Section: Radiodiagnosis

Original Research Article

MRI EVALUATION OF INTRACRANIAL NEOPLASMS WITH HISTOPATHOLOGICAL CORRELATION: ROLE OF DIFFUSION-WEIGHTED IMAGING AND ADC MAPPING

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ABSTRACT

Background: To evaluate the role of magnetic resonance imaging (MRI), including diffusion-weighted imaging (DWI) and apparent diffusion coefficient (ADC) mapping, in the characterization of intracranial neoplasms and to assess its correlation with histopathological findings. **Materials and Methods:** This retrospective observational study was conducted at PES Institute of Medical Sciences and Research from February 2025 to January 2026. A total of 22 patients with suspected intracranial neoplasms who underwent MRI followed by histopathological examination were included. MRI protocol comprised T1-weighted, T2-weighted, FLAIR, DWI with ADC mapping, susceptibility-weighted imaging, and post-contrast sequences, with MR spectroscopy performed in selected cases. Imaging findings were analyzed and correlated with histopathological diagnosis. Non-neoplastic lesions were excluded from final analysis. **Results:** Among the 22 cases, intra-axial tumors were more common, with gliomas constituting the majority, followed by extra-axial tumors, predominantly meningiomas. Other tumors included pituitary adenomas, medulloblastomas, oligodendrogliomas, and pleomorphic xanthoastrocytoma. High-grade tumors such as glioblastoma and medulloblastoma demonstrated marked diffusion restriction with low ADC values, correlating with increased cellularity on histopathology. Low-grade gliomas showed minimal or no diffusion restriction with relatively higher ADC values. Meningiomas exhibited variable diffusion characteristics, whereas pituitary adenomas typically showed no significant restriction. MRI showed good concordance with histopathological diagnosis in most cases. A few cases initially suspected as neoplastic were identified as non-neoplastic lesions (neurocysticercosis and brain abscess) and excluded from final analysis. **Conclusion:** MRI, supplemented by DWI and ADC mapping, is a reliable non-invasive modality for the evaluation and characterization of intracranial neoplasms. It provides valuable information regarding tumor nature and grading with good correlation to histopathology. However, histopathological examination remains essential for definitive diagnosis.

INTRODUCTION

Intracranial neoplasms constitute a heterogeneous group of lesions with diverse histopathological characteristics, clinical presentations, and prognostic outcomes. They include both primary tumors arising from brain parenchyma and its coverings, as well as secondary metastatic lesions. Accurate diagnosis and grading of these tumors are essential for appropriate therapeutic planning and prognostication. The recent advances in the classification of central nervous system tumors, particularly the 2021 WHO classification, emphasize the integration of histological and molecular features, thereby refining diagnostic accuracy and clinical relevance.[1]

Magnetic resonance imaging (MRI) is the imaging modality of choice for the evaluation of intracranial tumors due to its superior soft tissue contrast resolution, multiplanar capability, and absence of ionizing radiation. Conventional MRI sequences such as T1-weighted, T2-weighted, and fluid-attenuated inversion recovery (FLAIR) imaging provide detailed anatomical information regarding lesion location, extent, edema, and mass effect. Contrast-enhanced imaging further aids in assessing blood-brain barrier disruption and tumor vascularity, thereby helping in lesion characterization.[2]

In addition to conventional imaging, advanced MRI techniques such as diffusion-weighted imaging (DWI) and apparent diffusion coefficient (ADC) mapping have significantly enhanced the diagnostic capability of MRI. DWI reflects the mobility of water molecules within tissues and is particularly useful in assessing tumor cellularity. Highly cellular tumors restrict water diffusion, resulting in hyperintensity on DWI and corresponding hypointensity on ADC maps. This characteristic has been shown to correlate with tumor grade, especially in gliomas, where high-grade tumors exhibit lower ADC values compared to low-grade lesions.[3,6]

DWI and ADC also play a crucial role in differentiating neoplastic from non-neoplastic lesions and in distinguishing tumor recurrence from treatment-related changes. Several studies have demonstrated the utility of ADC values in predicting tumor aggressiveness, treatment response, and overall survival, particularly in high-grade gliomas such as glioblastoma.[3,4] Furthermore, diffusion characteristics can aid in differentiating metastatic lesions and other intracranial pathologies, thereby improving diagnostic confidence.[5]

Despite these advancements, MRI findings may overlap among different tumor types and between neoplastic and infective lesions. Conditions such as neurocysticercosis and brain abscess can mimic neoplastic lesions on imaging, posing diagnostic challenges. Therefore, histopathological examination remains the gold standard for definitive diagnosis, providing essential information regarding tumor type, grade, and molecular profile.[1]

In this context, the present study aims to evaluate the role of MRI, including DWI and ADC mapping, in the characterization of intracranial neoplasms and to assess its correlation with histopathological findings in a tertiary care setting.

MATERIALS AND METHODS

Study Design and Setting

This retrospective observational study was conducted in the Department of Radiodiagnosis at PES Institute of Medical Sciences and Research, a tertiary care center, over a period of one year from February 2025 to January 2026.

Study Population

The study included patients who were clinically suspected to have intracranial neoplasms and underwent magnetic resonance imaging (MRI) followed by histopathological evaluation.

Sample Size

A total of 22 cases with available MRI findings and histopathological confirmation were included in the study.

Inclusion Criteria

- Patients of all age groups with suspected intracranial neoplasms
- Patients who underwent preoperative MRI of the brain
- Patients with available histopathological diagnosis

Exclusion Criteria

- Patients without histopathological confirmation
- Patients with incomplete imaging data
- Non-neoplastic lesions (e.g., neurocysticercosis, brain abscess) were excluded from final correlation analysis

MRI Protocol

All patients underwent MRI brain using a standard tumor imaging protocol. The sequences included:

- Axial and sagittal T1-weighted imaging (T1WI)
- Axial T2-weighted imaging (T2WI)
- Fluid-attenuated inversion recovery (FLAIR) sequences
- Diffusion-weighted imaging (DWI)
- Apparent diffusion coefficient (ADC) mapping
- Susceptibility-weighted imaging (SWI)
- Post-contrast T1-weighted imaging following intravenous gadolinium administration

Magnetic resonance spectroscopy (MRS) was performed in selected cases for metabolic characterization.

Image Analysis

MRI scans were analyzed for the following parameters:

- Location (intra-axial / extra-axial / sellar / infratentorial)
- Lesion morphology (size, margins, solid/cystic components, necrosis)
- Signal characteristics on T1, T2, and FLAIR sequences
- Contrast enhancement patterns
- Perilesional edema and mass effect
- Midline shift and herniation
- Diffusion characteristics on DWI and ADC maps
- Spectroscopy findings (choline, NAA, lipid-lactate peaks where available)

Diffusion-Weighted Imaging and ADC Evaluation

DWI findings were assessed qualitatively and quantitatively:

- Restricted diffusion was defined as hyperintensity on DWI with corresponding hypointensity on ADC maps
- Facilitated diffusion was defined as absence of restriction with relatively higher ADC values

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- Diffusion characteristics were correlated with tumor cellularity and histopathological grading:
- High-grade tumors → expected diffusion restriction
- Low-grade tumors → no or minimal restriction

Histopathological Evaluation

All cases underwent surgical excision or biopsy, and specimens were examined in the Department of Pathology. Histopathological diagnosis was established based on microscopic evaluation and classified according to the WHO Classification of Central Nervous System Tumors (2021).

Data Correlation

MRI findings were correlated with histopathological diagnosis with respect to:

- Tumor type
- Tumor grade
- Diffusion characteristics

The concordance between radiological and histopathological diagnosis was assessed descriptively.

Statistical Analysis

Data were analyzed using descriptive statistics. Categorical variables were expressed as frequencies and percentages. The correlation between MRI diagnosis and histopathological findings was evaluated qualitatively.

Ethical Considerations

The study was conducted following institutional ethical guidelines. Patient confidentiality was maintained, and all data were anonymized prior to analysis.

RESULTS

A total of **22 cases** with suspected intracranial neoplasms were included in the study and correlated with histopathological diagnosis.

Demographic Distribution

The age of patients ranged from **7 to 64 years**, with a majority of patients in the **third to sixth decades** of life. Both pediatric and adult populations were represented. There was a slight female predominance among extra-axial tumors, particularly meningiomas.

Tumor Distribution

Based on Location

- **Intra-axial tumors:** Majority of cases
- **Extra-axial tumors:** Second most common
- **Sellar region tumors:** Notable proportion
- **Infratentorial tumors:** Predominantly pediatric

Based on Histopathological Diagnosis

The distribution of intracranial tumors based on histopathology is summarized in **Table 1**. Gliomas constituted the most common tumor group (**36.4%**), followed by meningiomas (**22.7%**) and pituitary adenomas (**18.2%**). Medulloblastomas accounted for **9.1%** of cases, while schwannomas and other tumors formed a smaller proportion.

Table 1: Distribution of Intracranial Tumors Based on Histopathology

Tumor Type	Number of Cases (n=22)	Percentage (%)
Gliomas (all grades)	8	36.4%
Meningiomas	5	22.7%
Pituitary adenomas	4	18.2%
Medulloblastoma	2	9.1%
Schwannoma	1	4.5%
Others	2	9.1%

The glioma subgroup included diffuse astrocytoma (WHO Grade II), anaplastic astrocytoma (WHO Grade III), glioblastoma (WHO Grade IV), oligodendroglioma (Grade II/III), and pleomorphic xanthoastrocytoma. Meningiomas included meningothelial, transitional, and secretory subtypes. Pituitary adenomas comprised acidophilic, null cell, and invasive macroadenomas.

MRI Characteristics

Gliomas

- Typically presented as intra-axial lesions with heterogeneous signal intensity
- Associated with perilesional edema, necrosis, and mass effect
- High-grade gliomas showed irregular margins and heterogeneous enhancement

Meningiomas

- Extra-axial, well-defined lesions
- Showed homogeneous contrast enhancement
- Some cases demonstrated calcification (SWI blooming)
- Associated with dural attachment and mass effect

Pituitary Adenomas

- Sellar lesions with suprasellar extension
- Showed homogeneous enhancement
- Caused compression of optic chiasma

Medulloblastoma

- Posterior fossa tumors arising from the fourth ventricle
- Caused obstructive hydrocephalus
- Showed intense post-contrast enhancement

Diffusion-Weighted Imaging (DWI) and ADC Findings

DWI and ADC findings showed a strong correlation with tumor grading, as summarized in **Table 2**.

High-grade tumors (WHO Grade IV), including glioblastoma and medulloblastoma, demonstrated marked diffusion restriction with low ADC values. Intermediate-grade tumors showed mild diffusion restriction with intermediate ADC values, whereas low-grade tumors (WHO Grade I–II) demonstrated no significant diffusion restriction with higher ADC values. Meningiomas showed variable diffusion characteristics depending on subtype, while pituitary

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adenomas did not show significant diffusion restriction.

Table 2: DWI and ADC Correlation with Tumor Grade

Tumor Grade	DWI Findings	ADC Values	Number of Cases
Low Grade (WHO I–II)	No restriction	High ADC	9
Intermediate Grade (WHO III)	Mild restriction	Intermediate ADC	5
High Grade (WHO IV)	Marked restriction	Low ADC	8

MRI–Histopathological Correlation

MRI findings showed good concordance with histopathological diagnosis in the majority of cases, particularly in:

- Differentiating high-grade vs low-grade gliomas
- Identifying extra-axial tumors such as meningiomas
- Characterizing sellar lesions

However, some overlap in imaging features was noted among glioma subtypes and between neoplastic and non-neoplastic lesions.

Non-Neoplastic Lesions

A small number of cases initially suspected as neoplastic were diagnosed as:

- Neurocysticercosis
- Brain abscess

These were excluded from final neoplasm correlation analysis.

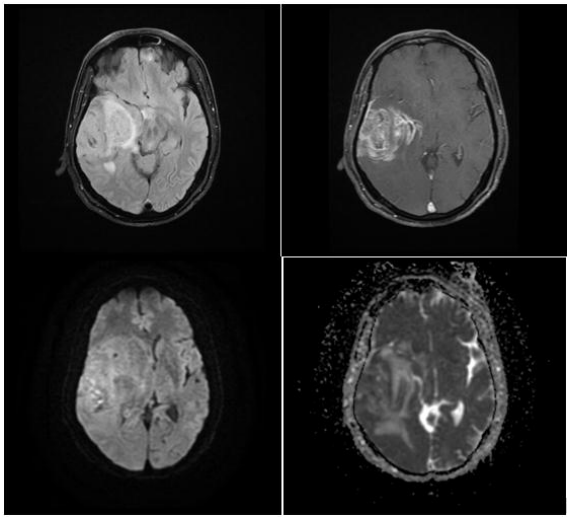

Figure 1: High Grade Glioma

Magnetic resonance imaging of a high-grade glioma involving the right temporoparietal region.
(a) Axial T2 FLAIR image showing a relatively well-defined hyperintense space-occupying lesion involving the right temporal and parietal lobes with significant surrounding edema involving adjacent frontal, parietal, and occipital lobes.
(b) Axial post-contrast T1-weighted image demonstrating heterogeneous enhancement of the lesion with associated pachymeningeal enhancement.
(c)Diffusion-weighted imaging (DWI, b1000) showing focal areas of diffusion restriction within the lesion.
(d) Corresponding ADC map showing low ADC values in the areas of restriction, suggestive of high tumor cellularity.
Imaging features are suggestive of a high-grade glioma.

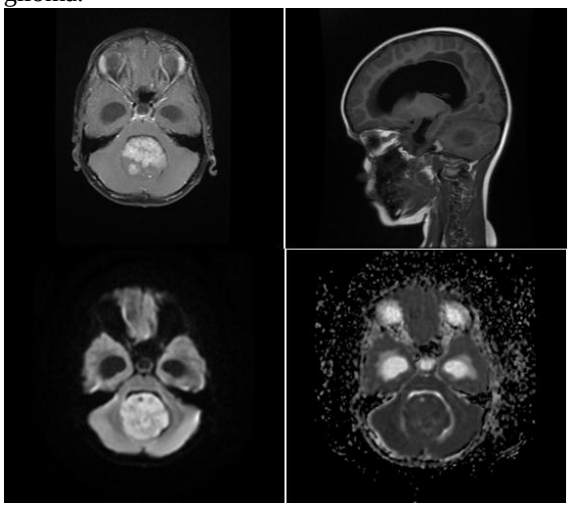

Figure 2: Medulloblastoma

Magnetic resonance imaging of a posterior fossa medulloblastoma arising from the roof of the fourth ventricle.
(a) Axial T1 fat-suppressed post-contrast image demonstrating a large, well-defined heterogeneously enhancing mass lesion arising from the roof of the fourth ventricle on the right side.
(b) Sagittal T2 FLAIR image showing the lesion causing obstruction of the ventricular system with resultant upstream hydrocephalus.
(c)Diffusion-weighted imaging (DWI) showing marked diffusion restriction within the lesion.
(d) Corresponding ADC map demonstrating low ADC values, consistent with high tumor cellularity.
Imaging features are suggestive of a WHO Grade IV tumor (medulloblastoma).

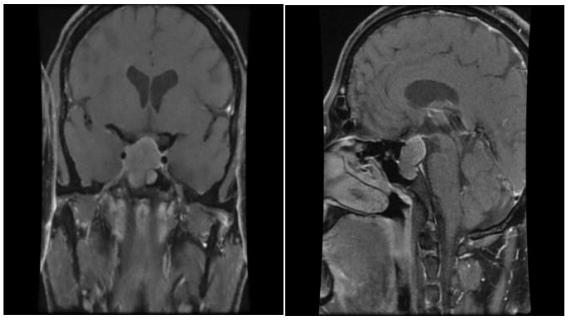

Figure 3: Invasive Pituitary Macroadenoma

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Magnetic resonance imaging of an invasive pituitary macroadenoma with suprasellar and infrasellar extension.
(a) Coronal **T1 fat-suppressed post-contrast image** demonstrating a well-defined, uniformly enhancing sellar mass involving the anterior lobe of the pituitary gland with suprasellar extension causing superior displacement and mild compression of the optic chiasma. Minimal parasellar extension is noted with mild compression of the cavernous segment of the internal carotid artery.
(b) Sagittal **T1 fat-suppressed post-contrast image** showing a large sellar lesion with diffuse widening and thinning of the bony sella, destruction of the sellar floor (Grade IV), and significant infrasellar extension into the right sphenoid sinus. The lesion also demonstrates suprasellar extension with displacement of the infundibulum and posterosuperior displacement of the posterior pituitary bright spot.
Imaging features are suggestive of an invasive pituitary macroadenoma.

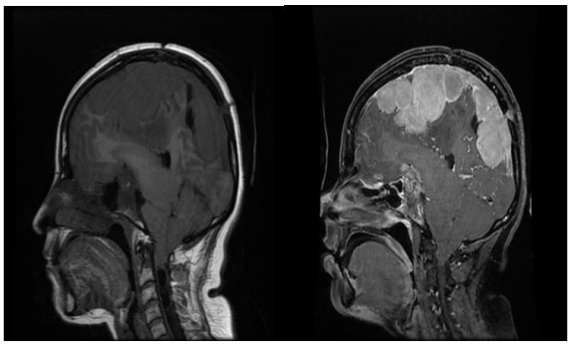

Figure 4: Multiple Intracranial Meningiomas

Magnetic resonance imaging of multiple intracranial meningiomas in a case of neurofibromatosis type 2 (NF-2).
(a) Sagittal **T2 FLAIR image** demonstrating multiple extra-axial lesions with significant mass effect, effacement of cortical sulci, and associated subfalcine and tonsillar herniation.
(b) Sagittal **post-contrast T1-weighted image** showing multiple homogeneously enhancing lesions with extensive involvement of the suprasellar region and skull base.
The lesions are associated with significant mass effect, ventricular compression, and herniation.

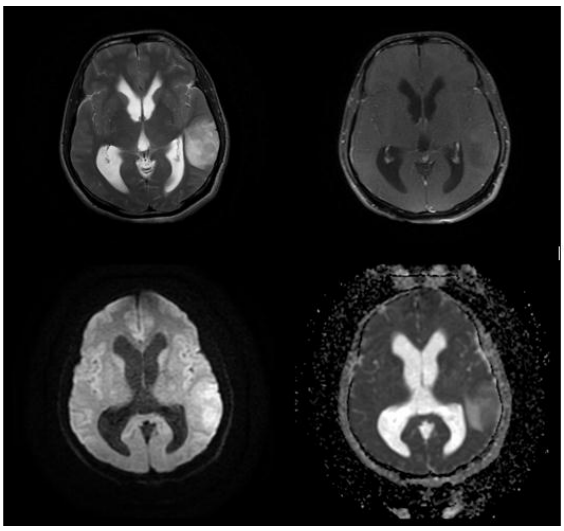

Figure 5: Low-Grade Glioma

Magnetic resonance imaging of a low-grade glioma in the left temporal lobe.
(a) Axial **T2-weighted image** showing a relatively well-defined lesion in the posterior aspect of the left temporal lobe, appearing of intermediate signal intensity with mild surrounding edema.
(b) Axial **post-contrast T1-weighted image** demonstrating patchy areas of enhancement in the superior aspect of the lesion with a non-enhancing cystic component inferiorly.
(c)Diffusion-weighted imaging (DWI) showing no evidence of diffusion restriction within the lesion.
(d) Corresponding **ADC map** demonstrating facilitated diffusion with relatively high ADC values.

DISCUSSION

Intracranial tumors comprise a diverse group of lesions with variable histopathological characteristics and clinical outcomes. Accurate preoperative diagnosis and grading are essential for appropriate management and prognostication. Magnetic resonance imaging (MRI) remains the imaging modality of choice due to its superior soft tissue resolution and multiplanar capability. In this study, conventional MRI sequences combined with diffusion-weighted imaging (DWI) and apparent diffusion coefficient (ADC) mapping were evaluated for their role in characterization and grading of intracranial tumors.
Gliomas constituted the most common group of tumors in the present study, consistent with previously reported literature. High-grade gliomas, particularly glioblastomas, demonstrated heterogeneous signal intensity, irregular margins, necrosis, and significant perilesional edema. These findings are in agreement with prior studies that describe such features as typical for aggressive tumors with rapid proliferation and angiogenesis.[1,2]
In contrast, low-grade gliomas appeared relatively well-defined with minimal edema and absence of necrosis.

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Diffusion-weighted imaging played a crucial role in tumor grading. High-grade tumors such as glioblastoma and medulloblastoma demonstrated marked diffusion restriction with low ADC values, reflecting high cellularity and reduced extracellular space. This inverse relationship between ADC values and tumor cellularity has been well established in previous studies.[3,4] Intermediate-grade tumors showed moderate restriction, whereas low-grade tumors demonstrated facilitated diffusion with higher ADC values. These findings support the utility of DWI and ADC as non-invasive biomarkers for tumor grading.

In the present study, medulloblastoma cases showed intense diffusion restriction, which correlates with their known hypercellular nature. Similar findings have been reported in earlier studies, where DWI has been shown to reliably differentiate medulloblastomas from other posterior fossa tumors.[5]

Meningiomas, the most common extra-axial tumors in this study, typically demonstrated homogeneous enhancement and well-defined margins. Diffusion characteristics in meningiomas were variable, which is consistent with existing literature suggesting that ADC values may vary depending on histological subtype and cellularity 6. However, typical imaging features such as dural attachment and extra-axial location allowed accurate diagnosis in most cases.

Pituitary adenomas in this study showed characteristic sellar location with suprasellar extension and optic chiasma compression. These lesions generally did not show significant diffusion restriction, which aligns with previous reports indicating that most pituitary adenomas have relatively low cellular density compared to high-grade tumors.[2]

The correlation between MRI findings and histopathology in this study was high, particularly in distinguishing high-grade from low-grade tumors and in identifying extra-axial lesions. However, overlap in imaging features was observed in certain cases, especially among glioma subtypes, highlighting the limitations of conventional MRI alone. This underscores the importance of incorporating advanced imaging techniques such as DWI and ADC mapping to improve diagnostic accuracy.

Non-neoplastic lesions such as neurocysticercosis and tuberculomas may mimic neoplastic lesions on conventional imaging. However, diffusion characteristics and spectroscopy findings can aid in differentiation. In the present study, such cases were excluded from final analysis, but their inclusion in initial evaluation reflects real-world diagnostic challenges.

Overall, the findings of this study are consistent with existing literature and reinforce the role of DWI and ADC as valuable adjuncts to conventional MRI in the evaluation of intracranial tumors. These techniques provide additional information regarding tumor cellularity and aggressiveness, thereby aiding in preoperative planning and management.

CONCLUSION

Magnetic resonance imaging (MRI) remains the cornerstone in the evaluation of intracranial tumors, providing comprehensive anatomical and morphological details essential for diagnosis and surgical planning. The present study demonstrates that conventional MRI sequences, when combined with advanced techniques such as diffusion-weighted imaging (DWI) and apparent diffusion coefficient (ADC) mapping, significantly improve the diagnostic accuracy in characterization and grading of intracranial neoplasms.

DWI and ADC values showed a strong correlation with tumor cellularity and histopathological grading. High-grade tumors, including glioblastoma and medulloblastoma, consistently demonstrated diffusion restriction with low ADC values, whereas low-grade tumors exhibited facilitated diffusion with higher ADC values. This highlights the role of diffusion imaging as a reliable, non-invasive biomarker in preoperative tumor grading.

MRI also proved highly effective in identifying tumor location and origin, particularly in differentiating intra-axial, extra-axial, and sellar lesions. Characteristic imaging features enabled accurate diagnosis of common tumors such as gliomas, meningiomas, and pituitary adenomas, with a high degree of concordance with histopathological findings.

However, certain limitations were observed, including overlap in imaging characteristics among tumor subtypes and challenges in differentiating neoplastic from non-neoplastic lesions in select cases. These findings emphasize the need for a multimodal imaging approach and correlation with clinical and histopathological data.

In conclusion, the integration of DWI and ADC mapping into routine MRI protocols provides valuable additional information that enhances lesion characterization, improves tumor grading, and aids in clinical decision-making. This approach can contribute to better treatment planning and prognostic assessment in patients with intracranial tumors.

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Conflicts of interest statement

The authors declare no conflicts of interest.

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