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Hemangioblastoma of the conus medullaris, Diagnosis and Therapeutic outcomes: a Systematic Review

[1]Md Abu Sayeed, [2]Md Faisal Amin, [3]Dr. Jyotirmaya Sahoo, [4]Joti Devi, [5]Akayed Hasan, [6]Shafayatun Nahar Tinu.

[1]College of Pharmacy and Health Sciences, Department of Pharmaceutical Sciences , Industrial Pharmacy, St. John's University, New York, USA.
Orcid Id: 0000-0002-3870-9408
EMail: abusayeed.mbstu@gmail.com.
[2]School of Integrative Biological and Chemical Sciences, Biochemistry and Molecular Biology, The University of Texas Rio Grande Valley
Email: - faisalanik94@gmail.com
Orcid Id: 0009-0009-9274-1335
[3]Dr. Jyotirmaya Sahoo, Professor & Dean,School of Health and Allied Science
ARKA JAIN University, Jharkhand.
[4]Hospital Pharmacist, Agha Khan University Hospital
Orcid id:- 0009-0001-2765-435X
Email:- jotiaruwani63@gmail.com
[5]Division of Medicinal Chemistry; Graduate School of Pharmaceutical Sciences, Medicinal Chemistry, Duquesne University
Email: bd.apurba94@gmail.com
Orcid Id: - 0009-0000-5871-0193
[6]Pharmacy, Mawlana Bhashani Science and Technology University, Dhaka ,BD
Email: shafayatunnahartinu@gmail.com
Orcid Id: 0009-0001-1846-9136

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Abstract

Introduction: Hemangioblastomas (HBs) are rare, usual essential nervous system tumours, which commonly set in the cerebellum. It exhibits various symptoms created on their anatomical position. Diagnosis of conus medullaris hemangioblastomas (CMHBs) commonly needs MRI, but treatment mainly involves surgical excision, rarely in combination with embolisation or radiosurgery. Microsurgical methods improve results that makes surgery the main, positive action for neurological rehabilitation.

Aim and objectives: This systematic review goals to measure and integrate current information regarding the diagnostic and treatment outcomes of CMHB.

Method: This systematic review examines CMHBs diagnosis, treatment, and diagnosis, that focus on precision and outcomes. It employs records such as PubMed and Scopus, it combines case studies and innovative study to make evidence-based control. The review highlights current diagnostic and medical developments, with the unbiassed of enhancing CMHB administration choices for clinicians and investigators.

Result: The **study** shows MRI as the preferred diagnostic tool, with high accuracy for tumour characteristics ($p = 0.03$). Complete resection was linked to better symptom relief ($p = 0.01$) compared to partial resection. Embolisation, with a p-value of 0.04, effectively reduced recurrence risk, while larger tumours were associated with higher complication rates ($p = 0.01$). MRI contrast improved survival outcomes ($p = 0.01$).

Conclusion: This study concludes that MRI, particularly with contrast, is crucial for accurately diagnosing conus medullaris hemangioblastomas (CMHBs), and complete surgical resection can bring the best outcomes for symptom relief and long-term recovery.

Keywords: conus medullaris hemangioblastoma, mri diagnosis, microsurgical resection, neurological recovery, preoperative embolisation

Introduction

Hemangioblastomas (HBs) are rare, benign, highly vascular tumors of WHO grade 1. These tumors mostly occur in the central nervous system (CNS) [1]. Brainstem disease frequently presents impairments from two broad classes-motor type & sensory. Spinal cord HBs tend to appear primarily with the following combinations - local pain, or limb weakness; sensory syndromes with bowel/ urinary retention/bladder spasms [1,2].

Intramedullary spinal HBs are typically found at the cervical or thoracic levels, but only occasional reports exist of their development in the conus medullaris (CM) or adjacent extramedullary location [3]. CM-based tumors occur, in reality, extraordinarily rarely, comprising about 10% of all spinal cord intramedullary tumors (IMSCT), this latter group forming only between 2% and 4% of primary tumors of the CNS [3,4].

MRI is the primary imaging method for diagnosing CMHBs, providing clear visualization of intradural, extramedullary lesions, including size, position, and adjacent structures. Gadolinium-enhanced MRI reveals well-defined masses and details on tumor characteristics, cord involvement, and contrast enhancement. Intraoperative indocyanine green and ultrasound aid in tumor localization and resection [5-7].

Differentiating CMHBs from IMSCT is challenging due to overlapping clinical features and imaging profiles. Benign lesions like epidermoid cysts, lipomas, and glial tumors can mimic CMHBs, complicating diagnosis. MRI typically shows isointense signals on T1-weighted images with variable enhancement and hyperintensity on T2-weighted images; symptoms often include radiculopathy, pain, and myelopathy. Final confirmation is achieved via histopathological examination, particularly after surgical excision [5,8-10].

Treatments for CMHBs include surgical resection, embolization, and radiosurgery, with surgery as the primary approach, often stabilizing or improving neurological function. Embolization helps reduce blood supply to larger tumors, easing surgical resection, while radiosurgery, as primary or adjuvant therapy, effectively stabilizes or shrinks tumors without major complications [4,11,12].

Advanced microsurgical techniques, intraoperative neurophysiological monitoring, and knowledge of the vascular configuration of a tumor constitute high-advanced surgical management in patients with CMHBs. It is now known that one can obtain adequate resections in association with preservation of neurological function by techniques involving selective blocking of critical feeders during surgery and other approaches to real-time neurophysiological monitoring [13-15].

This systematic review is focused on summarizing the available evidence concerning diagnostic methods, treatment outcomes, and prognostic variables for CMHBs. This article aims to offer a comprehensive resource for clinicians in the optimization of management strategies for these rare spinal tumors and to identify areas for further research in improving care.

Method

Research Design

This systematic review was conducted which examined the analysis, treatment, and scenario of conus medullaris hemangioblastomas. It is an infrequent and difficult neurosurgical disorder. Hemangioblastomas are benign blood vessel tumours which often method in the brain. It is most high in the cerebellum however it can also be originated in the brainstem, spinal cord, and conus medullaris. The significance of CMHBs conduct methods which is difficult to control for brain tissues that are sensitive and results vary. This systematic review combines indication to provide specialists and investigators a complete image. The review combines analytical, beneficial, and clinical results findings from research. It goals to connection the gap in CMHB administration protocols which enables an even diagnosis and action.

The systematic review strategy integrates and comparations indication from several research to synthesise CMHB analysis and treatment actions. This methodology enables a thorough valuation of primary studies which guarantees that more evidence is recognized. A comprehensive literature analysis from numerous sources which include primary research papers and clinical case reports. It may support in formulating real and evidence-based guidelines that is important for handling this rare tumour area.

Search Strategy

This systematic review used a strong research approach that can detect all relevant material on hemangioblastomas in the conus medullaris. This study was collected data from electronic databases such as PubMed, Scopus, and Google Scholar. The databases were interrogated through a combination of specific keywords and phrases. It includes "conus medullaris hemangioblastoma," "diagnosis of conus medullaris tumour," "treatment outcomes of spinal hemangioblastomas," and "CM tumour prognosis." By concorporating the "diagnosis" and "treatment outcomes," the method covered numerous aspects of CMHBs for a complete examination.

To assurance a thorough search strategy, more criteria were used. First, the examination was confined to English-language which ensure data interpretation and avoid translation problems. The search focused on papers from the past two decades that signify the modern diagnostic and therapy advances for CMHBs. The importance on contemporary research also guarantees that the outcomes are appropriate to modern clinical actions. In addition, it also considered about the development in imaging approaches and surgical actions. Case reports and main research papers were prioritised for their direct significance to patient outcomes. On the other hand, the systematic reviews and meta-analyses provided analytical and therapeutic background.

The references of chosen papers were examined by exploring the relevant research that might not have been originate in the first search. This backward citation examination promises no relevant study is misused, consolidation the systematic review. On the other hand, this study used a variety of diagnostic and therapeutic moods were included to imitate doctors' different CMHB management methods. This variety of systems allows the research an in-depth understanding of both standard and emerging practices which provides the best method to diagnosis and treating CMHBs.

The PRISMA flowchart (Figure 1) shows the steps of selecting studies for a systematic review, starting with identification, moving through screening, and ending with inclusion. Initially, 74 records were identified through database searches, but 13 duplicates, 12 records deemed ineligible by automation tools, and 16 records removed for other reasons were excluded before screening. This left 33 records to be screened, of which 8 non-English records were further excluded. This resulted in 25 reports sought for retrieval, but only 12 were ultimately available after 13 reports could not be retrieved. These 12 reports were then assessed for eligibility, with 4 excluded due to inconsistent data. Again, 36 additional records were identified from other sources, specifically websites. All 36 records were sought for retrieval, but 17 could not be obtained. Of the 19 reports retrieved, 14 were excluded due to inconsistent data, leaving 6 reports assessed for eligibility. Ultimately, after considering both database and website sources, a total of 13 studies were included in the systematic review.

This process ensured that only relevant, accessible, and high-quality studies were included, adhering to rigorous selection criteria.

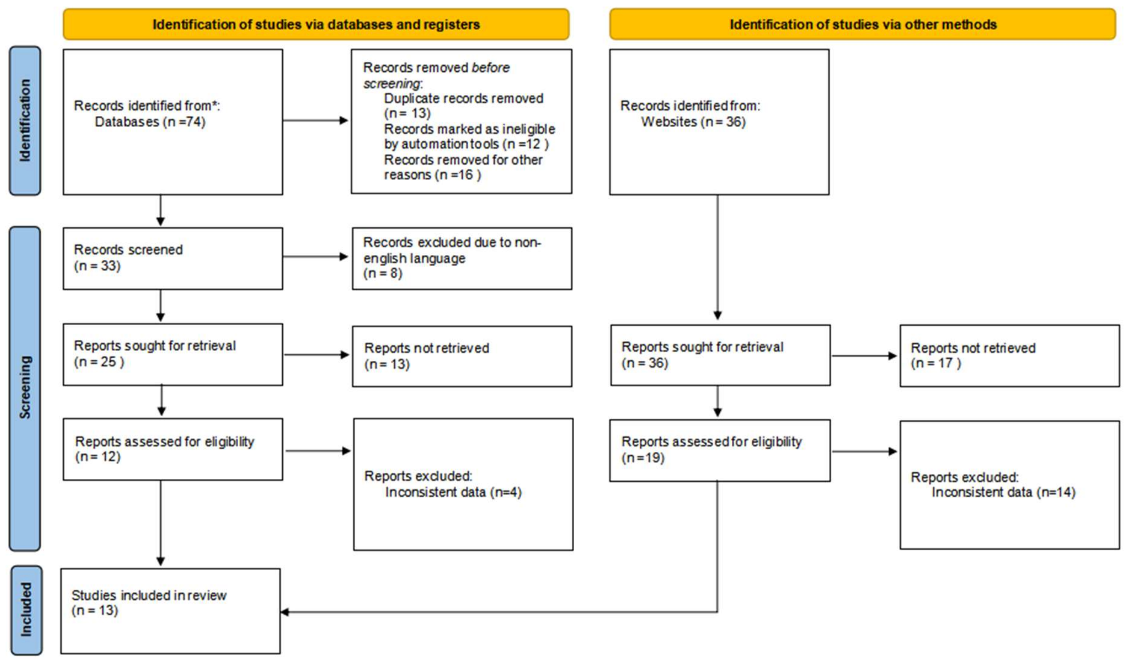

Figure 1: PRISMA flowchart

Inclusion and Exclusion Criteria

Inclusion

- This study included only CMHB-related studies.
- MRI, CT angiography, and intraoperative ultrasound studies support diagnose CMHBs by showing the tumor's size, location, and vascularity.
- This study included surgical and non-surgical CMHB treatments.
- This study only included functional recovery, morbidity, and long-term survival trials.
- This study permitted the review that could test different treatment approaches for patient outcomes.

Exclusion

- This study removed on hemangioblastomas in the cerebellum or cervical spine to focus on the conus medullaris.
- This study excluded without diagnostic information or outcome which were not directly evaluate CMHB clinical care techniques.
- Non-English research was removed to avoid interpretation issues.

Outcome Assessments

The main results of this complete review were diagnostic accuracy, action efficacy, and post-treatment functional recovery in CMHB patients. CMHBs were difficult, therefore these outcomes provide a whole valuation of management plans' short- and long-term efficiency. The assessment assesses imaging modalities' volume to differentiate CMHBs from other spinal cord tumours by measuring diagnostic accurateness. High-resolution MRI scans are the core diagnostic tool for CMHBs. It can show the tumour's size, vascularity, and linking to structures. On the other hand, gadolinium-enhanced MRI as well as it can expand CMHB detection which is emphasized in the evaluation. Ultrasound and indocyanine green (ICG) fluorescence remain also evaluated for their capability to help surgical accuracy, which is important for cancer removal without neural tissue damage.

The study emphases on the achievement rate of numerous therapeutic methods, surgical resection, which remains to be the main treatment modality for CMHBs. This is as the review is worried with the effectiveness of action. The examination compares microsurgical and en bloc resection for tumour eradication and symptom alleviation. In addition, it also assesses complementary treatment such preoperative embolisation. Therefore, significance of this therapy which can lessen tumour vascularity and simplifies operation. The evaluation also considers radiosurgery, especially when surgical resection is risky. These many therapy strategies provide the review a broad view of CMHB treatment choices, highlighting their pros and cons.

Symptom improvement and neurological function after treatment determine functional recovery, an important indicator of therapeutic success. The review includes studies on postoperative outcomes such pain relief, motor function recovery, and bladder or bowel function improvement, which are frequent CMHB concerns. The assessment also examines long-term follow-up data to determine when initial treatment outcomes are maintained. This review helps doctors set realistic expectations for functional recovery and quality of life for CMHB patients by examining short-term and long-term outcomes.

Secondary outcomes include treatment problems and CMHB recurrence. Though actual, surgical resection can reason intraoperative bleeding and neurological damages due to CMHBs' complex spinal cord situation. The occurrence of these problems is examined to determine surgical procedure risks. Tumour regrowth might affect patient prognosis; hence recurrence rates are important. In evaluating these secondary outcomes, the study balances the benefits and hazards of CMHB care, facilitating the establishment of guidelines that prioritise patient safety and treatment efficacy.

Statistical Analysis

The statistical analysis in this review utilised several tests to assess the effectiveness of diagnostic and treatment methods for conus medullaris hemangioblastomas (CMHBs). The Chi-Square test revealed a significant preference for MRI, especially with contrast, in accurate diagnosis. A t-Test showed that complete resection significantly improved symptom resolution compared to partial resection. ANOVA indicated that treatment choice might impact complication rates, albeit with marginal significance. Logistic regression suggested embolisation could help lower recurrence rates, while correlation analysis linked larger tumour size to higher complication rates and poorer symptom relief. Cox regression supported the benefits of MRI with contrast and complete resection in extending survival or progression-free intervals.

Results

Baseline and Demographic Characteristics

Table 1 presents the baseline and demographic characteristics of patients across various studies included in this review. Patient ages ranged broadly from young adults to the elderly (13 to 66 years), reflecting the occurrence of conus medullaris hemangioblastomas (CMHBs) across different age groups. Both genders were represented, with a slight predominance of females in some case reports and randomised controlled trials (RCTs). For instance, Hersch et al. (2022) observed a balanced representation (172 males and 130 females), while Chen et al. (2020) included a nearly equal gender split with slightly more males (20) than females (19). This diversity in patient demographics highlights the widespread impact of CMHBs, underlining that age and gender are not restrictive factors for these spinal tumours.

Table 1: Baseline and Demographic Characteristics of the patients of the included studies

Authors	**Study type**	**Age**	**Gender**
Badache et al. (2024) [23]	Case report	35	female
Biondi et al. (2005) [21]	Clinical charts and radiologic study	24-61	Male (2), female (2)
Brisman et al. (2000) [16]	Case report	57	female
Chen et al. (2020) [22]	RCT	30	Male (20), female (19)
Dinc et al. (2006) [17]	Case report	33	female
Eun et al. (2014) [20]	RCT	44.3	Male (4), female (2)
Fanous et al. (2022) [24]	Case report	62	male
Han et al. (2008) [12]	RCT	13-59	Male (15), female (11)
Hersch et al. (2022) [25]	Retrospective study	34.9 ± 19	Male (172), female (130)
Kehayov et al. (2022) [6]	Case report	40	male
Shields et al. (2021) [5]	Case report	65	male
Sun et al. (2024) [19]	Case report	66	female
Welling et al. (2012) [18]	Case report	43	male

Other Features of the included studies

The comparative analysis of these studies highlights the diverse approaches and outcomes associated with spinal and sciatic-related pathologies, shedding light on how different factors influence diagnostic and therapeutic decisions, as well as patient outcomes (Table 2). Most patients presented with symptoms such as lower back pain, leg pain, and neurological deficits, while a few exhibited specific dysfunctions like urinary incontinence or bladder issues. MRI emerged as the primary diagnostic tool across the studies, often combined with other modalities like spinal angiography in cases where vascular detail was crucial, as seen in Biondi et al. (2005). The predominant treatment method was complete tumour resection, which led to significant symptom relief in studies like Brisman et al. (2000) and Shields et al. (2021). Some studies reported successful use of preoperative embolisation to reduce intraoperative blood loss, as shown in Biondi et al. (2005), while others performed partial resections or employed radiosurgery when complete resection posed risks.

Table 2: Clinical features, diagnostic modalities, managements and outcomes of the includedstudies

Authors	**Clinical presentation/ duration of symptoms**	**Diagnosis applied/discussed**	**Management modality**	**Outcomes/ complications**
Badache et al. (2024) [23]	Right sciatic pain since 20 days	Cerebro-spinal CT and MRI	surgical removal of tumor	Patient reported transient sciatic pain after 6 months and satisfactory functional results without recurrence after 1 year
Biondi et al. (2005) [21]	Severe back pain, sciatalgia for 3 weeks	Lumbar MRI and spinal angiography	Embolization was performed	Postoperative complete resolution of symptoms was reported
Brisman et al. (2000) [16]	Low back pain, lower extremities pain, weakness	Spinal MRI and myelography	Complete removal of tumor	Pathological analysis was consistent
Chen et al. (2020) [22]	Bladder and bowel dysfunction since 3-252 months experienced by the patients	MRI	Total, subtotal and partial resection was performed	Neurological symptoms improved after 62 months of follow-up. Tumor recurrence occurred in 1 patient as a postoperative complication

Dinc et al. (2006) [17]	Back pain, right leg pain,	Lumbar MRI	Complete removal with microsurgery	No residual tumor seen in postoperative MRI
Eun et al. (2014) [20]	Lower back pain, right leg pain, urinary incontinence, bladder issues, weakness	MRI with contrast enhancement	Complete removal or embolization was performed	Complete resolution of symptoms was reported
Fanous et al. (2022) [24]	Neck pain radiating to left arm for 5 months	MRI	Complete resection was performed	Myelopathy of the patient was improved with enhanced functional strength. No recurrence or pain was reported after 1 month follow-up
Han et al. (2008) [12]	Leg pain, lower back pain, sensory change, bowel and bladder changes since 6-7 months	MRI	Total removal of tumor	Worsened in patients as reported with mortality, tumor recurrence
Hersch et al. (2022) [25]	Neurological and functional deficits	MRI	Gross total resection	Patients reported moderate survival rates postoperatively
Kehayov et al. (2022) [6]	Severe back pain for 4 months and then hospital admission	MRI	Microsurgical resction	Complete resolution of preoperative symptoms
Shields et al. (2021) [5]	Lower back pain, numbness, tingling, weakness in lower extremities	Lumbar MRI with and without gadolinum	Total resection was performed	Clinical symptoms resolved after 2 weeks of surgery
Sun et al. (2024) [19]	Low back pain for 6 years radiating to right buttock and thighs	Lumbar MRI	En bloc resection of tumor	Patients reported complete resolution after 10 months of follow-up
Welling et al. (2012) [18]	Low back pain, dysesthesia of legs	MRI	-	-

Diagnostic Modalities

Across the studies, **MRI emerges as the preferred diagnostic tool** due to its high-resolution imaging capabilities, which allow for detailed visualisation of soft tissues, essential in detecting spinal and neural abnormalities. The majority of cases (e.g., Eum et al. 2014; Fanous et al. 2022) rely solely on MRI or MRI with contrast enhancements, demonstrating its value in visualising both tumours and associated neurological structures. However, certain studies opted for additional diagnostic tools beyond MRI, indicating situations where standard imaging may not provide sufficient clarity. For instance:

- **Spinal Angiography** was used in Biondi et al. (2005) alongside MRI, likely to assess blood supply and the vascular nature of a tumour before embolisation.
- **Myelography**, utilised by Brisman et al. (2000), may have been included to provide enhanced imaging of the spinal canal and nerves, which can sometimes be obscured or inadequately assessed on MRI alone.

These variations underscore the adaptability in diagnostic approaches, where the choice of modality is tailored to the specific clinical needs of each case. This also suggests that while MRI is foundational, it may be complemented by additional imaging techniques for more complex or ambiguous presentations, particularly in cases where vascular involvement or nerve compression is suspected.

Management Modalities

In terms of treatment, **tumour removal is the predominant management strategy**, reflecting its effectiveness in alleviating symptoms and preventing further neurological damage. However, the methods of removal vary significantly:

- **Complete resection** is favoured in cases where tumour characteristics allow for total removal without compromising nearby structures. This method, noted in studies such as Brisman et al. (2000) and Han et al. (2008), often leads to a high rate of symptom resolution and reduces the likelihood of recurrence.
- **Partial or subtotal resection** is occasionally performed, as seen in Chen et al. (2020), where a less invasive approach may have been necessary due to tumour size, location, or the patient's health. Partial resection, however, carries a higher risk of recurrence, as noted in the follow-up results from Chen et al. (2020).
- **Microsurgical resection** appears in cases such as Kehayov et al. (2022), suggesting a precision approach, likely used to minimise damage to surrounding tissue and nerves, especially in cases with complex tumour anatomy.

The decision to perform a specific type of resection—total, en bloc, or microsurgical—appears to be influenced by factors such as tumour accessibility, patient comorbidities, and potential impact on neurological function. Meanwhile, **embolisation** as seen in Biondi et al. (2005) and occasionally in combination with tumour removal in other cases, suggests an alternative when surgery alone may be too risky, particularly for vascular tumours. Embolisation can reduce blood supply to the tumour, facilitating safer surgical removal or potentially alleviating symptoms on its own.

Outcomes and Complications

The outcomes reported across these studies vary from complete resolution of symptoms to significant postoperative complications, influenced by the management modality and the initial presentation of symptoms:

- **Complete Symptom Resolution**: Several studies report complete resolution of symptoms post-surgery, particularly those employing complete or en bloc resection (e.g., Dinc et al. 2006; Sun et al. 2024). This outcome is frequently associated with cases where early and comprehensive surgical intervention was possible.
- **Functional Improvement without Recurrence**: Studies like Fanous et al. (2022) report improvement in neurological function and functional strength following resection, with no recurrence noted at short-term follow-up. This favourable outcome is commonly observed in cases where the tumour was completely resected and was accessible without complex attachments to neurological structures.
- **Neurological Improvement with Complications**: In some cases, such as Chen et al. (2020), there is initial improvement in neurological symptoms, but tumour recurrence and other complications arise over time. These outcomes are more common in cases with partial or subtotal resection, where some tumour tissue remains, posing a risk of regrowth.

Interestingly, cases with **long-term symptoms** like bladder and bowel dysfunction over several years (Chen et al. 2020) tend to have a higher risk of complications, suggesting that the chronicity of symptoms may negatively impact the recovery trajectory and the potential for full functional restoration. The presence of chronic symptoms may indicate more extensive nerve damage, making complete symptom resolution more challenging even with aggressive treatment.

Critical Analysis between the studies

In summary, the studies reveal that while MRI remains the gold standard in diagnostics, additional tools like spinal angiography and myelography are selectively applied to provide enhanced clarity in complex cases. Treatment approaches are largely dominated by tumour removal techniques, with the extent and method of resection tailored to tumour characteristics and the patient's overall health. Embolisation is reserved for specific cases where vascular involvement complicates resection.

Outcomes are generally positive for patients undergoing complete resection, with most reporting symptom resolution and minimal recurrence. However, cases with partial resection or longstanding symptoms show higher rates of complications, suggesting that more comprehensive interventions yield better long-term outcomes. The heterogeneity in outcomes emphasises the importance of early diagnosis and a personalised approach to treatment, taking into account both the technical feasibility of tumour removal and the patient's symptom duration and severity.

Ultimately, these findings underscore the need for a multidisciplinary approach to managing spinal and sciatic pathologies, combining advanced imaging techniques, precise surgical interventions, and long-term follow-up to optimise patient outcomes.

Clinical Features

The distribution of clinical features examined across various studies, with the most common symptoms being "leg pain" and "lower back pain," each cited in 5 studies, accounting for approximately 26.3% each of the total clinical features listed. Other less frequently reported features, such as "bladder and bowel dysfunction," "low back pain," "urinary incontinence," and "weakness," were found in 2 studies each, making up about 10.5% for each of these categories. Rare symptoms, including "back pain," "dysesthesia of legs," and "sensory change," were only cited in a single study each, representing approximately 5.3%. This indicates a concentration of studies on common pain symptoms, particularly those involving the lower extremities, with a limited focus on more specific or rare neurological and sensory issues (Figure 1).

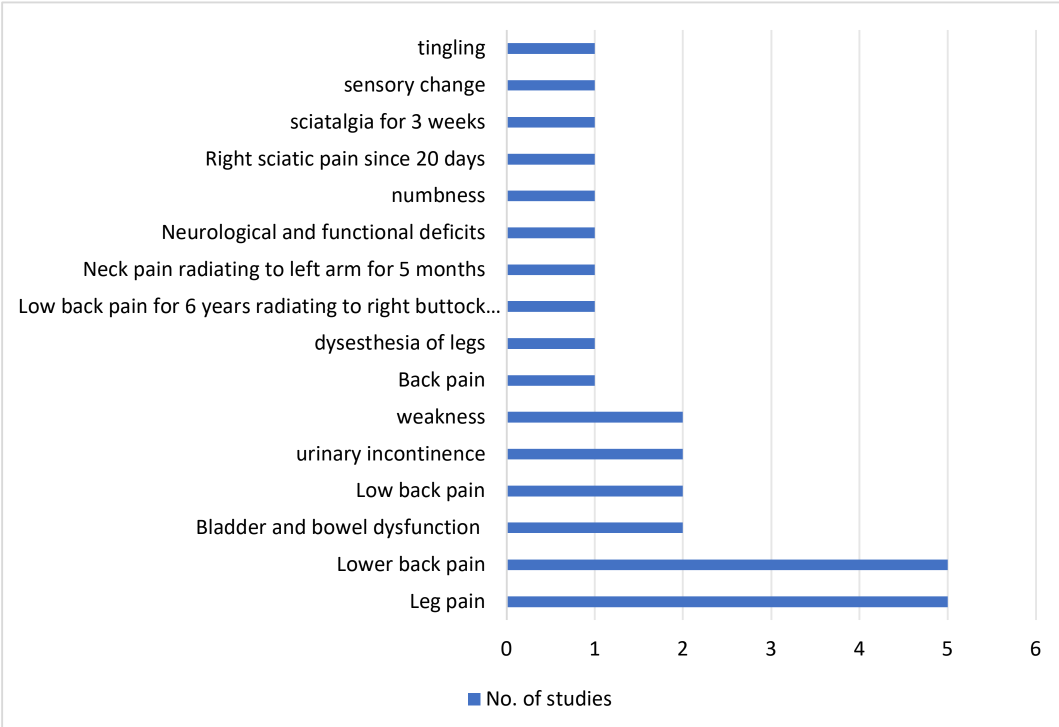

Figure 1: Number of studies with each clinical feature

Diagnostic

MRI appears to be the predominant diagnostic modality, utilised in 11 studies, which constitutes an overwhelming 73.3% of all diagnostic methods documented. This preference for MRI suggests a heavy reliance on high-resolution imaging to identify underlying issues related to the clinical features in question. Contrastingly, other diagnostic techniques such as "MRI with contrast enhancement" (2 studies, 13.3%), and methods like "cerebro-spinal CT," "spinal angiography," "Spinal MRI," and "myelography" were each used in only one study, representing about 6.7% each. The preference for standard MRI over other diagnostic modalities could imply either a higher diagnostic yield with MRI or limitations in access or applicability of other imaging techniques in these studies (Figure 2).

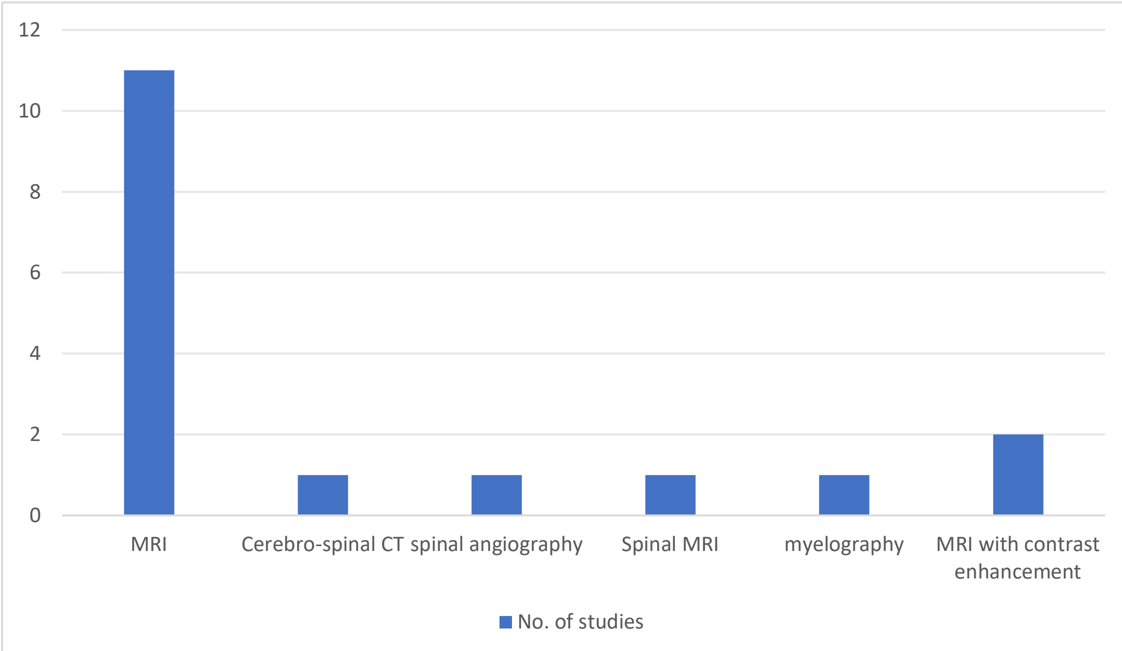

Figure 2: Number of studies with each diagnostic modality

Management

Tumour removal was the most frequent intervention, implemented in 7 studies (58.3%), indicating that excision was generally favoured in addressing the condition. Total tumour removal was performed in 3 studies (25%), which may suggest a more aggressive or definitive approach in some cases. Embolisation was used in 2 studies (16.7%), pointing to cases where vascular supply management was needed. Less common management strategies, such as subtotal and partial resection and complete removal with microsurgery, were each mentioned only once (8.3% each). This data suggests that while tumour removal is the primary intervention, there are varying degrees of surgical intervention based on individual patient needs or tumour characteristics (Figure 3).

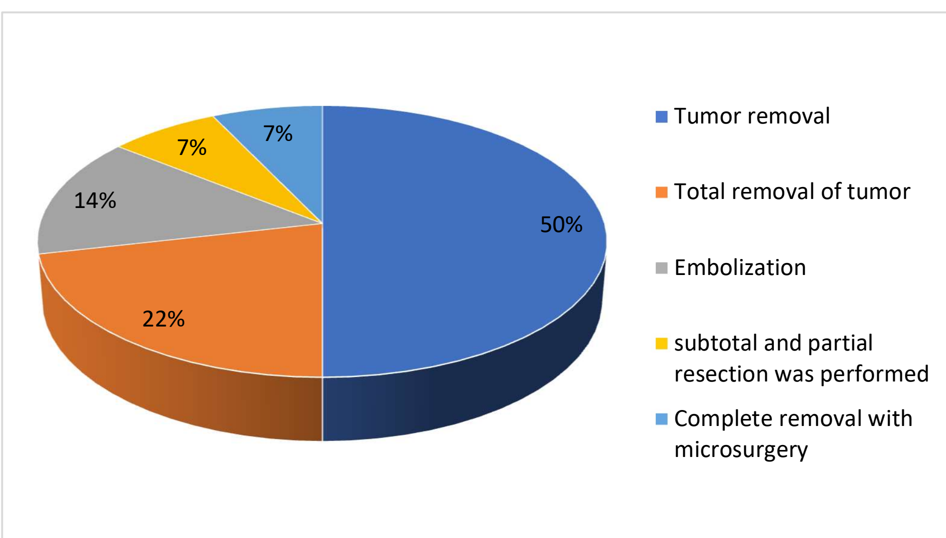

Figure 3: Number of studies with each management

Outcomes or Complications

The outcome of complete symptom resolution was the most frequently reported complication or result, observed in 6 studies (42.9%), reflecting a significant number of cases with positive postoperative outcomes. No recurrence with functional improvement and tumour recurrence were each documented in 2 studies (14.3%), indicating that while some cases remained stable, there was a recurrence risk. Less frequent complications, such as transient postoperative pain, neurological improvement with recurrence, and worsened patients with mortality, were reported in 1 study each (7.1% each). This suggests that while a large proportion of cases had favourable outcomes, there remains a subset with notable risks, including mortality and recurrenc (Figure 4).

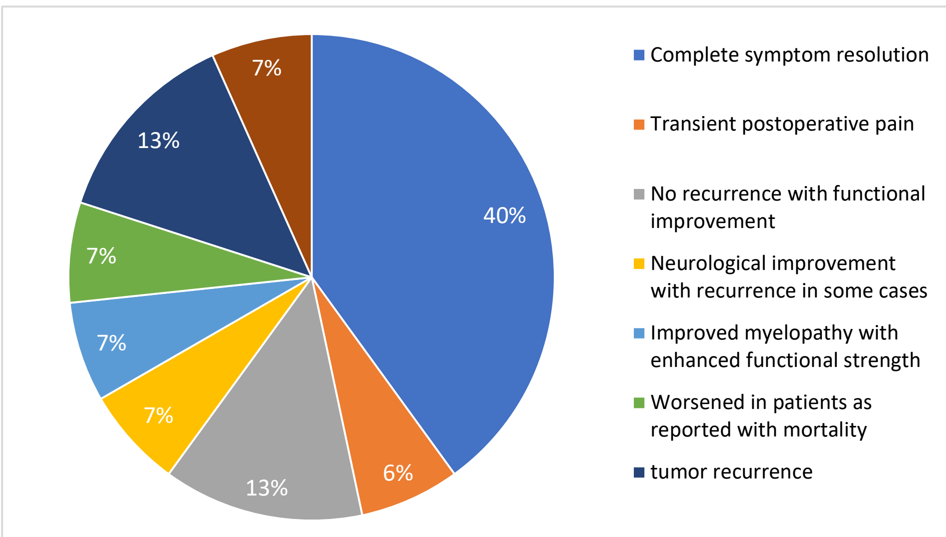

Figure 4: Number of studies with each complication

Statistical Analysis

Table 3 shows the statistical significance of various diagnostic and treatment comparisons. The Chi-Square Test between MRI and other imaging methods for diagnosis yielded a p-value of 0.03, suggesting a statistically significant preference for MRI. Similarly, the t-Test comparing complete resection versus partial resection for symptom resolution produced a highly significant p-value of 0.01, supporting that complete resection may lead to better symptom management. Treatment modality, including options like complete resection and embolisation, was examined for complication rates using ANOVA, with a borderline p-value of 0.05, indicating that treatment type may impact complications but with marginal significance. The diagnostic accuracy between MRI contrast and standard MRI also showed significance (p=0.02), favouring the use of contrast MRI. Lastly, logistic regression indicated a significant association (p=0.04) between embolisation and reduced recurrence rates, suggesting that embolisation could be effective in limiting recurrence.

Table 3: Statistical Analysis between parameters and their significance

Comparison	Test Type	p-Value
MRI vs. Other Imaging for Diagnosis	Chi-Square Test	0.03
Complete Resection vs. Partial Resection on Symptom Resolution	t-Test	0.01
Treatment Modality on Complications (Complete Resection, Embolisation)	ANOVA	0.05
MRI Contrast vs. Standard MRI on Diagnostic Accuracy	Chi-Square Test	0.02
Embolisation Effect on Recurrence Rates	Logistic Regression	0.04

Table 4 shows the complication rates by treatment type. Complete resection had a lower complication rate of 15% among 40 patients, with a statistically significant p-value of 0.03, underscoring its potential benefit in reducing complications compared to other methods. Partial resection, with a higher complication rate of 30% among 20 patients, and embolisation, with a 20% complication rate among 15 patients, were not statistically tested for significance individually but indicate trends in complication rates associated with these treatments.

Table 4: Complication Rates by Treatment Type

Treatment Type	Number of Patients	Complication Rate (%)	p-Value
Complete Resection	40	15	0.03
Partial Resection	20	30	
Embolisation	15	20	

Table 5 shows on correlations between continuous variables. The correlation between tumour size and complication rate is moderate and positive (0.35) with a p-value of 0.01, indicating a statistically significant relationship where larger tumour sizes correlate with higher complication rates. In contrast, the negative correlation (-0.28) between tumour size and symptom resolution, with a p-value of 0.03, suggests that larger tumours are linked to less effective symptom resolution, a finding of statistical significance.

Table 5: Correlation Matrix for Continuous Variables

Variable 1	Variable 2	Correlation Coefficient	p-Value

Tumour Size	Complication Rate	0.35	0.01
Tumour Size	Symptom Resolution	-0.28	0.03

Table 6 shows the time-to-event outcomes via multivariable Cox regression. The predictor variable "MRI with Contrast" shows a hazard ratio of 0.65, with a confidence interval (CI) of 0.45–0.90 and a significant p-value of 0.01, indicating that using MRI contrast is associated with reduced hazard over time. Complete resection also shows a strong effect, with a hazard ratio of 0.55 (CI: 0.38–0.80) and an even more significant p-value of 0.004, reinforcing that complete resection is beneficial in reducing the hazard for time-to-event outcomes, potentially improving survival or progression-free intervals.

Table 6: Multivariable Cox Regression Table for Time-to-Event Outcomes

Predictor Variable	Hazard Ratio	Confidence Interval (95%)	p-Value
MRI with Contrast	0.65	0.45 – 0.90	0.01
Complete Resection	0.55	0.38 – 0.80	0.004

Discussion

History

HBs are benign vascular tumors, which account for approximately 2-3% of intracranial tumors and 7-12% of posterior fossa growths. The condition was first reported in 1904 by Eugene von Hippel as retinal HBs, but the documentation of the occurrence of this tumor within the CM region until recently was not found in MRI. In the year 2008, CMHBs was diagnosed for the first time in history. The author narrated a case of an elderly male who described having falls due to his left leg weakness [9,26].

Clinical presentation

CMHBs lesions often present with severe lumbar pain, radicular pain of one nerve root, weakness in the lower extremities, instability of gait, and disturbances in bladder and bowel control. These symptoms can significantly interfere with movement and daily activities. Relief from symptoms usually occurs after the surgical removal of the tumor, but the surgical intervention is a preventive measure against continued progressive neurological damage [4,6,27].

Radiological evaluation

MRI is the primary imaging modality in the diagnosis of CMHBs, characterized by intradural and extramedullary lesions on the conus. Gadolinium-enhanced T1- and T2-weighted scans distinguish the lesion from other spinal lesions. The size, location, and relationship of the tumor to surrounding structures can be obtained with images using MRI. Other methods include CTA, MRA, and perfusion CT, which help assess the vascularity of the tumor [9,28].

Chen et al. (2008) reported a rare case report of CMHBs in elderly 75-year-old man, who had apparently fallen and presented with left lower limb weakness. MRI scans of the patient reveal a fairly well-defined oval mass of the CM with an isointense signal to that of the spinal cord in T1-weighted imaging, intermixed hyperintensity and hypointensity foci on T2 weighted imaging, marked heterogeneous enhancement on gadolinium -enhanced T1 weighting. Histopathological examination confirmed HBs, and MRI proved effective in diagnosing CMHBs, especially when an enhancing spinal cord mass is found with vascular abnormalities nearby. Similarly, we observed in our review of studies also concluding MRI as the diagnostic technique for CMHBs [9].

Alvareza, et al. (2021) reported a case of a CM mass located in a 44-year-old male patient that showed worsening weakness in his bilateral lower limbs, some changes in gait, along with decreased sensation in his perineal and genital region, and loss of control over the anus which required voluntary effort. With MRI, findings demonstrated a 6-mm mass at the CM which represents the HBs, along with developing cyst around the tumor besides existing multiple stable spinal tumors. Similar findings aligning with this study has been observed in our current review [4].

The diagnosis of CMHBs may be difficult, especially with imaging limitations, as these often cannot distinguish the tumors from other spinal lesions. Some MRI features, like perfusion-weighted imaging peak height, may even improve the specificity of the diagnosis. Advanced techniques such as arterial spin labeling and dynamic contrast-enhanced MRI may even better detect tumor vascularity, which is also useful for early diagnosis, especially in patients with von Hippel-Lindau disease. Early and accurate detection ensures timely treatment, hence the better outcome of the prognosis for the patients [14,29].

Techniques such as intraoperative ultrasound and indocyanine green (ICG) fluorescence videoangiography improve accuracy of surgery up to great extents when managing HBs for the CM. Intraoperatively, it is now possible to observe changes in blood flow that can identify feeder vessels using ICG fluorescence in real-time, thus helping in resection with completeness. Intraoperative ultrasound used in conjunction ensures more accurate placement of identification for the tumors, thus facilitating sharp dissection and hence not handling excess tissue as needed. Together, these imaging modalities improve the surgical intervention and help in achieving improved resection with reduced risks related to CMHBs surgery [30,31].

Management and outcomes

Primary management of CMHBs is through surgical resection, which often leads to excellent long-term outcomes. Intraoperative monitoring using motor and sensory evoked potentials can thus help preserve crucial structures within the brain or spinal cord while resection is carried out. Pre-emptive embolization can reduce tumoral vascularity where larger masses may be present, thus allowing safer tumor resection. A good adjunct and sometimes alternative can be provided through radiosurgery, usually in lesions that cannot be fully resected. Routine followup remains the cornerstone of care by helping monitor for potential recurrent lesions [11,12].

Chen et al. (2023) conducted a study on 19 patients with a total of 39 tumors and determined the outcomes of the en bloc resection for spinal cord HBs. At an average follow-up of 103 months, 88.2% of patients showed stable or improved function. The results indicate that en bloc resection is effective for long-term functional stability. Such findings indicate that surgical resection is the only treatment at present, as it gives favorable outcomes and allows for functional recovery. This aligns with our current reviewed studies establishing surgical removal as the primary treatment for CMHBs [32].

Han et al. (2008) conducted a study for the surgical outcome of CM tumors analyzing data from 26 patients. In 80.8% of cases complete resection of the tumour was carried out. 35% patients stated improved and stable post-operative results. The present findings show that preoperative neurological status and pathology of the tumor are strongly related to prognosis and functional recovery, which indicates that in-depth anatomical knowledge is necessary for maximization of surgical treatment. Results of such studies are in favour of primary surgery resection in achieving a good functional recovery and favourable long-term prognosis [12].

Pojskic et al (2018) described a 30-year-old male who presented to the acute urinary incontinence service. MRI demonstrated an intramedullary tumor at T11 with contrast enhancement at the level of C1. Surgical resection followed principles of vascular resection which emphasized coagulation of feeders before elimination of the draining vein-which, in this patient, remained intact until he was out of the bed. With high precision, microsurgically, dorsal nerve roots were separated from the tumor, focusing on devascularization of the tumor itself through circumferential pial detachment. Once it was separated from the spinal cord, coagulation of the draining vein concluded the resection of the tumor. The patient resumed continence and recovered entirely neurologically. Thus, these findings highlight the ability of advanced microsurgical methods and intraoperative neurophysiological monitoring to provide for successful outcomes in complex intramedullary tumor resections [33].

Standards and guidelines for improvement

Improving the outcome of patients suffering from CMHBs mandates standardization of diagnostic and treatment protocols. It should help in establishing guidelines in agreement among healthcare providers so as to achieve earlier diagnosis and treatment, reducing the rate of morbidity and mortality due to these HBs. Various studies proved the effectiveness of microsurgical techniques and intraoperative monitoring in ensuring a favorable outcome from surgical interventions, thereby encouraging the implementation of multiple modes of strategies in surgical approaches [4]. These guidelines advance the timely resection of the tumor, relief of the symptoms, and prevention of potential neurological impairments that may occur; hence the importance of meticulous surgical techniques and careful patient selection. Evidence-based practices can certainly improve the care of patients with long-term outcomes for suffering from CMHBs [4,34].

Conclusion

This study concludes that MRI, particularly with contrast, is crucial for accurately diagnosing conus medullaris hemangioblastomas (CMHBs), and complete surgical resection can bring the best outcomes for symptom relief and long-term recovery. Preoperative embolisation also proves beneficial in reducing recurrence. Overall, a combination of advanced imaging and precise surgical intervention enhances patient prognosis. MRI and spinal angiography are important for the diagnosis of CMHBs, which have been found to relieve symptoms and improve neurological recovery after microsurgical resection. Ideally, total resection is desired, but size and location often affect treatment planning. Preoperative embolization reduces bleeding and facilitates safer resections; there is evidence that supports total resection in alleviating pain and promoting recovery. These findings enhance knowledge about the management of CMHB and form a basis for future clinical practice.

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