EDITORIAL

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Radiological Imaging in Diagnosing Orbital Pathologies

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Orbital pathologies encompass a broad spectrum of conditions, including tumors, inflammatory disorders, and infections. Given the overlapping clinical signs and symptoms among these conditions, radiological imaging plays a crucial role in accurate diagnosis and management. This editorial provides an overview of key imaging modalities used in assessing orbital lesions, with a focus on their diagnostic advantages and limitations.

The main imaging modalities used in orbital pathologies are computed tomography (CT) and magnetic resonance imaging (MRI). While CT remains an essential tool for assessing bony abnormalities and allows some soft tissue visualization, MRI provides superior soft tissue visualization and aids in determining the extent of orbital disease. A compartment-based approach, which categorizes lesions based on their anatomical location, facilitates the distinction between tumors and other pathological changes by analyzing specific imaging characteristics, lesion morphology, and spatial distribution.

The classification of orbital lesions is typically based on four anatomical compartments: the ocular globe, the muscle cone, and the intraconal and extraconal spaces.[1,2] This approach enhances diagnostic precision by correlating lesion location with potential pathological processes.

CT is a form of ionizing radiation. It uses X-rays to produce cross-sectional images of the body by measuring the attenuation of the X-ray beam as it passes through tissues. It measures the attenuation of different tissues in units of Hounsfield (HU), which in turn determines the density of images displayed on CT scan. It is a linear scale that quantifies the density of tissues, with water being 0 HU and air being -1000 HU. More dense tissues, such as bones, have positive Hounsfield values, while less dense tissues, like fat, have negative Hounsfield values.

MRI is a form of non-ionizing radiation. It employs a different technique, which essentially utilizes magnetic fields to generate cross-sectional images. Unlike CT, MRI images depend on signal intensity, which are a measure of T1 or T2 relaxation, depending on the sequence being utilized. The signal intensity of tissues in MRI images is influenced by several factors, including the type of radiofrequency pulse and gradient waveforms used, the intrinsic T1 and T2 properties of different tissues, and their proton density. By adjusting these parameters, radiologists can generate various pulse sequences, each optimized for specific diagnostic purposes. Commonly employed sequences include T1-weighted, T2-weighted, and proton density-weighted images.

T1-weighted images are particularly useful for visualizing normal anatomical patterns, where fat appears bright while fluids appear dark. Conversely, T2-weighted imaging is more effective in detecting pathological changes, as fluid-containing abnormalities, such as edema, inflammation, or neoplasms appear bright.

Recent advancements in high-resolution MRI technology have further improved image quality and diagnostic precision. Modern scanners incorporate sophisticated pulse sequences that allow for better differentiation of tissue types and pathological processes, thereby enhancing the detection and characterization of orbital lesions.[3]

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CT in orbital imaging

A CT machine is composed of an X-ray tube, filter, collimator, detector array, and a gantry. This assembly rotates around the patient, who lies on a motorized table moving through the scanner. Modern multidetector CT scanners provide faster scanning times and higher-resolution images, which are particularly beneficial for detailed imaging of the heart, abdomen, and orbital structures.

The data collected by the detectors consist of multiple X-ray images captured from various angles. A computer processes these raw images to generate two-dimensional tomographic slices, which can be reconstructed in any desired plane. Additionally, CT data can be reformatted into detailed three-dimensional representations, enhancing the visualization of complex anatomical structures.

In some scanning protocols, the table moves incrementally, pausing after each slice acquisition, while in other protocols, it moves continuously. The latter approach, known as helical or spiral CT, allows for uninterrupted data collection as the patient moves in a straight line while the detectors rotate around them, producing a seamless volumetric dataset.

The principles of tomographic imaging extend beyond CT to nuclear medicine techniques, such as single-photon emission CT (SPECT) and positron-emission tomography (PET), where emitted radiation from radiopharmaceuticals is detected by sensors surrounding the patient.[4] These signals are processed using computational algorithms to generate cross-sectional images of metabolic and functional activity.

CT is considered the primary imaging modality for evaluating orbital pathology due to its rapid acquisition and spatial resolution. However, MRI is often preferred in specific scenarios, such as assessing lesions at the orbito-cranial junction, orbital vascular abnormalities, or cases where the relationship between the lesion and the optic nerve is unclear on CT scans.[5]

CT can be particularly valuable in diagnosing orbital masses, including tumors and inflammatory conditions, by assessing lesion density and contrast enhancement patterns. It is also the modality of choice for detecting calcifications and evaluating osseous orbital abnormalities or suspected metallic foreign bodies. Several orbital pathologies, including retinoblastoma, cavernous hemangioma, optic nerve sheath meningioma, and dermoid cysts, frequently exhibit calcification, making CT an indispensable tool in their assessment.[6]

MRI in orbital pathology

MRI provides superior soft tissue contrast and is particularly helpful in determining disease extent, lesion localization, and compartment involvement. It is highly effective in differentiating between benign and malignant lesions and is an essential imaging modality for evaluating both orbital and intracranial abnormalities.[1,7]

A study involving 145 participants (55.2% female and 44.8% male), primarily aged 18–30 years, demonstrated MRI's high diagnostic accuracy, with 93.1% accuracy in identifying benign masses and 88.3% accuracy in diagnosing malignant masses.[7]

Research has consistently highlighted MRI's superiority over CT in terms of soft tissue contrast, flow sensitivity, and the absence of ionizing radiation, making it particularly advantageous for characterizing orbital compartments and vascular abnormalities.[6,8]

Advanced MRI techniques, such as dynamic contrast-enhanced (DCE) MRI and diffusion-weighted imaging (DWI), are being increasingly explored for their role in oncologic applications, particularly in the evaluation of head and neck tumors.[8] DWI, combined with apparent diffusion coefficient (ADC) mapping, provides valuable quantitative data that enhances tumor characterization. Generally, malignant orbital tumors exhibit lower ADC values compared to benign lesions due to their hypercellularity, enlarged nuclear size, and reduced extracellular space.[8]

DWI generates image contrast based on the diffusivity of water molecules within tissues, offering a powerful tool for investigating pathological changes. By utilizing ADC values, echo-planar imaging in DWI facilitates the distinction between benign and malignant orbital masses. Infiltrative orbital masses typically appear hypointense on T2-weighted images, whereas well-defined, hyperintense lesions are more easily characterized. Malignant masses, particularly orbital lymphomas, demonstrate both quantitatively and visually lower ADC values due to restricted diffusion, which correlates with increased cellularity and a higher nuclear-to-cytoplasmic ratio.[6]

Despite its diagnostic advantages, ADC measurements in clinical practice are subject

to variability due to some factors such as MRI acquisition parameters, magnetic field strength, and the method used for selecting the region of interest. A previous study has highlighted these challenges, emphasizing the need for standardized imaging protocols to ensure consistency in ADC evaluation.[8]

Advancements in MRI and DWI for orbital pathology

Studies indicate that the combination of MRI scanning, ADC analysis, and clinical findings significantly enhances the accuracy of differentiating between benign and malignant orbital masses.[8] One study reviewing 40 pediatric orbital masses (9 malignant and 31 benign) identified an ADC cut-off value of 1.14×10^{-3} mm^2/sec, yielding a sensitivity of 84% and specificity of 100%, effectively distinguishing benign from malignant lesions.[9]

Certain orbital tumors can mimic benign conditions, leading to diagnostic challenges. For example, rhabdomyosarcoma can resemble benign conditions, such as an infantile hemangioma, particularly when adjacent skeletal structures remain unaffected. However, an ADC threshold below 1.159×10^{-3} mm^2/sec consistently differentiates between these two entities.

Additionally, distinguishing idiopathic orbital inflammation (IOI) from lymphoma is critical, as their treatments differ significantly. While lymphoma is typically managed with chemotherapy and/or radiotherapy, IOI is treated with immunosuppressive agents or corticosteroids. DWI and arterial spin labelling have proven useful in this context, with lymphoma exhibiting markedly reduced diffusivity and relatively increased perfusion.[2]

Studies suggest that ADC values for orbital lymphoma generally fall between 0.44 and 0.92×10^{-3} mm^2/sec. One investigation demonstrated a 100% accuracy in differentiating orbital lymphoma from IOI when using an ADC threshold of 1.0×10^{-3} mm^2/sec and an ADC ratio below 1.2×10^{-3} mm^2/sec (range = $1.02–2.28 \times 10^{-3}$ mm^2/sec).[6]

Radiological imaging exhibits variable accuracy in diagnosing orbital conditions. For example, in cases of thyroid eye disease, imaging-based diagnosis achieves an accuracy of 73.2%, while non-specific orbital inflammation demonstrates an accuracy of 77.3%. Given the potential overlap in clinical and radiological features, precise differentiation is essential, as these conditions require distinct management strategies.[10]

One of the primary challenges in orbital imaging is differentiating sarcoidosis from lymphoma, as both conditions may present similar findings on cross-sectional imaging. Sarcoidosis is a chronic, multisystemic granulomatous disease that frequently involves the orbit, leading to pseudotumoral intra-orbital masses, optic nerve thickening, or lacrimal gland and extraocular muscle infiltration, which is usually bilateral. Additionally, intracranial extension may occur. Even on DWI, sarcoidosis may closely resemble lymphoma. However, the presence of lung lesions, bilateral hilar lymphadenopathy, and elevated serum angiotensin-converting enzyme levels supports a diagnosis of sarcoidosis. A biopsy remains the gold standard for confirming non-caseating granulomas, which are characteristic of sarcoidosis.[6,11]

Orbital lesions encompass a diverse range of pathologies, including tumors, inflammatory diseases, and infections, necessitating advanced imaging techniques for accurate diagnosis and management. MRI and CT serve as essential modalities in this field, each with specific advantages. MRI, with its superior soft tissue contrast and functional imaging capabilities, plays a pivotal role in detecting lesion extent and differentiating between benign and malignant processes. Techniques such as DCE-MRI and DWI have significantly enhanced diagnostic precision, particularly in oncological applications.

CT remains the primary diagnostic imaging modality for orbital evaluation, particularly for detecting osseous abnormalities, calcifications, and foreign bodies. Multidetector CT scanners facilitate rapid acquisition and high-resolution imaging, making CT indispensable in ophthalmology. While MRI is often considered a secondary modality, it is crucial for assessing lesions at the orbito-cranial junction, vascular abnormalities, and cases requiring precise optic nerve evaluation.

Recent advancements, including quantitative ADC mapping and functional MRI techniques, have further refined the ability to characterize orbital masses. Despite these technological developments, certain conditions, such as sarcoidosis and lymphoma, continue to pose diagnostic challenges. In such cases, a multimodal approach, incorporating clinical assessment, imaging findings, and histopathological

confirmation, remains essential to ensure accurate diagnosis and optimal patient management.

REFERENCES

1. Gokharman D, Aydin S. Magnetic resonance imaging in orbital pathologies: a pictorial review. J Belg Soc Radiol 2018 Jan;101(1):5.
2. Joseph AK, Guerin JB, Eckel LJ, Dalvin LA, Keating GF, Liebo GB, et al. Imaging findings of pediatric orbital masses and tumor mimics. Radiographics 2022;42(3):880-897.
3. Mafraji MA. Magnetic resonance imaging. MSD Manual Professional Edition. 2023 [cited 2025 Feb]. Available from: https://www.msdmanuals.com/professional/special-subjects/principles-of-radiologic-imaging/magnetic-resonance-imaging.
4. Mafraji MA. Computed Tomography. MSD Manual Professional Edition. 2023 [cited 2025 Feb]. Available from: https://www.msdmanuals.com/professional/special-subjects/principles-of-radiologic-imaging/computed-tomography-ct.
5. Tawfik HA, Abdelhalim A, Elkafrawy MH. Computed tomography of the orbit - a review and an update. Saudi J Ophthalmol 2012 Oct;26(4):409-418.
6. Purohit BS, Vargas MI, Ailianou A, Merlini L, Poletti P-A, Platon A, et al. Orbital tumours and tumour-like lesions: exploring the armamentarium of multiparametric imaging. Insights Imaging 2016 Feb;7(1):43-68.
7. Samad A, Shoukat S, Nisar P, Varsha, Bibi A, Sanjna, et al. Diagnostic accuracy of MRI in detecting orbital masses keeping histopathology as gold standard. J Health Rehabil Res 2024;4(1):1148-1152.
8. Soliman A, Aggag M, Abdelgawwad A, Aly W, Yossef A. Role of diffusion weighted MRI in evaluation of orbital lesions. Al-Azhar Int Med J 2020;1(3):331-336 .
9. Jaju A, Rychlik K, Ryan ME. MRI of pediatric orbital masses: role of quantitative diffusion-weighted imaging in differentiating benign from malignant lesions. Clin Neuroradiol 2020 Sep;30(3):615-624.
10. Lee MJ, Hamilton BE, Pettersson D, Ogle K, Murdock J, Dailey RA, et al. Radiologic imaging shows variable accuracy in diagnosing orbital inflammatory disease and assessing its activity. Sci Rep 2020 Dec;10(1):21875.
11. Ji B, Khatun N, Mostafidi E, Gupta R, McFarlane SI. Sarcoidosis versus lymphoma: a clinical diagnostic dilemma in a patient with extensive lymphadenopathy. Cureus 2023 Aug;15(8):e43281.