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# ROLE OF QUANTITATIVE DIFFUSION-WEIGHTED IMAGING IN DIFFERENTIATING BENIGN AND MALIGNANT ORBITAL MASSES – A CROSS SECTIONAL STUDY

**Radio-Diagnosis**

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## ABSTRACT

The orbit is a highly complex anatomical compartment that contains the globe, optic nerve, extraocular muscles, vessels, and supporting connective tissue. A wide spectrum of benign and malignant lesions can arise within this space, often leading to impaired vision, ocular motility disturbances, and reduced quality of life. Accurate diagnosis and characterization of orbital masses are therefore essential for effective treatment planning and prognostic assessment. Conventional imaging techniques such as computed tomography and standard magnetic resonance imaging (MRI) are invaluable in evaluating orbital pathology; however, significant overlap in imaging features frequently limits their ability to reliably distinguish between benign and malignant lesions. Diffusion-weighted imaging (DWI), an advanced MRI technique, has recently emerged as a promising adjunct in orbital imaging. By assessing the Brownian motion of water molecules within tissues and calculating the apparent diffusion coefficient (ADC), DWI provides indirect insights into tissue microstructure and cellularity. Malignant tumors, with their higher cellular density and reduced extracellular space, tend to exhibit restricted diffusion and correspondingly lower ADC values compared with benign lesions. Multiple studies have demonstrated the potential of DWI and ADC mapping in differentiating orbital masses such as lymphoma, optic nerve glioma, cavernous hemangioma, and inflammatory pseudotumor. Although some overlap in ADC values exists, malignant lesions consistently show lower values, supporting the diagnostic utility of this technique. Importantly, DWI is non-invasive and does not require contrast, making it particularly valuable in patients with contraindications. This study evaluates the role of quantitative diffusion-weighted imaging in distinguishing benign from malignant orbital masses.

## KEYWORDS

3T MRI, DWI AND ADC, Orbital Masses, Benign, Malignant.

## INTRODUCTION

The orbit is a highly complex anatomical region containing the globe, optic nerve, extraocular muscles, vascular structures, and connective tissue, all of which may be affected by a wide range of pathological conditions. Orbital masses, whether benign or malignant, can significantly compromise vision, ocular motility, and overall quality of life. Therefore, accurate characterization of these lesions is essential for appropriate treatment planning and prognostic evaluation.

Conventional imaging modalities such as computed tomography (CT) and standard magnetic resonance imaging (MRI) have long been used in the evaluation of orbital pathology. However, due to overlapping imaging features, these techniques often fall short in reliably distinguishing benign from malignant lesions. Advanced MRI techniques, particularly diffusion-weighted imaging (DWI), have emerged as promising non-invasive tools that provide additional functional information beyond morphology.

DWI assesses the random motion of water molecules within tissues, quantified by the apparent diffusion coefficient (ADC). Malignant tumors, characterized by higher cellularity and reduced extracellular space, generally demonstrate restricted diffusion with lower ADC values. Conversely, benign lesions tend to exhibit higher ADC values, reflecting less cellular density and relatively free diffusion. This property makes DWI an important imaging biomarker for differentiating orbital masses. Importantly, it does not require contrast administration, making it suitable for patients with contraindications to gadolinium.

The present study aims to evaluate the role of quantitative diffusion-weighted imaging in differentiating benign and malignant orbital masses.

## REVIEW OF LITERATURE

The orbit is a pear-shaped bony cavity formed by seven bones: sphenoid, frontal, zygomatic, ethmoid, lacrimal, maxilla, and palatine. It measures approximately 30 cc in volume, with a depth of 40–45 mm in adults. The orbital cavity houses the globe, optic nerve, extraocular muscles, vessels, lacrimal gland, fat, and connective tissue. Its walls are thin in certain regions, especially the lamina papyracea, making it susceptible to disease spread from adjacent sinuses. Accurate evaluation of orbital masses is vital, as they may significantly affect vision, ocular motility, and cosmesis.

DWI is a non-invasive MRI technique that assesses the Brownian motion of water molecules. This is quantified by the apparent diffusion coefficient (ADC), which reflects tissue cellularity and extracellular space. Malignant tumors, characterized by high cellular density and reduced extracellular space, restrict diffusion and show low ADC values. In contrast, benign lesions usually have higher ADC values, reflecting less restricted diffusion.

Several studies have demonstrated the utility of DWI in differentiating orbital lesions. Malignant tumors such as lymphoma, rhabdomyosarcoma, and metastases typically exhibit ADC values between 0.40–0.80 $\times 10^{-3}$ mm²/s, whereas benign lesions like cavernous hemangioma and schwannoma show values above 1.2 $\times 10^{-3}$ mm²/s. A threshold ADC cut-off of 1.0–1.2 $\times 10^{-3}$ mm²/s has been proposed for reliable differentiation.

Thus, quantitative DWI adds functional insight to conventional MRI, improving diagnostic accuracy, guiding management, and aiding in treatment response assessment of orbital masses.

## MATERIALS AND METHODS

This cross-sectional observational study was conducted in the Department of Radiology, Tertiary Care Centre, Central India, over a period of two years. The study population comprised patients with clinically suspected orbital masses referred for orbital MRI.

Inclusion criteria were patients diagnosed with orbital mass lesions and those providing informed consent. Exclusion criteria included patients with contraindications to MRI (pacemakers, metallic implants), non-consenting/uncooperative patients, and those with prior orbital surgery for mass lesions referred for follow-up.

Sample size estimation was based on a previously published study (Mundhada et al.) with an expected proportion of 0.8636, precision of 2%, and 95% confidence interval. Using the standard formula, the required sample size was calculated as 31.

MRI examinations were performed on a 3T Siemens MAGNETOM VIDA scanner. The imaging protocol included scout sagittal T1-weighted images, 3D FLAIR brain screening, axial and coronal T1- and T2-weighted sequences with fat suppression, and contrast-enhanced T1-weighted fat-suppressed images in axial, coronal, and sagittal planes. Axial diffusion-weighted imaging (DWI) with ADC mapping was performed in all cases, and additional gradient-echo or balanced steady-state sequences were obtained if required.

ADC maps were generated, and quantitative ADC values were calculated by placing region of interest (ROI) within the solid portion of lesions, avoiding cystic, necrotic, or hemorrhagic areas.

Data were tabulated in Microsoft Excel and analyzed using SPSS v24. Continuous variables were expressed as mean ± SD, categorical variables as frequencies/percentages, and independent t-test was applied. A $p \leq 0.05$ was considered statistically significant. Ethical approval was obtained, and patient confidentiality was strictly maintained.

## RESULTS AND OBSERVATIONS

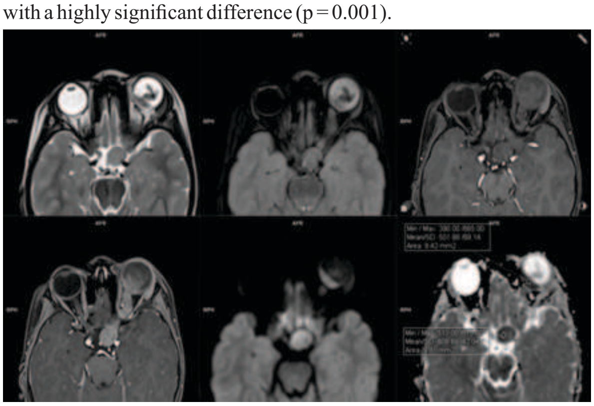
A total of 31 patients with orbital mass lesions were evaluated in this study.

The age distribution revealed that the majority of patients (58.1%) were younger than 20 years, highlighting a predominance of orbital lesions in the pediatric and adolescent age group. Patients aged above 60 years accounted for 19.4%, while those between 20–40 years and 40–60 years contributed 12.9% and 9.7%, respectively. The mean age of presentation was 28.05 ± 5.89 years. With respect to sex distribution, females formed a slight majority at 54.8%, while males accounted for 45.2%.

Clinical presentations were highly variable. The most common complaints included headache with drooping eyelid and frozen globe, leukocoria with exotropia, proptosis with decreased vision, swelling over the eyelid, and painful swelling with vision loss, each reported in 6.5% of patients. Other presentations, such as conjunctival melanoma, optic nerve glioma, sudden vision loss, trauma, and peri-orbital edema, were infrequent, appearing in only one participant each.

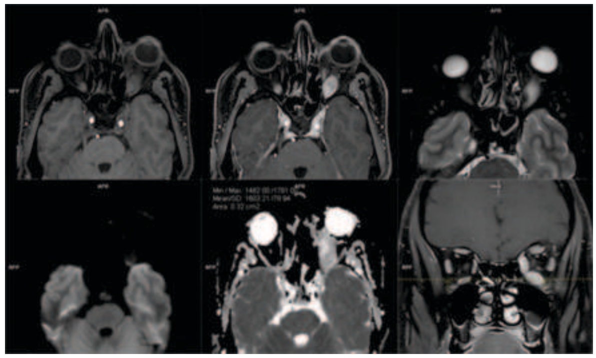
MRI demonstrated a wide spectrum of findings. The most frequent abnormalities (6.5% each) were intraocular lesions with calcific foci, intraorbital abscess with cellulitis, optic neuritis with myositis, orbital apex lesions with bony involvement, and preseptal orbital lesions. Other isolated findings included bilateral orbital masses, choroidal detachment, optic nerve atrophy, and intracranial extension. Diffusion-weighted imaging further stratified lesions: 48.4% showed no restriction, while definite diffusion restriction was observed in 19.4%. Peripheral restriction, mild restriction, and patchy areas of restriction were also documented.

Imaging impressions most often suggested orbital hemangioma (9.7%). Other diagnoses, including retinoblastoma, lymphoproliferative disorders, peri-orbital cellulitis, and optic neuritis with myositis, were less frequent. Final categorization showed benign lesions in 64.5% of cases and malignant lesions in 35.5%. Quantitative analysis revealed that benign lesions had a significantly higher mean ADC value (1.24 ± 0.32) compared to malignant lesions (0.76 ± 0.41), with a highly significant difference ($p = 0.001$).



3 year old female child presented with leukocoria and swelling in left eye. MRI ORBIT shows T2 hypointense lesion in the left eyeglobe extending along left optic nerve and optic chiasma which appears hypointense on FLAIR, isointense on T1, with enhancement on post contrast T1 images. It shows diffusion restriction with mean ADC VALUE of 0.5 x 10-3 mm2/sec. The imaging diagnosis was malignant neoplastic etiology- likely retinoblastoma.

The patient was given neoadjuvant chemotherapy followed by surgery. Postoperative HPE report revealed Retinoblastoma.



19 year old female with proptosis, MRI Orbit reveals swelling involving enlargement of medial and inferior recti muscles with mean ADC value of 1.6 x 10-3 mm2/sec – suggestive of benign etiology- thyroid opthalmopathy. Further biochemical testing revealed hyperthyroidism.

## SUMMARY AND CONCLUSION

This study highlights the important role of quantitative diffusion-weighted imaging (DWI) and apparent diffusion coefficient (ADC) values in the evaluation of orbital masses. A significant difference was observed between benign and malignant lesions, with malignant tumors demonstrating lower ADC values, consistent with their higher cellular density and restricted water diffusion. These findings reinforce the value of ADC as a non-invasive imaging biomarker that can improve diagnostic accuracy when conventional MRI characteristics are inconclusive.

The results also emphasize the heterogeneity of orbital lesions, both in their clinical presentations and imaging patterns. While conventional MRI provides detailed anatomical and structural information, the addition of DWI and ADC mapping offers functional insights that complement morphologic assessment. This combined approach can help clinicians narrow differential diagnoses, stratify risk, and optimize treatment planning. Importantly, ADC analysis may also aid in monitoring therapeutic response in malignant lesions, as changes in diffusion properties can precede measurable changes in lesion size.

Despite its promising role, the study acknowledges certain limitations, including a relatively small sample size, single-center design, and potential referral bias in a tertiary care setting. Future research with larger, multicentric cohorts is required to establish standardized ADC cut-off values for differentiating specific orbital pathologies. Nevertheless, the present study demonstrates that incorporating DWI and ADC evaluation into routine orbital MRI protocols has the potential to reduce the need for invasive diagnostic procedures, thereby improving patient care and aligning with the broader movement toward precision, non-invasive radiological diagnostics.

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