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Retinoblastoma: Beyond Imaging and What We Must Know: A Scoping Review

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Abstract

Background: Retinoblastoma is a rare and aggressive childhood eye cancer where early diagnosis significantly influences treatment outcomes and survival. Disparities in diagnostic capabilities between high- and low-resource settings, particularly in countries like Kenya, present substantial challenges in disease management.

Objectives: The objective of this study is to evaluate the role, availability, and effectiveness of various imaging modalities in the diagnosis of retinoblastoma, with a specific focus on contrasting their application in high-resource versus low-resource settings. The study also aims to explore how combining diagnostic methods and leveraging telemedicine can enhance early detection in under-resourced areas.

Eligibility criteria: This review includes global and local studies that examine the use, diagnostic performance, and accessibility of imaging modalities such as indirect ophthalmoscopy, AB scan ultrasound, CT scans, and MRI, with a focus on their relevance to both advanced and resource-limited healthcare environments.

Sources of evidence: The evidence is drawn from an array of international and Kenyan-based studies addressing diagnostic imaging practices and healthcare disparities in retinoblastoma detection and treatment.

Charting methods: Data were synthesized by comparing the use and diagnostic utility of each imaging modality in different settings, assessing limitations, and identifying opportunities for improvement through the integration of technologies and healthcare system enhancements.

Results: Indirect ophthalmoscopy and AB scan ultrasound are widely used in Kenya due to their relative affordability and availability but are limited in detecting advanced stages of the disease. MRI provides higher diagnostic accuracy but remains largely inaccessible in rural or under-resourced regions due to its cost and the need for specialized staff. The study finds that combining multiple imaging modalities significantly improves diagnostic precision. Furthermore, telemedicine emerges as a promising tool to connect rural practitioners with urban specialists, enhancing diagnostic reach and efficiency.

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Conclusions: To improve early diagnosis and treatment outcomes for retinoblastoma in Kenya and similar low-resource settings, it is essential to invest in diagnostic infrastructure, particularly in advanced imaging technologies. Equally important is the training of healthcare personnel to ensure the accurate use and interpretation of these technologies. Systemic healthcare reforms and the adoption of telemedicine can play a transformative role in addressing current disparities, making early detection more attainable and improving overall patient outcomes.

Introduction

Background of the study

Retinoblastoma is a malignant tumor of the retina that predominantly affects children under five years of age. Worldwide, it constitutes about 3% of pediatric cancers, emphasizing the need for early diagnosis to improve survival rates. The use of imaging modalities is crucial in diagnosing, staging, and monitoring retinoblastoma. Different regions, however, employ varied imaging practices based on their available healthcare infrastructure. Globally, more advanced healthcare systems utilize sophisticated imaging techniques, while low-resource settings often rely on more accessible, cost-effective options [35]. One of the most important diagnostic tools is indirect ophthalmoscopy, which allows for a detailed examination of the retina. It remains the primary modality for initial evaluation, especially for detecting early intraocular tumors and leukocoria, a white reflex in the pupil. Ophthalmologists use this non-invasive procedure to examine the entire retina and identify the size and location of any suspicious lesions. Given its ease of use and availability, indirect ophthalmoscopy remains a widely adopted practice worldwide, particularly in regions with limited access to more advanced imaging tools [20].

Following ophthalmoscopy, an AB scan ultrasound is often used to further assess tumor characteristics. This imaging modality is highly effective in visualizing the size, structure, and internal calcifications of the tumor, which are common in retinoblastoma. AB scan is a non-invasive and cost-effective tool that is frequently employed in low- and middle-income countries, where it serves as an essential component of retinoblastoma diagnosis due to its affordability and diagnostic accuracy [37]. In regions with limited healthcare resources, this modality plays a critical role in ensuring timely diagnosis.

Another commonly used imaging modality is the Computed Tomography (CT) scan, which is particularly valuable in detecting intraocular calcifications—a hallmark of retinoblastoma. CT scans are also effective in assessing extraocular extension and invasion of the tumor into adjacent structures, such as the optic nerve and brain. However, the use of CT imaging has been declining in favor of other modalities due to concerns about radiation exposure, especially in children. Despite this trend in high-resource settings, CT scans remain indispensable in regions where MRI is less accessible due to its diagnostic reliability [5].

Magnetic Resonance Imaging (MRI) is increasingly becoming the preferred imaging modality for comprehensive staging and evaluating retinoblastoma. Unlike CT, MRI does not involve ionizing radiation, making it a safer option for young children. It offers superior soft-tissue contrast, which is crucial for evaluating optic nerve involvement and extraocular extension. While MRI provides the most detailed images and is favored in high-resource settings, its high cost and limited availability pose significant challenges in low-income countries, restricting its widespread use [35].

In Kenya, retinoblastoma diagnosis often faces challenges due to limited access to advanced imaging modalities like MRI and CT scans. Most diagnostic practices in the country rely on indirect ophthalmoscopy and AB scan ultrasound, which are more readily available and cost-effective. However, delays in diagnosis are common due to the scarcity of advanced imaging equipment in many healthcare facilities. Improving access to MRI and CT imaging, along with enhanced training for healthcare providers, is essential to achieving earlier and more accurate diagnoses of retinoblastoma in Kenya [28]. Addressing these gaps was critical in improving treatment outcomes for Kenyan children affected by this serious disease.

Statement of the problem

Retinoblastoma is one of the most common ocular malignancies affecting children, accounting for 2-4% of all pediatric cancers globally [35]. It primarily occurs in children under five years, with an incidence rate of 1 in every 15,000 to 20,000 live births [5]. Early diagnosis is critical in preventing metastasis and ensuring better survival rates. Advanced imaging modalities like indirect ophthalmoscopy, AB scan ultrasound, CT scans, and MRIs play crucial roles in diagnosing, staging, and treatment planning for retinoblastoma. However, access to these imaging tools, as well as timely diagnosis, varies significantly across regions, particularly in low-resource settings. The global burden of retinoblastoma is compounded by inequities in healthcare systems, where mortality rates remain disproportionately high in low-income countries [28].

In Kenya, the incidence of retinoblastoma remains significant, with late diagnosis and inadequate access to advanced imaging tools continuing to hamper effective treatment outcomes [12]. According to recent reports, childhood cancers account for about 7.4% of the total cancer burden in the country, with retinoblastoma being among the leading forms. A lack of access to MRI and CT scans, coupled with a shortage of specialized healthcare personnel, often results in late-stage diagnosis, making treatment less effective. The survival rate for retinoblastoma in low-income countries like Kenya is substantially lower than in high-resource countries, where advanced diagnostic modalities are more readily available [28,29].

Several studies have explored the use of imaging in retinoblastoma diagnosis and management. Shields et al. [35] highlighted the role of indirect ophthalmoscopy as a primary diagnostic tool and discussed its efficacy in identifying intraocular tumors. Munier et al. [20] examined AB scan ultrasound and its utility in assessing tumor characteristics, particularly in regions with limited access to MRI. Fabian et al. [5] compared CT scans and MRI, emphasizing MRI's superiority in providing detailed soft tissue contrast and staging accuracy. Shome et al. [37] further reviewed the role of MRI in detecting optic nerve invasion. Research by Kashyap et al. [11] studied the use of combined imaging modalities to improve early detection rates. A analysis by Chantada et al. [2] explored imaging trends across different regions, underscoring disparities in diagnostic access. Additionally, a study by Sharma et al. [34] investigated the impact of delayed diagnosis in low-resource settings and its correlation with poorer outcomes.

Despite the wealth of research on imaging modalities for retinoblastoma, gaps remain. Conceptually, there is limited understanding of how combined imaging techniques could further enhance early diagnosis, particularly in low-resource settings. Contextually, studies have largely focused on high-income countries, with minimal attention paid to how imaging disparities affect outcomes in regions like Sub-Saharan Africa. Methodologically, there has been a lack of comprehensive analyses that synthesize the findings from various global studies to identify actionable strategies for improving diagnostic practices in low-income settings. The current analysis seeks to fill these gaps by integrating data from multiple studies, focusing on both the efficacy of imaging modalities and the contextual challenges faced by healthcare systems in Kenya and similar settings.

Objectives of the study

The objective of this study was to conduct an analysis on the role of various imaging modalities, including indirect ophthalmoscopy, AB scan ultrasound, CT scan, and MRI, in the diagnosis of retinoblastoma, with a focus on improving diagnostic practices in both global and Kenyan contexts.

Scope of the study

This review examines the role of imaging modalities in the diagnosis and management of retinoblastoma, focusing on improving practices in both global and Kenyan contexts. It maps the available evidence on indirect ophthalmoscopy, A-scan ultrasound, CT scan, and MRI, exploring their contributions to early detection, staging, treatment planning, and monitoring. The review goes beyond simply describing these modalities to investigate the factors influencing their accessibility and effective implementation, particularly in resource-constrained settings like Kenya. This review considers literature published between 2019 and 2024.

The scope encompasses a broad range of literature, including studies on diagnostic accuracy, clinical utility, cost-effectiveness, and implementation challenges. It considers the perspectives of various stakeholders, such as clinicians, radiologists, policymakers, and patients. Geographically, the review prioritizes understanding the Kenyan healthcare system while situating it within global trends and best practices. This includes examining the availability and application of imaging technologies in Kenya, identifying barriers to access (e.g., infrastructure, training, cost), and exploring potential strategies for improving diagnostic capacity.

Methods

This scoping review was conducted following the PRISMA-ScR (Preferred Reporting Items for Systematic Reviews and Meta-Analyses Extension for Scoping Reviews) guidelines to ensure methodological transparency and reproducibility.

Protocol and registration

No formal protocol was registered for this review. However, the methodology was designed in accordance with established scoping review frameworks, including the PRISMA-ScR checklist, to ensure a systematic and comprehensive approach. Should a protocol be developed retrospectively, it will be submitted to an appropriate repository such as the Open Science Framework (OSF).

Eligibility criteria

Studies were included based on the following criteria: (1) they discussed imaging modalities in the diagnosis of retinoblastoma, (2) they focused on either global practices or regional contexts, especially Kenya and other low-resource settings, (3) they were published between January 2019 and December 2024, although seminal works prior to 2019 were considered for contextual relevance, and (4) they were published in English. Peer-reviewed journal articles, grey literature, government reports, and NGO publications were included to capture a comprehensive range of perspectives and data. The rationale for this broad inclusion criterion was to ensure that the review reflects both academic knowledge and real-world practices, especially in under-resourced healthcare systems.

Information sources

A systematic search was conducted across the following electronic databases: PubMed, Scopus, Web of Science, Embase, and Google Scholar. Additional grey literature was retrieved from international organizations such as the World Health Organization (WHO), the International Agency for Research on Cancer (IARC), Kenya's Ministry of Health, and non-governmental organizations involved in eye care. Manual hand-searching of reference lists from relevant studies was also conducted to capture additional sources that may not have been identified through database searches. The final search was executed in January 2025.

Search strategy

The search strategy combined controlled vocabulary (e.g., MeSH terms) and free-text terms. Example search terms included combinations of:

("retinoblastoma" OR "retinal blastoma" OR "eye cancer") AND

("ophthalmoscopy" OR "ultrasound" OR "CT scan" OR "MRI" OR "imaging") AND

("diagnosis" OR "management") AND

("Kenya" OR "low-resource" OR "developing countries").

Search filters were applied to limit results to the English language and the years 2019–2024. Full search strings for at least one database (e.g., PubMed) are available upon request to facilitate reproducibility.

Selection of sources of evidence

All identified records were imported into a reference management tool and screened for duplicates. Two reviewers independently screened titles and abstracts for relevance. Full-text articles were retrieved for studies that met inclusion criteria or where relevance was unclear. Discrepancies between reviewers were resolved through discussion or consultation with a third reviewer to ensure consistent application of the eligibility criteria.

Data charting process

A standardized data charting form was developed and pilot-tested on a small subset of studies to ensure clarity and consistency. Data charting was conducted independently by two reviewers, with any disagreements resolved through consensus. The form included predefined fields for study characteristics, imaging modalities used, regional focus, diagnostic outcomes, and reported challenges or recommendations.

Data items

Key data items extracted included publication year, study location, imaging modality discussed, accessibility of the modality, diagnostic effectiveness, healthcare infrastructure context, and recommendations for improving diagnostic outcomes. Assumptions regarding generalizability to similar low-resource contexts were noted where applicable.

Critical appraisal of individual sources of evidence

Critical appraisal of individual studies was not formally undertaken, as is consistent with the objectives of a scoping review. The goal was to map the available evidence rather than assess study quality or risk of bias. However, the credibility and relevance of each source were considered in the context of its contribution to the review's objectives.

Synthesis of results

A narrative synthesis approach was used to summarize findings from the charted data. Patterns were identified based on imaging modality, geographic setting, and reported barriers or facilitators to diagnostic access and accuracy. The synthesis highlighted both gaps in the literature and promising practices, particularly in the Kenyan healthcare context and other low-resource environments.

Results

Indirect ophthalmoscopy

Shields et al. [35] conducted a study in the United States evaluating the effectiveness of indirect ophthalmoscopy for retinoblastoma diagnosis. They found it highly effective for initial tumor identification but noted its limitations in detecting optic nerve invasion. The researchers recommended using it in combination with advanced imaging techniques, such as MRI, for better staging and monitoring of the disease. While accessible and non-invasive, the study highlighted its inability to provide detailed imaging of deeper ocular structures. This underscores its complementary role rather than a standalone diagnostic tool.

Wanjiru et al. [40] investigated the use of indirect ophthalmoscopy in Kenya and found it to be the most widely used diagnostic tool due to its low cost. However, its limited ability to detect tumor spread beyond the eye was a significant drawback. The researchers observed that this limitation often led to late-stage diagnoses and poor prognoses for patients. They suggested integrating more advanced modalities, such as CT or MRI, into Kenya's healthcare system. The study highlighted the urgent need for improved diagnostic infrastructure to enhance early detection rates.

Chantada et al. [2] conducted a global review focusing on the reliance on indirect ophthalmoscopy in low-resource settings. They observed that while the modality was affordable and easy to use, it was insufficient for advanced diagnostic needs. The study emphasized the disparities between low- and high-income countries, where advanced imaging is more prevalent. Recommendations included increasing funding for diagnostic tools and training healthcare workers in resource-limited areas. This would ensure more accurate diagnoses and better treatment outcomes.

Ololade and Opio [28] analyzed the role of indirect ophthalmoscopy across Sub-Saharan Africa, highlighting its widespread use due to economic constraints. The study found that while effective for initial screening, its limitations significantly affected comprehensive disease staging. They pointed out the critical need for policy reforms to subsidize advanced imaging technologies. The authors also advocated for partnerships with international health organizations to improve access to better diagnostic tools. This study underscored the disparity in healthcare resources and its impact on patient outcomes.

Njuguna et al. [27] examined the challenges of using indirect ophthalmoscopy in Kenyan hospitals, focusing on the training of healthcare personnel. The lack of adequately trained professionals often resulted in suboptimal use of the modality, further complicating diagnosis. The study recommended investing in specialized training programs to enhance diagnostic precision. They also proposed incorporating telemedicine to bridge gaps in expertise across urban and rural areas. These measures were deemed essential for improving the diagnostic landscape for retinoblastoma in Kenya.

AB scan ultrasound

Munier et al. [20] conducted a study in Europe to assess the utility of AB scan ultrasound in diagnosing retinoblastoma. They found that the modality was particularly effective in measuring tumor size and evaluating its internal structure, making it a valuable tool when MRI was unavailable. However, they noted that the AB scan's limited capacity to detect extraocular extension and optic nerve involvement could hinder accurate staging. The authors recommended combining AB scan ultrasound with other imaging techniques, such as MRI or CT, for comprehensive diagnosis. This study emphasized the importance of using multiple diagnostic approaches to improve retinoblastoma diagnosis in resource-limited settings.

In a similar study by Mwangi et al. [24] in Kenya, the authors highlighted AB scan ultrasound as the most common imaging tool used in diagnosing retinoblastoma. They noted its affordability and ease of access, making it suitable for low-resource settings like rural Kenyan hospitals. Despite these advantages, the study pointed out that AB scan ultrasound could not always provide sufficient detail for determining tumor characteristics and extraocular spread. The researchers suggested integrating MRI into the diagnostic process to enhance diagnostic accuracy. The study concluded that while AB scan ultrasound remains an essential tool, it should not be relied upon exclusively for staging the disease.

Kashyap et al. [11] analyzed the use of AB scan ultrasound in Asian and African countries, finding it to be the primary imaging modality in regions with limited access to advanced technologies. They reported that it was particularly valuable in assessing intraocular tumor dimensions and guiding therapeutic decisions. However, the study emphasized the need for more sophisticated imaging tools to detect the full extent of disease, such as extraocular spread or optic nerve invasion. The researchers recommended improving healthcare access to technologies like MRI and CT to support more accurate diagnosis. This analysis underscored the challenges faced by low- and middle-income countries in diagnosing retinoblastoma.

Shome et al. [37] investigated the role of AB scan ultrasound in India, where the modality was frequently used due to its cost-effectiveness. They found that it provided useful information about the size and location of the tumor, aiding in treatment planning. However, they also highlighted the tool's limitations in detecting complications such as optic nerve involvement or the presence of metastases. The study concluded that while AB scan ultrasound remained a crucial tool in India, complementary imaging methods like MRI would be essential for accurate diagnosis and staging. The authors advocated for policies that would improve access to a range of imaging modalities in resource-constrained regions.

Fabian et al. [5] conducted a comparative study of AB scan ultrasound and other imaging technologies like CT and MRI in diagnosing retinoblastoma across several European countries. The study found that while AB scan ultrasound was effective in providing preliminary information, it was less reliable than MRI in detecting extraocular spread and optic nerve involvement. The researchers noted that AB scan ultrasound was particularly useful in rural and low-resource settings where advanced imaging technologies were scarce. They recommended that ultrasound be integrated with MRI for a more accurate diagnosis, ensuring that the disease is staged properly for optimal treatment. This study underscored the importance of a multimodal approach to diagnosing retinoblastoma.

CT scan

Fabian et al. [5] conducted a study comparing CT scans and MRI in diagnosing retinoblastoma in Europe. They found that CT scans, although widely accessible and relatively inexpensive, lacked the sensitivity of MRI in detecting soft tissue abnormalities, such as optic nerve involvement and extraocular spread. Despite these limitations, the study emphasized that CT scans were often used in low-resource settings, where MRI was less accessible. The researchers recommended that CT scans be used as a complementary tool in combination with other modalities like ultrasound and MRI to improve diagnostic outcomes. This study highlighted the ongoing disparity in imaging access between high-income and low-resource regions.

In a study by Kimani et al. [15] conducted in Nairobi, Kenya, the role of CT scans in diagnosing retinoblastoma was examined. The study found that while CT scans were frequently used in public hospitals due to their affordability and availability, they provided less detailed information compared to MRI, particularly in detecting early intraocular disease and optic nerve invasion. The authors called for greater investment in MRI technology to enhance diagnostic accuracy. They also recommended a more integrated use of CT scans in initial screenings, followed by MRI for more detailed assessments. This study illustrated the diagnostic gap between urban and rural healthcare facilities in Kenya.

Chantada et al. [2] explored global trends in the imaging of retinoblastoma, noting that in many low- and middle-income countries, CT scans remained the primary imaging modality due to their lower costs and wide availability. However, the authors highlighted that CT scans posed concerns regarding radiation exposure, particularly in pediatric patients, which could increase the risk of secondary cancers. The study suggested that while CT scans were useful in detecting calcification within the tumor, MRI provided a more detailed view of soft tissue structures, offering a more reliable diagnosis in the long term. The authors called for improved infrastructure to make MRI more accessible in these regions.

Shome et al. [38] evaluated the use of CT scans in India for diagnosing retinoblastoma and found that the modality was still commonly employed in many institutions, especially in regions where MRI was unaffordable. The study found that while CT scans could detect bony involvement and calcification, they often missed key soft tissue details, such as optic nerve invasion. The authors concluded that CT scans should be used as a supplementary tool in retinoblastoma diagnosis, recommending the integration of MRI for a more comprehensive and accurate assessment. This research underscores the need for better healthcare infrastructure in resource-poor settings to improve diagnostic accuracy.

Kashyap et al. [11] conducted a review of imaging practices for retinoblastoma across Asia and Africa, where CT scans were frequently utilized as the primary diagnostic tool in many regions. The study found that while CT scans were instrumental in detecting large tumors and calcifications, they often provided insufficient information about the extent of intraocular involvement or optic nerve involvement. The authors recommended that MRI be incorporated into the diagnostic process to overcome these limitations and improve early-stage detection. This study reinforced the importance of developing integrated diagnostic strategies, particularly in underserved areas.

MRI

Shields et al. [35] conducted a study on the role of MRI in diagnosing retinoblastoma in the United States. The researchers found that MRI was the gold standard for diagnosing retinoblastoma, providing superior contrast resolution and allowing for detailed assessment of intraocular and extraocular extension. They emphasized MRI's role in detecting optic nerve involvement, which is critical for staging the disease and planning treatment. However, the study also noted that the high cost and limited availability of MRI in low-resource settings could hinder its widespread use. The authors suggested that healthcare systems invest in expanding MRI access to improve diagnostic capabilities for retinoblastoma, particularly in underdeveloped areas.

Munier et al. [20] explored the impact of MRI on retinoblastoma diagnosis in Europe, highlighting its role in improving diagnostic accuracy. The study found that MRI was especially useful for detecting extraocular extension, optic nerve invasion, and lymph node involvement, areas where other imaging modalities such as CT or ultrasound fell short. The researchers acknowledged the high cost of MRI but argued that its diagnostic benefits justified the investment, particularly in terms of better treatment outcomes and survival rates. They called for public health policies to prioritize funding for MRI equipment, especially in tertiary hospitals. The study highlighted MRI's essential role in improving outcomes for children diagnosed with retinoblastoma.

Sharma et al. [33] assessed the role of MRI in diagnosing retinoblastoma in South Asia, where advanced imaging tools are often scarce. They found that MRI offered the best diagnostic accuracy in detecting both intraocular and extraocular disease. The study emphasized MRI's ability to visualize soft tissue structures in detail, which is crucial for staging the disease and determining the best course of treatment. However, the researchers also highlighted the challenges posed by limited MRI availability and the high costs associated with its use. They recommended a strategy to make MRI more accessible in developing countries to improve early diagnosis and reduce mortality rates.

Ololade & Opio [28] conducted an analysis of imaging practices in Sub-Saharan Africa, focusing on the use of MRI in diagnosing retinoblastoma. They found that MRI provided unmatched diagnostic precision in detecting extraocular extension and optic nerve involvement. However, they observed that the high costs and limited access to MRI machines in many African countries created significant barriers to its use. The study called for initiatives to improve MRI access, such as partnerships with international organizations or government programs to subsidize the costs of imaging for children with retinoblastoma. This research highlighted the need for targeted investments in medical technology to reduce the disparity in diagnostic accuracy between high- and low-resource settings.

A study by Kashyap et al. [11] investigated the role of MRI in retinoblastoma diagnosis across Asia and Africa, where access to advanced imaging was highly variable. They found that while MRI was the most reliable method for detecting both intraocular and extraocular involvement, its limited availability in low-income countries was a major barrier to early detection. The study suggested that countries in these regions should focus on expanding MRI access, perhaps by introducing mobile MRI units or facilitating partnerships with international medical organizations. The authors concluded that improving access to MRI could significantly reduce the mortality rate associated with retinoblastoma in underserved regions.

Critical review

The reviewed studies underscore the vital role that imaging modalities play in diagnosing retinoblastoma, yet significant disparities remain between high- and low-resource settings. While MRI is consistently highlighted as the gold standard for retinoblastoma diagnosis due to its superior soft tissue resolution and ability to detect optic nerve involvement and extraocular extension, its high cost and limited availability in resource-poor regions remain a major concern [35,37]. This challenge is particularly pronounced in countries like Kenya and India, where advanced imaging technologies are not uniformly accessible across urban and rural areas. These disparities contribute to delayed diagnoses, which often result in poorer prognoses and higher mortality rates.

Furthermore, studies suggest that in the absence of MRI, other imaging modalities such as indirect ophthalmoscopy and AB scan ultrasound are widely used, particularly in low-income settings [20,40]. While these modalities are more affordable, they have limitations in terms of detecting the full extent of the disease. For instance, indirect ophthalmoscopy often fails to reveal optic nerve invasion or extraocular spread, which are crucial for staging the disease and planning treatment [35,36]. AB scan ultrasound, although useful for assessing tumor size, cannot provide the same level of detail as MRI or CT scans, especially in cases involving deep ocular structures [11]. This indicates that reliance on these methods alone may lead to underdiagnosis or misdiagnosis, emphasizing the need for complementary imaging strategies.

Another critical issue highlighted across multiple studies is the lack of trained personnel to operate and interpret advanced imaging tools in low-resource settings [27]. Even when MRI and CT are available, the effectiveness of these tools can be compromised without the expertise to use them accurately. This underscores the importance of not just investing in medical equipment but also in healthcare worker education and training. Without skilled personnel to operate and interpret imaging results, the diagnostic benefits of these technologies are severely diminished, which can delay treatment and affect patient outcomes.

Despite these challenges, several studies point to promising solutions to bridge the gap in imaging access. The use of telemedicine to facilitate remote consultations and interpretations has emerged as a promising strategy, particularly in Kenya [25]. By enabling rural hospitals to share imaging results with specialists in urban centers, telemedicine has been shown to improve diagnostic accuracy and reduce delays in treatment. However, for telemedicine to be effective, significant investments are needed to build infrastructure, improve internet connectivity, and ensure that healthcare professionals are trained in using telemedicine tools.

Additionally, the integration of multiple imaging modalities appears to enhance diagnostic accuracy in retinoblastoma cases. Combining AB scan ultrasound, CT, and MRI can provide a more comprehensive view of the tumor's extent and assist in accurate staging [17]. This multi-modal approach ensures that even if one imaging technique fails to capture certain aspects of the disease, others can compensate, leading to more reliable diagnoses. Expanding access to such combined diagnostic strategies, particularly in underserved areas, could significantly improve early detection and patient outcomes.

Discussion

Summary of evidence

This scoping review examined the diagnostic effectiveness and contextual application of various imaging modalities—indirect ophthalmoscopy, AB scan ultrasound, CT scan, and MRI—for diagnosing retinoblastoma, particularly in low-resource settings like Kenya. Across the literature, MRI emerged as the most reliable imaging modality, with superior sensitivity and specificity for detecting intraocular, extraocular, and optic nerve involvement [20,35]. Despite its diagnostic superiority, MRI's limited accessibility due to high costs and infrastructural requirements restricts its widespread use in under-resourced regions.

The review also established that indirect ophthalmoscopy remains a frontline tool, especially in economically constrained settings, due to its affordability and accessibility. However, it lacks the ability to detect deeper ocular and extraocular involvement, which is essential for accurate staging. Similarly, AB scan ultrasound is widely used for measuring tumor size and internal structure but is insufficient on its own for full disease evaluation. CT scans, while more detailed than ophthalmoscopy or ultrasound, expose patients to radiation and are less effective than MRI in soft tissue assessment.

- The themes emerging across studies include:Accessibility versus accuracy of diagnostic tools
- Infrastructure and training gaps in low-resource settings
- The importance of multimodal imaging to improve diagnostic outcomes
- The value of telemedicine and policy reform in bridging diagnostic disparities

These findings directly relate to the review's objectives of mapping diagnostic strategies for retinoblastoma and evaluating their effectiveness and accessibility, particularly in low- and middle-income countries.

Limitations

This scoping review has several limitations. First, the reliance on published literature may have introduced publication bias, as studies showing favorable outcomes for advanced imaging technologies may be more likely to be reported. Second, data heterogeneity across included studies—especially variations in study design, sample sizes, and outcome measures—limited direct comparisons and prevented meta-analysis. Third, geographical bias was present, as most of the included studies focused on specific regions (e.g., Kenya, India, and Sub-Saharan Africa), which may not represent broader global contexts. Finally, some studies lacked detailed reporting on implementation outcomes, such as cost-effectiveness or long-term survival, which are critical for understanding the real-world utility of different imaging tools.

Conclusions

In response to the review question, what are the current practices and challenges in imaging-based diagnosis of retinoblastoma in low-resource settings?, this scoping review concludes that while multiple imaging modalities are in use, MRI remains the gold standard. However, widespread implementation is hindered by financial, technical, and personnel-related barriers.

The evidence supports the adoption of multimodal imaging approaches, combining affordable tools like ophthalmoscopy and ultrasound with advanced imaging such as MRI or CT, where feasible. To reduce diagnostic delays and improve survival outcomes, investment in infrastructure, training, and policy support is essential. Emerging strategies like telemedicine and portable imaging devices present promising avenues for future implementation, particularly in rural and underserved areas.

Next steps should include health policy reforms to promote equitable access to imaging technologies, integration of telemedicine platforms, and further research on cost-effective diagnostic interventions tailored for low-resource environments.

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