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DIAGNOSTIC ACCURACY OF DIFFUSION-WEIGHTED IMAGING IN POSTERIOR FOSSA TUMOR

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ABSTRACT

Background: Infratentorial intra-axial tumors in the cerebellum and brainstem differ between pediatric and adult populations. While MRI is essential for diagnosing posterior fossa tumors, its ability to differentiate tumor types and grades is limited. Diffusion-weighted imaging (DWI) and apparent diffusion coefficient (ADC) measurements offer additional insights into tumor cellularity and malignancy potential.

Objective: This study aims to evaluate the diagnostic accuracy of DWI and ADC values in differentiating posterior fossa tumors in pediatric and adult patients.

Methods: Conducted at the Department of Radiodiagnosis and Imaging, Sher I Kashmir Institute of Medical Sciences, Soura Srinagar, this study involved 68 patients (22 pediatric, 46 adult). MRI, including DWI, was performed, and ADC values were measured using region-of-interest (ROI) placement. Data were analyzed using SPSS, with statistical significance set at $p \leq 0.05$.

Results: Pediatric tumors included pilocytic astrocytomas, ependymomas, medulloblastomas, and brainstem gliomas, while adult tumors comprised metastases, meningiomas, hemangioblastomas, schwannomas, and cystic lesions. Medulloblastomas exhibited lower ADC values due to high cellularity, while pilocytic astrocytomas showed higher ADC values. In adults, ADC values effectively differentiated metastases, meningiomas, hemangioblastomas, and schwannomas.

Conclusion: DWI and ADC mapping provide valuable diagnostic insights for posterior fossa tumors, aiding in differentiation between tumor types. However, they should be integrated with conventional MRI and histopathological analysis for comprehensive tumor characterization. Further studies with larger cohorts and advanced imaging techniques may enhance diagnostic precision.

Keywords: Diffusion-weighted imaging, apparent diffusion coefficient, posterior fossa tumors, MRI

INTRODUCTION

Infratentorial intra-axial masses, which develop in the cerebellum or brainstem, differ significantly between pediatric and adult populations. Approximately 65% of pediatric brain tumors originate in the posterior fossa, with pilocytic astrocytoma, medulloblastoma, ependymoma, and brainstem

glioma being the most prevalent. In children, MRI and CT findings, when considered alongside tumor location, patient age, and sex, can accurately predict tumor histology in over 70% of cases[1]. While MRI plays a crucial role in diagnosing and evaluating brain tumors, it provides limited insight into tumor type and grading. Posterior fossa tumors include a wide range of neoplasms arising in the hindbrain, creating diagnostic challenges due to their anatomical complexity and diverse histopathological features[2]. These tumors commonly present with nonspecific symptoms such as headaches, ataxia, cranial nerve deficits, and hydrocephalus, making precise diagnosis essential for proper clinical management[3]. Though conventional imaging methods like CT and MRI are fundamental for diagnosing posterior fossa tumors, their ability to differentiate tumor types and determine tumor grade remains somewhat restricted[4]. Diffusion-weighted (DW) MRI offers additional insights by analyzing the microscopic movement of water protons, which conventional MRI alone cannot provide. This imaging technique has been applied to classify tumor grades, distinguish tumor types, and diagnose other brain space-occupying lesions[5]. Recent studies have investigated the role of DWI in assessing tumor grade and type in pediatric posterior fossa brain tumors[6]. Since ADC measurement reflects variations in water content and diffusion – potentially influenced by factors such as vasogenic edema – it is a valuable tool for tumor assessment[7]. The movement of water within the interstitium is a key factor contributing to increased ADC values[8]. Malignant tumors typically exhibit lower ADC values than benign tumors due to their high cellular density, which restricts water molecule diffusion[9]. Currently, DWI is utilized for cancer diagnosis[10], tumor grading[11], and monitoring treatment response[12]. However, ADC values often overlap across different tumor grades and types, making it unreliable as a sole diagnostic tool for brain tumors[13-15]. Conversely, several studies suggest that DWI can accurately differentiate between benign and malignant tumors as well as distinct histological subtypes of posterior fossa tumors[16-19]. ADC measurements in contrast-enhancing solid tumor regions of pediatric patients have shown significantly higher values in pilocytic astrocytomas compared to ependymomas and medulloblastomas[8]. Additionally, ependymomas tend to have higher ADC values than PNETs, with no overlap observed. Since the ADC values of ependymomas are consistently above 1×10^{-3} mm²/s and those of PNETs remain below this threshold, preoperative ADC measurement can aid in differentiating between these two tumor types within the fourth ventricle[20]. Medulloblastomas exhibit increased signal intensity on DWI and lower ADC values due to their densely packed cellular structure[21]. Water diffusion assessment in tissues is complex and influenced by factors such as medium viscosity, diffusion barriers, molecular crowding, active transport mechanisms, capillary bulk flow, and observation duration.

Tumor cellularity likely affects diffusion barriers and molecular crowding but not necessarily other contributing factors[16]. In pediatric patients, infratentorial tumors account for 54% to 70% of cases, whereas their prevalence in adults is notably lower, ranging between 15% and 20%. In contrast, supratentorial tumors are more common in adults[17]. Among adults, 15% to 20% of brain tumors occur in the posterior fossa, with subacute strokes being the most frequent lesion in this region. Vestibular schwannomas and cerebellar metastases represent the most common neoplastic lesions in the extra-axial and intra-axial categories, respectively[2]. Numerous studies have underscored the potential of DWI in improving the diagnostic accuracy of posterior fossa tumors. By measuring the apparent diffusion coefficient (ADC), researchers have sought to assess tumor cellularity and aggressiveness, thus aiding in preoperative planning and prognosis. Additionally, DWI has shown promise in distinguishing between benign and malignant posterior fossa lesions, a critical differentiation that significantly impacts treatment decisions and patient outcomes[18,19].

OBJECTIVE

To assess the diagnostic accuracy of diffusion-weighted imaging (DWI) and apparent diffusion coefficient (ADC) values in the evaluation and differentiation of posterior fossa tumors in both pediatric and adult populations.

MATERIAL AND METHODS

This study was conducted at the Sher I Kashmir Institute of Medical Sciences, Soura Srinagar. A total of sixty-eight patients participated in the study. Each patient underwent a thorough medical history review, neurological assessment, and MRI examination, which included both conventional MRI and diffusion-weighted imaging (DWI). Conventional MRI scans were performed with patients in the supine position using a standard head coil, ensuring that the head remained in a neutral position. For sagittal and axial T1-weighted non-contrast imaging, the parameters included a repetition time (TR) of 600 ms, an echo time (TE) of 15 ms, a slice thickness of 5 mm, and a 1 mm interslice gap. The field of view (FOV) was set at 230 × 183 × 130, with a matrix size of 256 × 163. Axial T2-weighted fast spin-echo images had parameters of 4000/100 (TR/TE), a 5 mm slice thickness, a 1 mm interslice gap, an FOV of 230 × 183 × 130, and a matrix of 350 × 224. Axial fluid-attenuated inversion recovery (FLAIR) images were captured with TR/TE values of 6000/90, a slice thickness of 5 mm, an interslice gap of 1 mm, an FOV of 230 × 183 × 130, and matrix sizes of 350 × 224 and 256 × 174. Additionally, contrast-enhanced axial, coronal, and sagittal T1-weighted images were acquired. DWI was carried out using a multi-section, single-shot spin-echo planar imaging (EPI) sequence with b-values of 0.5 and 1000 mm^2/s. Diffusion gradients were applied sequentially in three orthogonal directions. The imaging parameters included a slice thickness of 5 mm, an interslice gap of 1 mm, a 250-mm FOV, and a 128 × 256 matrix. The total acquisition time for DWI was approximately 80 seconds. The imaging process generated three types of images: orthogonal images, trace images, and apparent diffusion coefficient (ADC) maps. ADC maps were automatically calculated using the MRI software. Following this, contrast-enhanced T1-weighted imaging was performed after intravenous administration of a contrast agent at a dosage of 0.1 mmol/kg.

All DWI data were transferred to a dedicated computer workstation for further analysis, where signal intensity and ADC values were determined. The ADC values were obtained by positioning regions of interest (ROIs) manually, with each ROI's values automatically computed and recorded in units of 10^{-3} mm^2/s. ADC measurements were conducted using an ellipsoid ROI method, ensuring a uniform area between 50–100 mm^2. Three ROIs were placed in different sections of each tumor. The first ROI was positioned centrally within a homogeneously enhancing region of the tumor, while the other two ROIs were placed in similarly enhancing areas on separate sections, avoiding overlap with the first. The mean ADC value, along with the standard deviation (SD), was calculated from these three ROIs for statistical analysis. Data analysis was performed using SPSS (Statistical Package for the Social Sciences), version 20. ADC values were reported as mean ± standard deviation (SD). Group differences were assessed using univariate ANOVA. Correlations between variables were determined using Pearson's correlation test. A p-value of ≤ 0.05 was considered statistically significant, while a p-value ≤ 0.001 indicated high statistical significance. In contrast, a p-value > 0.05 was regarded as non-significant.

RESULTS

The study cohort consisted of 68 patients (38 males and 30 females) diagnosed with posterior fossa brain tumors. They were classified into two primary groups based on age: pediatric and adult. The diagnoses were determined using radiographic MR imaging and histopathological evaluation, except for brain stem gliomas in children and metastatic brain tumors in adults. Brain stem gliomas were identified solely through imaging and follow-up due to the challenges in obtaining biopsies. These tumors are inoperable and managed primarily with radiotherapy. Similarly, metastatic brain tumors in adults were diagnosed based on MRI findings, patient history, and follow-up assessments.

Pediatric Group

The pediatric group included 22 patients aged 2 to 15 years, with a mean age of 7.3 years. This group comprised 8 males and 14 females. The patients were further categorized into:

- **Juvenile Pilocytic Astrocytomas (JPA)** – 6 cases
- **Ependymomas** – 4 cases

- **Medulloblastomas** – 6 cases
- **Brain Stem Gliomas** – 6 cases

A comparison between the 1ROI and 3ROI methods for each pediatric tumor subtype revealed no significant difference (p = 0.572). All JPA cases had a cystic component with a solid mural nodule, appearing with increased signal intensity (SI) on DWIs (b0) and decreased SI on DWIs (b1000), indicative of free diffusion similar to cerebrospinal fluid (CSF).

Table 1: Mean ADC Values for Pediatric Posterior Fossa Tumors

Tumor Type	ADC ($\times 10^{-3}$ mm²/s)		p-value
	Mean	Standard Deviation (SD)	
JPA	1.63	± 0.05	< 0.001
Medulloblastoma	0.73	± 0.06	< 0.05
Ependymoma	1.15	± 0.07	< 0.05
Brain Stem Glioma	1.37	± 0.12	< 0.05

Adult Group

The adult group consisted of 46 patients aged 24 to 65 years, with a mean age of 46.4 years. This group comprised 30 males and 16 females. The distribution of posterior fossa tumors among adults was as follows:

- **Metastasis** – 10 cases
- **Cerebellar (Infratentorial) Meningiomas** – 8 cases
- **Hemangioblastomas** – 6 cases
- **Cerebellopontine Angle (CPA) Acoustic Schwannomas** – 10 cases
- **CPA Epidermoid Tumors (Cysts)** – 4 cases
- **Arachnoid Cysts** – 4 cases
- **CPA Meningiomas** – 4 cases

A comparison of 1ROI and 3ROI methods within each adult subgroup found no significant difference (p = 0.641). All hemangioblastoma cases exhibited a cystic component with a solid mural nodule, showing increased SI on DWIs (b0) and decreased SI on DWIs (b1000), signifying free diffusion comparable to CSF.

Table 2: Mean ADC Values for Pediatric Posterior Fossa Tumors

Tumor Type	ADC ($\times 10^{-3}$ mm²/s)		p-value
	Mean	Standard Deviation (SD)	
Epidermoid Tumors (Cysts)	0.85	± 0.07	< 0.05
Arachnoid Cysts	2.95	± 0.02	< 0.05

DISCUSSION

The findings of this study align with previous literature regarding the role of DWI and ADC values in differentiating posterior fossa brain tumors. The study aimed to evaluate the efficacy of ADC values in distinguishing between various tumor types in pediatric and adult patients, and the results confirmed significant differences between different tumor subtypes, reinforcing previous research findings.

In the pediatric group, our study demonstrated a significant difference in mean ADC values between juvenile pilocytic astrocytoma (JPA), medulloblastoma, ependymoma, and brain stem glioma, which is consistent with the study by Rumboldt Z et al., (2006)[22]. Their study, which included 31 pediatric patients, also found a significant difference between ADC values of JPA and medulloblastoma, as well as between ependymoma and medulloblastoma. This supports the role of

ADC in distinguishing highly cellular tumors like medulloblastomas from tumors with lower cellularity such as JPAs. However, our study did not find a significant difference between JPA and ependymoma, which is also in agreement with their findings. The high ADC values in JPAs are attributed to their low cellularity and vacuolated tumor matrix, which aligns with histopathological findings in prior research (Kleihues P et al., 2002)[23]. Similarly, the low ADC values of medulloblastomas can be explained by their densely packed small cells with a high nuclear-to-cytoplasmic ratio [11]. Our results showed no overlap between ADC values of JPA and medulloblastoma, which contradicts the findings of Schneider JF et al., (2007)[14], who reported some degree of overlap. However, the differentiation between ependymoma and medulloblastoma was confirmed in our study, which supports Yamasaki F et al., (2005)[24], who found that ADC values were highly accurate in distinguishing between ependymomas and primitive neuroectodermal tumors (PNETs).

In the adult cohort, our study found that ADC values for cerebellar meningiomas ranged between 0.88 and 1.42 × 10−3 mm²/s, which is consistent with the range reported by Tantawy HI et al., (2010)[25] (0.72 to 1.8 × 10−3 mm²/s). Additionally, our findings for ADC values of CPA acoustic schwannomas were higher than those for CPA meningiomas, which supports the study by Pavlisa G et al., (2008)[26]. This may be due to the higher extracellular matrix content and elongated Schwann cells contributing to greater water diffusion in acoustic schwannomas (Sadeghi N et al., 2003)[27]. In the case of metastatic brain tumors, our study did not find a significant difference in ADC values when compared to hemangioblastomas (solid mural nodule), which is consistent with findings reported by Cha J et al., (2017)[28]. Furthermore, Quadery FA and Okamoto K (2003)[29] also noted that hemangioblastomas generally have higher ADC values relative to other cerebellar tumors, which aligns with our results.

Regarding tumor-like cystic lesions, the findings in our study confirmed the differentiation between CPA epidermoid tumors and arachnoid cysts based on DWI and ADC values. Epidermoid tumors showed restricted diffusion with low ADC values, while arachnoid cysts demonstrated free diffusion with high ADC values. This is in agreement with Lai PH et al., (2007)[30] and additional studies that reported significant differences between these cystic lesions (Chen S et al., 2001 and Hakyemez B et al., 2005)[31,32]. The restricted diffusion in epidermoid tumors can be attributed to their high protein and cholesterol content, as well as keratinaceous debris, which contribute to lower ADC values (Sirin S et al., 2005)[33]. While our study reinforces the significance of DWI and ADC values in differentiating posterior fossa tumors, it also highlights the limitations of relying solely on these imaging sequences. As noted in prior research, including studies by Schneider JF et al., (2007)[14] and Lalwani AK and Jackler RK, 1993[34], a combination of conventional MRI sequences, contrast enhancement patterns, and histopathological correlation remains essential for accurate tumor characterization. Therefore, while DWI serves as a valuable adjunct in tumor classification, it should not be used in isolation.

Overall, our results confirm the usefulness of ADC values in distinguishing between different tumor types in both pediatric and adult patients. These findings contribute to the growing body of evidence supporting the role of DWI in preoperative planning and postoperative follow-up for posterior fossa tumors. Future studies with larger sample sizes and multimodal imaging approaches may further refine diagnostic accuracy and improve tumor differentiation in clinical practice.

CONCUSION

This study confirms the value of Diffusion-Weighted Imaging (DWI) and Apparent Diffusion Coefficient (ADC) values in differentiating posterior fossa brain tumors in pediatric and adult patients. Significant ADC variations were observed among tumor types, with medulloblastomas showing lower ADC values due to high cellularity, while JPAs exhibited higher ADC values. In adults, ADC measurements effectively distinguished between metastases, meningiomas, hemangioblastomas, schwannomas, epidermoid tumors, and arachnoid cysts. While DWI and ADC mapping are valuable diagnostic tools, they should be used alongside conventional MRI and

histopathological analysis for accurate tumor characterization. Future studies with larger cohorts and advanced imaging techniques may further enhance diagnostic precision.

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