ORIGINAL ARTICLE

Diagnostic Accuracy of B-Scan and Contrast-Enhanced High-Resolution Magnetic Resonance Imaging (MRI) for Detection of Retinoblastoma Taking Histopathology as Gold Standard

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Abstract:
To determine the diagnostic accuracy of B-scan ultrasound and contrast-enhanced MRI (CE-MRI) for detecting retinoblastoma, using histopathology as the gold standard.
Methods: This cross-sectional validation study was conducted at the Radiology Department of Bahawal Victoria Hospital (BVH), Bahawalpur, from June to December 2024. Children aged 6 months to 5 years with clinical suspicion of retinoblastoma were included. Exclusion criteria included prior diagnosis, treatment (chemotherapy or radiotherapy), or ocular trauma. All participants underwent B-scan ultrasound, CE-MRI, and surgical evaluation. Data was analyzed using SPSS v23.0. The values of sensitivity, specificity, positive predictive value (PPV) and negative predictive value (NPV) were calculated.
Results: We analyzed 64 patients who were suspected of having retinoblastoma. The mean age of patients was 2.6 ± 1.35 years. Overall diagnostic accuracy of B-scan was 62.50% and for CE MRI was 89.1%. B-scan ultrasound had sensitivity and specificity of 75% and 35% respectively. CE MRI was positive in 49 patients (76.6%) having sensitivity and specificity of 97.7% and 70% respectively.
Conclusion: B-scan is a cost-effective initial investigation with good sensitivity, and CE-MRI shows higher overall diagnostic performance. *Al-Shifa Journal of Ophthalmology 2025; 21(4): 247-252. Al-Shifa Trust Eye Hospital, Rawalpindi, Pakistan.*

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Introduction:

The most common primary eye cancer in children, and the most common paediatric ocular tumor in Pakistan is Retinoblastoma. It is estimated to occur in one out of every 15,000-20,000 live births worldwide [(1,2)]. The condition is treatable, with a high survival rate when diagnosed early and confined to the eye, provided no metastatic risks are present [(3)]. The prevalence rate of retinoblastoma has been reported to be 38.9% [(4)].

Children with retinoblastoma commonly present with leukocoria (a white reflection in the pupil), though strabismus (misalignment of the eyes), redness, and vision loss may also occur [(5,6)]. Diagnosis depends on the imaging techniques like B-scan ultrasonography and MRI of the orbits. Ultrasound of the orbits should be conducted in all suspected cases before

proceeding with MRI [7,8]. The anatomy of the eye, with its fluid-filled chambers and superficial position, is well-suited for B-scan imaging. Minimal pressure is applied during the scan to avoid collapsing the damage to the anterior chamber. It is contraindicated in cases of eye trauma or cases suspected for rupture [9].

Findings regarding the diagnostic performance of B-scan have demonstrated good outcomes with a sensitivity of 94.2%, specificity of 98.8% and diagnostic accuracy of overall 94.9% ($p < 0.0001$) for different ocular conditions [10]. However, MRI is thought as the gold standard investigation to be used in pre-treatment evaluation, especially in confirming the diagnosis, evaluating tumor extent, and identifying associated conditions like intracranial primitive neuroectodermal tumors, its accuracy in detection of choroidal invasion is lower at 68% [11].

Historically, retinoblastoma was nearly always fatal just over a century ago. However, advancements in early tumor detection, such as indirect ophthalmoscopy, and improvements in enucleation techniques have dramatically increased survival rates with only 5% in 1896 to 81% survival rate by 1967 [12].

The leukocoria is the most frequent symptom of presentation in retinoblastoma and there are other symptoms such as strabismus and loss of sight. The medical symptoms differ according to disease stage [13]. Although MRI is less specific than CT scanning for retinoblastoma due to its lower sensitivity for detecting calcifications, it can still reveal calcium deposits as areas of low signal intensity across various pulse sequences [14].

The aim of this study is to compare the diagnostic accuracy of B-scan ultrasonography with retinoblastoma in comparison with MRI. Given that MRI is expensive, less accessible, and often requires anesthesia in young children, B-scan offers a more practical and cost-effective alternative, that reduce reliance on MRI and easing both the financial and emotional burden on patients especially those with claustrophobia.

Methodology:

A cross-sectional study was conducted at the Radiology Department of the Bahawal Victoria Hospital (BVH), Bahawalpur, between June to December of 2024. Institutional Ethical Review Board of Quaid-e-Azam Medical College, Bahawalpur gave ethical approval to this study. The ethical approval was granted under Registration Number: RAD-2023-032-4141, dated 25-03-2025. The inclusion criteria were children between the age of 6 months and 5 years presenting with clinical manifestations of leukocoria, poor vision and strabismus. Exclusion criteria involved children who had already been diagnosed with retinoblastoma, those who had undergone chemotherapy or radiotherapy, and children with a history of ocular trauma. Guardians/parents in the study were informed and gave informed consent for the study participants. Total 64 children were included in the study.

A detailed medical history was taken from children visiting the radiology department for retinoblastoma investigation. Patients were recruited using a consecutive non-probability sampling technique. B-scan ultrasound was performed for both eyes using a 7.5 - 10 MHz probe. Following the B-scan, the same patients underwent MRI examinations of both eyes using a 1.5 Tesla MRI machine. The histopathology report of patients who underwent surgical resection was recorded in data collection form. All imaging was conducted and interpreted by an experienced radiologist with over 5 years of paediatric neuro-ophthalmic imaging experience. All patients underwent enucleation, and histopathological examination of the resected specimens was performed.

The SPSS software (version 23.0) was used to analyse the data. Clinicopathological and demographic data were documented. The diagnostic accuracy such as sensitivity, specificity, positive predictive value (PPV),

negative predictive value (NPV), and the overall accuracy was evaluated through 2x2 contingency table comparing the imaging results (B-scan and CE-MRI) and the histopathological diagnosis as the gold standard. Sensitivity, specificity, PPV and NPV confidence intervals (95%) were calculated using the Wilson score.

Results:

We enrolled 64 cases in our study that met the inclusion criteria. 54(84.4%) patients were male and 10 (15.6%) were female. The mean age of the patients was 2.6 ± 1.35 years. B-scan ultrasound of both eyes detected retinoblastoma in 46 (71.9%) patients, while 49 (76.6%) patients were positive on MRI. On histopathology, overall retinoblastoma was diagnosed in 44 (68.6%) patients as illustrated in Table 1. The sensitivity, specificity and diagnostic accuracy of the B-scan ultrasound were 75%, 35% and 62.50% respectively. The positive predictive value and negative predictive value were 71.7% and 38.9% respectively.

Contrast enhanced MRI had overall diagnostic accuracy of 89.1%. The sensitivity, specificity, positive predictive value and negative predictive value calculated were 97.7%, 70%, 87.8% and 93.3% respectively.

Table 1. Patient Characteristics and Clinical Characteristics

Parameters	Mean ± SD
Age	2.6 ± 1.35 years
	Frequency (n=64)
B scan Findings (positive)	46 (71.9%)
CE MRI (positive)	49 (76.6%)
Histopathology (positive)	44 (68.6%)

Table 2. Diagnostic Accuracy of B scan Ultrasound and Contrast-enhanced MRI keeping Histopathology as gold standard.

Diagnostic Accuracy Parameters	B- scan Ultrasound (Eyes)	CE MRI
Sensitivity	75% (CI: 59.7–86.8%)	97.7% (CI: 87.7–99.9%)
Specificity	35% (CI: 15.4–59.2%)	70% (CI: 45.7–88.1%)
Positive Predictive Value (PPV)	71.7% (CI: 56.2–83.5%)	87.8% (CI: 75.2–95.3%)
Negative Predictive Value (NPV)	38.9% (CI: 17.3–64.3%)	93.4% (CI: 68.0–99.8%)
Diagnostic Accuracy	62.50%	89.1%
False Positives (n)	13	6
False Negatives (n)	11	1

CI: Confidence Interval

Discussion:

In patients with retinoblastoma, on ultrasound the tumor appears as hyperechoic lesion with irregular margins. It can be either diffuse or well-defined localized lesion. Calcium deposits, a hallmark of retinoblastoma, are distinctly visualized as highly hyperechoic areas on ultrasonography. Ultrasound can be useful in detecting retinal detachment in some cases or thickening of the choroid [(15)]. Retinoblastoma affects the posterior segment of the eye and shows calcification and vascularity on colour Doppler imaging. The mean age of the patients in our study was 2.6 ± 1.35 years which aligned with

the literature already published in the past [16,17]. A and B-scan ultrasonography were retrospectively assessed on 132 eyes of 126 suspected retinoblastoma patients in one of the studies [18], with 6 bilaterally lesioned patients. Ultrasonographic results were compared to the histopathologic identification after enucleation in 129 cases and to the indirect ophthalmoscopic diagnosis in three bilateral cases. Ultrasonography was found to be accurate in 115 cases (87.12%), false-negative was 9.09% and false-positive was 3.79%. Out of the 88 cases where tumor typing has been conducted, mixed-type was the largest with 74 cases (84.09%). Cystic, solid and diffuse infiltrating were not very common types. These findings underscore the reliability of ultrasonography, particularly B-scan, as an effective tool for the initial assessment and diagnosis of retinoblastoma [19]. Our study reported 71.9% cases to be positive on B scan with true positive cases of 75%. The results support its utility in clinical practice, offering valuable information for early detection and management.

In our study there were 10% cases with bilateral retinoblastoma. In contrast, one study on the Indian population reported a slightly higher incidence of bilateral tumors at 43% [19]. In the bilateral cases of our sample, the B-scan ultrasound was an effective method in detecting the lesion on both eyes since their echogenicity was identical across both eyes that is, hyperechoic intraocular lesions containing calcium. Nonetheless, the lesion sizes and areas were different in eyes. CE-MRI added further data, especially the posterior extent of the tumours, assessing the potentiality of the optic nerve involvement. Although binocular disease was better identified by both modalities, there was greater visibility of soft tissue changes within the intraocular and orbits visualized by MRI scans; this can often be missed on ultrasound.

Magnetic resonance imaging (MRI) has a critical role in the diagnosis of retinoblastoma particularly where there is involvement of optic nerve. The affected optic nerve usually looks thick and irregular on MRI and the nerve coupled with the surrounding tissue shows high enhancement. Previous studies have demonstrated that MRI can achieve a specificity of up to 80% and a sensitivity of 74% in detecting optic nerve invasion [20,21]. Our study showed sensitivity and specificity of MRI as 97.7% and 70% respectively. This high diagnostic performance positions MRI as the most superior non-invasive technique for evaluating optic nerve involvement in retinoblastoma.

In the context of retinoblastoma, there is limited data available regarding the diagnostic accuracy of MRI. Previous studies by Barkhof et al. [22] and Schueler et al. [23] are among the few that have compared MRI findings with histopathological results following enucleation. However, these studies had smaller sample sizes, with the first analyzing only 18 patients and the second involving 21 patients [24]. Our study also had small sample size of 69, with only 44 cases of retinoblastoma.

Our findings suggest that MRI shows promise in detecting smaller retinoblastoma lesions due to its superior spatial and contrast resolution. Despite these technological improvements, challenges remain, such as motion artifacts during longer scan times and MRI's limited ability to detect calcifications, a key feature in retinoblastoma diagnosis.

Also, there is one study conducted by de Jong MC et al., in which high-resolution MRI was used to detect small intraocular seeds and other risk factors that may result in metastasis and are not seen on fundus [25]. Meta-analysis study performed by the same research group also stated that the conventional MRI has a sensitivity of up to 88% (95% CI, 20%–100%) when used to diagnose retinoblastoma [25]. Our study also showed sensitivity of 97.7%.

The limitations of the study are the use of a smaller sample size as well as the possibility of both false-negative and false-

positive results in both B-scan and MRI. The diagnostic accuracy of these imaging techniques is also subject to operator expertise, leading to variability in results. This study was conducted in one facility, which can restrict its applicability to wider population or different healthcare settings. This study did not focus on lesion features (e.g., size, laterality, staging). In spite of this, MRI has been shown to identify the presence of optic nerve involvement and high-risk features but this was not the major interest in our study and histopathological correlation of such characteristics was not done.

Conclusion:

The study concluded that B-scan ultrasonography demonstrates significant diagnostic accuracy when compared with MRI in the evaluation of retinoblastoma. MRI showed superior diagnostic performance in this study, its main strength lies in evaluating intraocular tumor extent and detecting associated high-risk features. As a result, incorporating B-scan can effectively reduce the reliance on MRI in some cases, alleviating the strain on healthcare resources and minimizing costs for both hospitals and society.

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