The most frequent sources of disagreement were underestimation or overestimation of glioma grade, atypical imaging appearances of metastases, ependymal tumors with unusual location or enhancement, and uncommon tumors whose imaging features overlapped with more prevalent entities. Several discordant lesions nevertheless had a radiological differential diagnosis that included the final histopathological entity, indicating that disagreement often represented prioritization within a reasonable differential rather than complete diagnostic incompatibility.

Table 1. Demographic, clinical, and anatomical characteristics of the study population (N = 180)

Variable	Value
Age, years, mean $\pm$ SD	43.6 $\pm$ 18.2
Age $\leq$ 20 years	23 (12.8%)
Age 21–40 years	55 (30.6%)
Age 41–60 years	68 (37.8%)
Age >60 years	34 (18.9%)
Male sex	99 (55.0%)
Female sex	81 (45.0%)
Retrospective component	120 (66.7%)
Prospective component	60 (33.3%)
Headache	122 (67.8%)
Vomiting	75 (41.7%)
Seizures	58 (32.2%)
Focal neurological deficit	50 (27.8%)
Visual symptoms	25 (13.9%)
Supratentorial location	129 (71.7%)
Infratentorial location	39 (21.7%)
Spinal location	12 (6.7%)
Intra-axial compartment	104 (57.8%)
Extra-axial compartment	76 (42.2%)

Table 2. Histopathological spectrum and radiology–histopathology concordance

Histopathological category	Cases, n (%)	Radiologically concordant, n	Concordance (%)
Gliomas	70 (38.9%)	60	85.7
Meningiomas	47 (26.1%)	45	95.7
Schwannomas	16 (8.9%)	15	93.8
Ependymomas	10 (5.6%)	8	80.0
Embryonal tumors	9 (5.0%)	8	88.9
Metastatic tumors	12 (6.7%)	9	75.0
Other CNS tumors	16 (8.9%)	8	50.0
Total	180 (100%)	153	85.0

Table 3. MRI characteristics according to histological grade among gliomas (n = 70)

MRI characteristic	Low grade (n = 31)	High grade (n = 39)	p value
Ill-defined/infiltrative margins	14 (45.2%)	31 (79.5%)	0.003

Heterogeneous enhancement	9 (29.0%)	31 (79.5%)	<0.001
Necrosis	3 (9.7%)	27 (69.2%)	<0.001
Restricted diffusion	7 (22.6%)	25 (64.1%)	0.001
Moderate/severe peritumoral edema	8 (25.8%)	28 (71.8%)	<0.001
Mean ADC ($\times 10^{-3}$ mm ² /s)	1.21 $\pm$ 0.18	0.86 $\pm$ 0.16	<0.001
Correct radiological grade	27 (87.1%)	28 (71.8%)	0.121

DISCUSSION

The present study shows that preoperative imaging is highly concordant with histopathology in a wide range of CNS tumors, and identifies clinically relevant regions of disagreement. The overall concordance between radiology and histopathology was 85.0% with a κ value of 0.81. This level of consensus is useful for the clinical application of modern neuroimaging in the preoperative setting, but the 15% disagreement rate still underscores the ongoing need for tissue diagnosis. The finding is in keeping with the rule that radiological pattern recognition is best when the location and morphology of the tumour is typical, while infiltrative neoplasms and rare lesions often have similar appearances.

The demographic and histological distribution was generally similar to the hospital-based experience in India. The most common histological type in the present series was glioma and the most common extra-axial tumor was meningioma. In a large NIMHANS registry, Jaiswal et al. reported meningiomas, glioblastomas and nerve sheath tumors as the major groups of intracranial tumors in adults [4]. In the same way, Gupta et al. highlighted the diversity of primary CNS tumors and the importance of multi-disciplinary approach to their management [5]. There is also a significant contribution from neuroepithelial and meningeal tumors as documented in histopathological series from South India and more recent data from a rural tertiary centre [6,7]. Relative frequencies vary between institutions due to differences in neurosurgical referral patterns, case mix in pediatrics, availability of radiotherapy, and inclusion/exclusion of spinal and metastatic lesions.

The high concordance for meningiomas and schwannomas can be understood clinically. These tumors tend to occur in extra-axial compartments and frequently have a recognizable morphology, attachment patterns, enhancement and effects on adjacent structures. Pant et al. reported very high concordance in multiple extra-axial CNS tumor sites and found that a location-based radiological approach is especially helpful in limiting the differential diagnosis [3]. Similarly, radiologic–pathologic analysis of intradural extramedullary tumors of the spine has demonstrated that understanding the imaging characteristics and compartment of the tumor greatly enhances the diagnostic specificity [15]. Conventional imaging was highly concordant for the two most common types of meningioma (95.7%) and schwannoma (93.8%) in the present analysis.

Gliomas had good but lower tumor-type concordance than meningiomas, and radiological grading was less accurate than basic tumor recognition. This is a significant difference. While many infiltrating gliomas can be easily detected on conventional MRI, the histological grade indicates cellularity, mitotic activity, microvascular proliferation, necrosis, and, more recently, molecular changes which may not be apparent on a single anatomical sequence. In this study, heterogeneous enhancement, necrosis, diffusion restriction, marked edema and lower ADC values were all correlated with high grade histology. These relationships are biologically plausible as increased cellularity will decrease extracellular water motion, and angiogenesis, blood–brain barrier disruption, tissue destruction and necrosis will lead to heterogeneous enhancement and edema.

This is confirmed by previous imaging literature. Law et al. demonstrated that perfusion MRI and proton spectroscopy can provide additional information to conventional MRI for the grading of gliomas, with relative cerebral blood volume and metabolic ratios offering complementary information [9]. Kang et al. showed that ADC histogram parameters were able to differentiate low-grade from high-grade gliomas and that lower percentile ADC values were particularly useful [10]. In the current study, mean ADC was significantly lower in high-grade gliomas and diffusion restriction was about three times more common than in low-grade gliomas. However, the sensitivity of radiological grading was 71.8%, suggesting that the absence of aggressive imaging features is not reliable to rule out high-grade histology. Apparent discrepancies may also be due to sampling heterogeneity, as large infiltrating tumors may have areas of varying cellularity and grade.

The literature shows that meningioma diffusion metrics behave in a manner that highlights the need for the interpretation of both radiology and pathology. Surov et al. reported associations between ADC measurements, meningioma grade, proliferative index and cellularity [11] and Watanabe et al. reported that minimum ADC at high b values correlated with histological grade [12]. On the other hand, Santelli et al. found that conventional ADC parameters were not effective in

distinguishing benign from atypical or malignant meningiomas [13]. These discrepancies could be due to scanner parameters, field strength, b values, region-of-interest placement, tumor heterogeneity, grade distribution, and changing pathological criteria. Therefore, diffusion measures can be used to aid risk stratification, but cannot replace histopathology. Biopsy targeting is also important for radiological–histological correlation. Dowling et al. showed spatial relationships between MR spectroscopic abnormalities and histological findings in resection specimens, with increased choline and decreased N-acetylaspartate indicating viable tumor [14]. This principle is always applicable when a lesion is heterogeneous: imaging can help determine the most biologically active or most diagnostically informative area, and biopsy samples may not contain necrotic or low-grade-appearing tissue. Representative sampling is even more critical in the era of integrated diagnosis, as molecular classification can rely on the acquisition of viable tumor of sufficient quality and quantity [2].

The present study has practical implications. First, a confident diagnosis of a typical extra-axial lesion is generally reliable, but should always be confirmed pathologically when tissue is obtained. Second, the radiological evaluation of glioma grade should be performed based on multiparametric evaluation, not only on the enhancement. Third, discordant cases require a structured multidisciplinary review as discrepancies can indicate unusual imaging phenotypes, sampling errors or histological mimics. Fourth, local correlation audits can aid radiologists and pathologists to identify institution-specific diagnostic pitfalls and enhance communication in tumor boards.

There are a few caveats to note. This was an analysis from one center, and therefore is not population based. Retrospective and prospective cases may have variations in imaging protocols and documentation. Conventional MRI and diffusion parameters were the primary methods used for correlation as advanced perfusion, spectroscopy, and molecular testing were not consistently available for all lesions. The number of uncommon tumors was small, limiting the accuracy of estimates of tumors. Lastly, histopathology was employed as the reference standard, but intratumoral heterogeneity can also impact limited biopsy samples. More detailed molecular classification and central neuropathology review in a larger multicenter study with standardized MRI protocols would yield more robust estimates of the level of concordance between the current WHO-defined entities.

CONCLUSION

Clinicoradiological evaluation is a valuable pre-operative tool for diagnosis of central nervous system tumours, especially for common extra-axial tumours like meningiomas and schwannomas. MRI characteristics such as heterogeneous enhancement, necrosis, diffusion restriction, extensive edema, and decreased ADC are helpful to identify the aggressive biology of glioma; however, imaging alone is not sufficient to reliably grade all patients with glioma. The histopathological examination is therefore essential for the definitive diagnosis, classification and grading of the tumor and for treatment planning. Diagnostic error can be minimized, biopsy targeting can be improved, and clinical decision making can be enhanced by routine radiology-pathology correlation, preferably in a multidisciplinary neuro-oncology setting.

REFERENCES

1. Price M, Ballard CAP, Benedetti JR, Kruchko C, Barnholtz-Sloan JS, Ostrom QT. CBTRUS Statistical Report: Primary Brain and Other Central Nervous System Tumors Diagnosed in the United States in 2018-2022. *Neuro Oncol.* 2025;27(Suppl 4):iv1-iv66. doi:10.1093/neuonc/noaf194. PMID: 41092086.
2. Louis DN, Perry A, Wesseling P, Brat DJ, Cree IA, Figarella-Branger D, et al. The 2021 WHO Classification of Tumors of the Central Nervous System: a summary. *Neuro Oncol.* 2021;23(8):1231-1251. doi:10.1093/neuonc/noab106. PMID: 34185076.
3. Pant I, Chaturvedi S, Jha DK, Kumari R, Parteki S. Central nervous system tumors: radiologic pathologic correlation and diagnostic approach. *J Neurosci Rural Pract.* 2015;6(2):191-197. doi:10.4103/0976-3147.153226. PMID: 25883479.
4. Jaiswal J, Shastri AH, Ramesh A, Chickabasaviah YT, Arimappamagan A, Santosh V. Spectrum of primary intracranial tumors at a tertiary care neurological institute: a hospital-based brain tumor registry. *Neurol India.* 2016;64(3):494-501. doi:10.4103/0028-3886.181535. PMID: 27147159.
5. Gupta T, Epari S, Moiyadi A, Shetty P, Goda JS, Krishnatry R, et al. Demographic profile, clinicopathological spectrum, and treatment outcomes of primary central nervous system tumors: retrospective audit from an academic neuro-oncology unit. *Indian J Cancer.* 2017;54(4):594-600. doi:10.4103/ijc.IJC_543_17. PMID: 30082541.
6. Thambi R, Kandamuthan S, Sainulabdeen S, Vilasiniamma L, Abraham TR, Balakrishnan PK. Histopathological analysis of brain tumours: a seven year study from a tertiary care centre in South India. *J Clin Diagn Res.* 2017;11(6):EC05-EC08. doi:10.7860/JCDR/2017/25623.9990. PMID: 28764170.

7. Maurya G, Kannaujia SK, Rashmi R, Singh SK, Omhare A, Aggarwal R. The spectrum of central nervous system tumors at a tertiary care center primarily serving a rural population. *Cureus*. 2024;16(3):e57335. doi:10.7759/cureus.57335. PMID: 38690458.
8. Jain A, Sharma MC, Suri V, Kale SS, Mahapatra AK, Tatke M, et al. Spectrum of pediatric brain tumors in India: a multi-institutional study. *Neurol India*. 2011;59(2):208-211. doi:10.4103/0028-3886.79142. PMID: 21483119.
9. Law M, Yang S, Wang H, Babb JS, Johnson G, Cha S, 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(10):1989-1998. PMID: 14625221.
10. Kang Y, Choi SH, Kim YJ, Kim KG, Sohn CH, Kim JH, et al. Gliomas: histogram analysis of apparent diffusion coefficient maps with standard- or high-b-value diffusion-weighted MR imaging-correlation with tumor grade. *Radiology*. 2011;261(3):882-890. doi:10.1148/radiol.11110686. PMID: 21969667.
11. Surov A, Gottschling S, Mawrin C, Prell J, Spielmann RP, Wienke A, et al. Diffusion-weighted imaging in meningioma: prediction of tumor grade and association with histopathological parameters. *Transl Oncol*. 2015;8(6):517-523. doi:10.1016/j.tranon.2015.11.012. PMID: 26692534.
12. Watanabe Y, Yamasaki F, Kajiwara Y, Takayasu T, Nosaka R, Akiyama Y, et al. Preoperative histological grading of meningiomas using apparent diffusion coefficient at 3T MRI. *Eur J Radiol*. 2013;82(4):658-663. doi:10.1016/j.ejrad.2012.11.037. PMID: 23313707.
13. Santelli L, Ramondo G, Della Puppa A, Ermani M, Scienza R, d'Avella D, et al. Diffusion-weighted imaging does not predict histological grading in meningiomas. *Acta Neurochir (Wien)*. 2010. doi:10.1007/s00701-010-0657-y. PMID: 20428902.
14. Dowling C, Bollen AW, Noworolski SM, McDermott MW, Barbaro NM, Day MR, et al. Preoperative proton MR spectroscopic imaging of brain tumors: correlation with histopathologic analysis of resection specimens. *AJNR Am J Neuroradiol*. 2001;22(4):604-612. PMID: 11290466.
15. Soderlund KA, Smith AB, Rushing EJ, Smirniotopolous JG. Radiologic-pathologic correlation of pediatric and adolescent spinal neoplasms: Part 2, intradural extramedullary spinal neoplasms. *AJR Am J Roentgenol*. 2012;198(1):44-51. doi:10.2214/AJR.11.7121. PMID: 22194478.