

<https://doi.org/10.31689/rmm.2023.30.4.283>

REVIEW

Contemporary Management Approaches for Spinal Subdural Hematoma in the Pediatric Population: Scoping Review

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Abstract

This scoping review study describes the assessment of articles relevant to the management of spinal subdural hematoma in the pediatric population. The assessment of the articles was conducted following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) Extension for Scoping Reviews guidelines. Of the 14 articles analyzed, the main focus was on management as well as evidence-based approaches in cases of pediatric spinal subdural hematoma. In the reviewed articles, various aspects related to intervention techniques, prevention strategies, and post-treatment follow-up were discussed. The findings of this review highlight the importance of a holistic and evidence-based approach in managing cases of spinal subdural hematoma in the pediatric population. The clinical implications of these findings may help improve medical understanding and practice in effectively managing this complex condition.

Keywords: spinal subdural hematoma, pediatric, management, evidence-based, scoping review.

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INTRODUCTION

Spinal subdural hematoma, an uncommon yet clinically significant neurological condition, poses a unique challenge in the realm of pediatric medicine. Defined as the accumulation of blood between the dura mater and arachnoid mater layers of the spinal cord, this condition can result from various etiologies, including trauma, coagulopathies, vascular malformations, or spontaneous occurrences.¹ Because there are no bridging veins or significant blood vessels in the intraspinal subdural area that could potentially produce subdural haemorrhage, the prevalence of spinal subdural hematoma (SDH) is far lower than that of cranial SDH.^{2,3} However, bleeding may originate from injury to the radicular veins covering the spinal subdural region. Conversely, one of the rarest kinds of spinal hematomas are subdural hematomas.⁴ The risk of cerebral haemorrhage in the paediatric population is elevated by factors such as head trauma, haematological coagulopathy, and the administration of chemotherapeutic drugs.⁵ Although rare, spinal subdural hematoma can lead to substantial neurological deficits and morbidity in affected pediatric patients.

Understanding the pathogenesis, diagnostic methods, and evidence-based treatments of spinal subdural hematoma in children is essential for effective therapy as well as improve emergency operations centers that can respond more quickly⁶. Surgical evacuation, conservative care, and minimally invasive procedures have been reported in the literature, but a full synthesis is needed. A scoping review can fill this gap by methodically investigating and mapping paediatric spinal subdural hematoma management methods and neurosurgeons need to consider prior to operating patients with degenerative diseases of the spine⁷. This study aims to provide a holistic overview of the current state of knowledge in this domain by collating and analysing diverse sources of information, including clinical studies, case reports, and expert opinions. It seeks to elucidate the range of management strategies, their associated outcomes, and emerging trends, ultimately improving understanding of best practices and areas for further research.

METHODS

In this study, we conducted a scoping review to comprehensively analyze and synthesize the existing liter-

ature pertaining to the management approaches employed for spinal subdural hematoma in the pediatric population. that comprehensively examines the various management strategies utilized for spinal subdural hematoma in pediatric patients. This review intends to identify and synthesize the available literature on treatment approaches, outcomes, and trends in order to provide an overview of the current state of knowledge and guide potential avenues for further research and clinical practice improvements in this specific medical context. The synthesis of existing literature will elucidate the range of treatment approaches, including surgical and non-surgical interventions, their respective outcomes, complications, and any emerging trends in practice. The review will identify common themes, gaps in research, and potential areas for improvement in the management of this condition. Additionally, it will offer insights into the effectiveness and safety of different interventions, serving as a valuable resource for healthcare practitioners, researchers, and policymakers involved in pediatric neurosurgery and spinal hematoma management. PRISMA Extension for Scoping Reviews guidelines were used to conduct this scoping review.

Research Question: A research question was developed to align the concept being researched with the target population. This research question directly addresses the concept of management strategies for spinal subdural hematoma, while focusing specifically on the pediatric population. It aims to investigate the range of approaches utilized, as well as their associated outcomes and any evolving patterns in clinical practice, providing a clear framework for scoping review. Thus, the question for this scoping review is: "What are the diverse management strategies employed for spinal subdural hematoma in pediatric patients, and what is the current state of knowledge regarding their efficacy, outcomes, and emerging trends?"

Inclusion Criteria: The keywords used to identify relevant literature were selected based on the PCC (population, concept, context) framework and generated in consultation with academic librarians. Each of the keywords that had been determined in population, concept, and context were inputted in each database with the joining word "AND" to get the relevant literature.

Population: Pediatric patients (children and adolescents) who have been diagnosed with spinal subdural hematoma. Initially, using the keyword (children OR pediatric OR adolescents) AND ((spinal

subdural hematoma) OR (spinal hemorrhage). The search terms used a combination of keywords and controlled vocabulary terms (MeSH terms) to ensure a comprehensive retrieval of relevant literature.

Concept: The management strategies employed for spinal subdural hematoma in the pediatric population. This includes surgical interventions, non-surgical approaches, conservative management, minimally invasive techniques, and any other therapeutic strategies aimed at addressing spinal subdural hematoma in children and adolescents.

Context: The medical context in which the review is focused is the treatment and management of spinal subdural hematoma in pediatric patients. This encompasses various clinical settings, such as hospitals, medical centers, and research institutions, where different management approaches are implemented to address this specific medical condition in children and adolescents.

Type of Sources: This review considered primary research that had been reviewed in the form of quantitative, qualitative, or mixed methods studies.

Study Selection: Inclusion criteria in scoping reviews often evolved during the article search process to match the research question with the results of the articles obtained. In this scoping review, the inclusion criteria set were relatively stable during the review stage, namely 1) primary research study; 2) full text; 3) published between 2013 and 2023; and 4) English language. While the exclusion criteria set in this review were studies with topics that did not directly discuss spinal subdural hematoma and pediatric population; keywords that were not discussed in the core of the study; studies that did not contain all the keywords searched; and the research was found to be irrelevant.

Search Strategy: This scoping review looked at the available literature using searches in PubMed, Science Direct, MEDLINE, Embase, Scopus and Google Scholar. These three databases were chosen because of their extensive collection of literature related to the topic of this review. Articles published between January 1, 2013 and December 31, 2023, in full text, involving research on pediatric with spinal subdural hematoma, and written in English were considered for this literature evaluation.

All identified literature from the three databases was collected and summarized in Microsoft Excel and Zotero. Subsequently, a title review of the literature was conducted to eliminate duplicate articles. After elimi-

nating duplicates, potential literature was reviewed based on titles and abstracts to exclude literature that did not meet the inclusion criteria, namely non-full text literature, review articles, and not in English. Articles that passed the screening process were reviewed in full text to identify their relevance and eligibility. Two reviewers independently examined and compiled data from the relevant literature, and if there were any disagreements, a third reviewer was brought in to settle the matter. This scoping review was documented in the PRISMA Extension for Scoping Reviews (PRISMA-ScR), which detailed the methodology and findings (Figure 1).

Data Mapping: Data mapping or extraction is a process to summarize important information from the literature relevant to the research question that has been set. The mapped data included the author's name and year of publication, etiology, study subject, spinal location, presented symptoms, treatment type (surgery, conservative), and outcomes. Following the tabulated results, a narrative summary is offered to elaborate on the most salient findings from each set of data extractions and how they relate to the research objectives.

RESULTS

Article Search Results: The article search involved three stages, that are identification, screening, and feasibility evaluation. The identification phase began with a search for relevant publications in three databases, yielding 158 articles published between January 1, 2013 and December 31, 2023 and relevant to the review's keywords. All identified article titles were summarized in Microsoft Excel and sorted alphabetically for duplication, resulting in 21 duplicate articles that were excluded from the review process. Next, 137 articles were screened based on title and abstract to assess the relevance of the articles to the predefined inclusion criteria. A total of 32 articles that met the inclusion criteria were found and 105 articles did not meet the inclusion criteria, namely in the form of review articles, no abstract/results available, and not in English. A total of 32 articles that passed the screening process were then reviewed in full text to assess their eligibility, so 18 articles that did not match the review topic were found. Fourteen articles relevant to this topic were found, resulting in a total of 14 articles reviewed. (Figure 1).

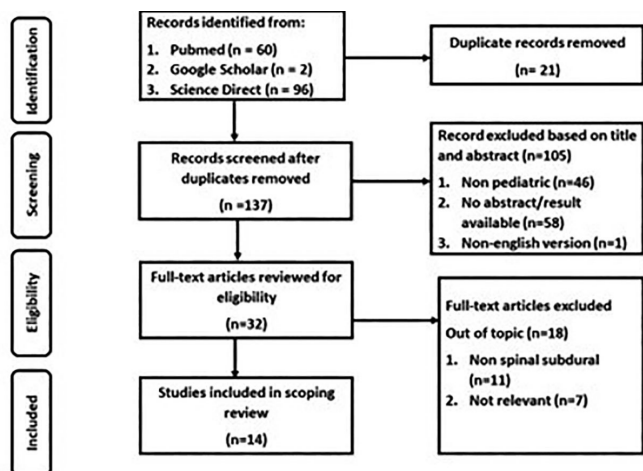


Figure 1. PRISMA-ScR flow chart of the study selection process

Article Eligibility Results: From the 14 literatures, the incidence of spinal subdural hematoma in the age range predominantly affects males compared to females. The incidence from 2013 to 2023 was higher in the age range of 0-5 years, with 7 males and 2 females affected. In the age range of 6-10 years, 2 males and 1 female were affected. In the age range of 11-15 years, 3 males and 2 females were affected. In the age range of 16 and above, 2 males were affected. Spinal subdural hematoma is more common in males across all age groups within the pediatric population.

It's evident that spinal subdural hematomas in the pediatric population can arise from various factors, including congenital conditions, trauma (both accidental and nonaccidental), coagulation disorders, and other medical issues. According to non-Traumatic Cases this study reports, Cyst in an 11-year-old male⁸, subdural schwannoma in a 14-year-old female⁹, congenital von Willebrand disease and treatment in a 13-year-old fe-

male¹⁰, arachnoid cysts in a 7-year-old male¹¹, unspecified case in a 14-year-old male¹², case related to Dengue Fever with cervicodorsal symptoms¹³, no previous disease in a 7-year-old female¹⁴, severe hemophilia in a 15-month-old case¹⁵ and although rare, it may also caused by spinal cord hemorrhage. Spontaneous spinal subdural hematomas (SSDH, aplastic anemia in an 11-year-old male¹⁶, comorbidities from congenital malformations in a 14-year-old female¹⁷. While the studies that reports a traumatic Cases comes from, minor head trauma history in a 20-year-old male¹⁸, non-accidental injury in a 2-year-old male due to domestic abuse¹⁹, nonaccidental trauma in a 5-month-old boy²⁰, no recent trauma history in a 16-year-old male²¹.

Based on the imaging techniques employed, here's a description of the diagnostic methods used for classifying the cases of spinal subdural hematomas in the pediatric population. Convergent imaging for Magnetic Resonance Imaging (MRI) and Computed Tomography (CT) scan providing a comprehensive view for accurate evaluation and confirmation by Lohani⁸, Ma⁹, Rangwala¹⁹, Michon de Marais¹⁷ and Koksai¹⁸ and Baou Madawi¹⁶ use combination MRI and MRA for detailed anatomical and vascular assessment. And the rest uses MRI for primary diagnostic modality by Ben¹⁰, Lee¹¹, Satyarthee¹², Baruah¹³, Hong²⁰, Sarehar¹⁵ and although rare, it may also caused by spinal cord hemorrhage. Spontaneous spinal subdural hematomas (SSDH, and Ahrari²¹.

The findings encompass a range of spinal regions and conditions. They include cases of traumatic and non-traumatic etiologies, spanning cervical, thoracic, and lumbar/sacral regions. Congenital conditions, trauma, and underlying diseases are implicated in figure 2.

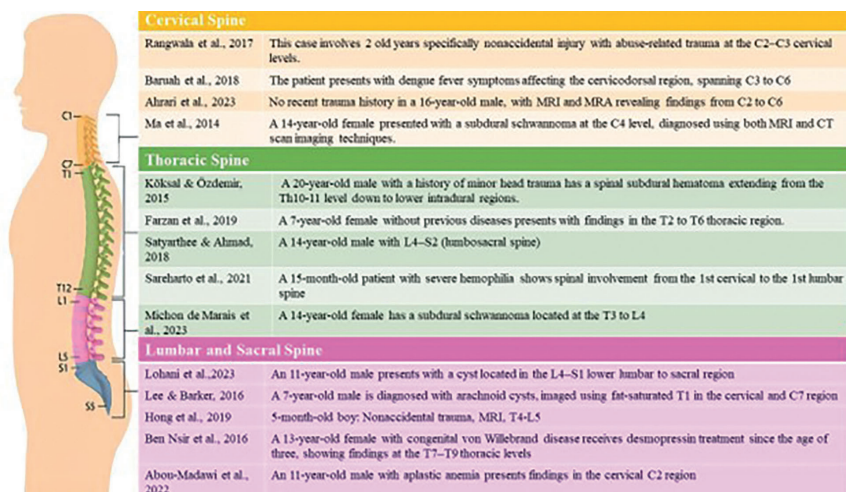


Figure 2. A summary of the provided locations of spinal subdural hematomas sorted by spinal anatomy

The compilation of clinical scenarios underscores the intricate interplay between spinal abnormalities and their corresponding neurological manifestations. Across diverse cases, a range of conditions has been identified through advanced imaging techniques such as MRI and CT scans. From cysts causing severe back pain radiating to the thighs, to a subdural schwannoma triggering bilateral upper extremities weakness, these cases demonstrate the profound impact of spinal pathologies on neurological function. Additionally, traumatic incidents like minor head trauma and nonaccidental injuries have been localized to specific spinal levels, leading to a spectrum of symptoms such as pain in the lumbar region, weakness in both upper and lower extremities, and even acute quadriparesis accompanied by urinary incontinence. Moreover, the presence of congenital disorders, such as von Willebrand disease, further showcases the intricate relationship between genetics and spinal health, influencing areas like the T7–T9 thoracic levels.

In another context, the narrative shifts to encompass broader neurological implications arising from spinal conditions. These scenarios highlight diverse presentations, including cases of severe back pain confined to the thoracic spine, lower back pain, and even nonaccidental trauma manifesting as lower extremity pain and acute paraplegia. Unique features like cranial and spinal subdural hematomas, evident through imaging, add a layer of complexity to the diagnostic landscape. Furthermore, the presence of spinal cord injuries, as indicated by acute onset quadriparesis, reflects the delicate nature of spinal structures and their pivotal role in motor function. Amidst this array of cases, the mention of nonaccidental trauma underscores the crucial importance of accurate diagnosis and intervention in instances of potential abuse. These scenarios collectively emphasize the necessity of a comprehensive approach to spinal and neurological health, considering both traumatic and congenital origins, and tailoring treatments to address the intricate relationship between spinal abnormalities and associated neurological deficits.

The presented instances provide valuable insights into a range of management approaches for spinal conditions, highlighting diverse outcomes. Surgical interventions featured prominently, showcasing varying degrees of effectiveness. A combination of surgery and oral steroids yielded a favorable result. In contrast, the application of a bilateral pterional resulted in incom-

plete lesion removal and the formation of a pseudomeningocele. Notably, laminectomy procedures proved to be successful, leading to positive clinical outcomes. However, where durotomy was employed, the patient's recovery was suboptimal. Similarly, a combination of laminectomies and subdural irrigation did not demonstrate any discernible improvement. Additionally, the challenges associated with hemophilia significantly affected the recovery process, despite the implementation of surgical and therapeutic interventions. Conservative management strategies also played a pivotal role, as evidenced by the maintenance of stability, while other studies achieved varying outcomes through conservative measures. Ultimately, the favorable outcome was attributed to the completion of a laminectomy procedure.

DISCUSSION

The cases of pediatric spinal subdural hematomas presented in the studies demonstrate a wide age range, spanning from infancy to adolescence, with the youngest being a 5-month-old boy and the oldest being a 20-year-old male. The gender distribution among the reported cases is diverse, encompassing both males and females and the number of cases in male is outweigh female. Research specifically addressing demographics in children and adolescents is limited. Case reports of spinal subdural hematoma from trauma and non-trauma range from 44 to 60%¹⁹The reported cases encompass a diverse array of etiologies contributing to spinal subdural hematomas in both traumatic and non-traumatic contexts. Non-traumatic cases involve structural anomalies such as cysts, subdural schwannomas, and arachnoid cysts, which can disrupt normal spinal anatomy and lead to bleeding. Additionally, congenital conditions like von Willebrand disease, severe hemophilia, and aplastic anemia demonstrate the role of underlying coagulation disorders in precipitating these hematomas. Moreover, the unusual case of spinal subdural hematoma associated with Dengue Fever underlines the potential for viral infections to trigger bleeding disorders and contribute to the condition. In nonaccidental instances, the sinister role of domestic child abuse highlights the significance of considering abuse as a potential cause in cases where trauma history is ambiguous or lacking, emphasizing the crucial role of thorough evaluation and clinical suspicion in uncovering hidden etiologies.²²

The diagnostic methods employed to classify cases of spinal subdural hematomas in the pediatric population reveal a comprehensive approach, as highlighted by the utilization of convergent imaging techniques such as MRI and CT scans. This synergistic approach is demonstrated by studies including Lohani⁸, Ma⁹, Rangwala¹⁹, Michon de Marais¹⁷, and Köksal¹⁸, where the combination of MRI and CT scans ensures a thorough evaluation for accurate diagnosis and confirmation. Furthermore, the study by Abou-Madawi¹⁶ takes precision a step further by incorporating both MRI and MRA to provide intricate anatomical and vascular assessment. The preference for MRI as the primary diagnostic modality, observed in the remaining cases, underscores its efficacy in delineating spinal subdural hematomas. This amalgamation of imaging techniques reflects a meticulous and multi-faceted diagnostic strategy aimed at enhancing the understanding and classification of these cases in the pediatric population.

The significance of neurosurgical management in addressing spinal subdural hematomas (SDH) within the pediatric population, as evident from the cases presented (C4, T7-T9, C3-C6, T2-T6, T4-L5, 1st cervical to 1st lumbar spine, C2-C6, T3-L4), underscores the crucial role of surgical interventions in cases where neurological deficits or acute symptoms are prominent. Neurosurgical procedures like bilateral pterional, laminectomy, durotomy, and subdural irrigation have been employed with varying degrees of success. Notably, cases involving acute onset quadriparesis, paraplegia, or rapid progressive weakness often necessitated surgical intervention to alleviate significant neurological impairments. The success achieved through neurosurgical approaches, resulting in favorable outcomes and symptom resolution, highlights the critical importance of timely intervention to prevent permanent neurological deficits in pediatric patients. However, the variable outcomes in cases of lower motor neuron lesions, influenced by factors such as underlying conditions like hemophilia, indicate the complexity of management decisions. These cases emphasize the need for a nuanced approach that considers not only the severity of symptoms but also individual patient factors and potential underlying coagulation disorders. The documented success of neurosurgical interventions in resolving significant neurological deficits underscores their pivotal role in ameliorating acute clinical presentations and highlights the importance of multidisciplinary collaboration to determine the optimal management strategy for pediatric spinal SDH.²³

The significance of conservative management in treating spinal subdural hematomas (SDH) within the pediatric population, as exemplified by the cases presented (L4-S1, C7, C2-C3, L4-S2, 1st cervical to 1st lumbar spine, C2), underscores the potential efficacy of a non-invasive approach in select scenarios. The decision to opt for conservative management is particularly notable when considering the delicate nature of the pediatric spine and the potential complications associated with surgical interventions. The successful outcomes observed in cases managed conservatively highlight that this approach can lead to symptom resolution and stable conditions, reducing the need for more invasive procedures. Notably, the absence of significant neurological deficits or worsening symptoms in conservatively managed cases (such as lower back pain, postprandial emesis, and persistent vomiting) emphasizes the importance of careful patient assessment and individualized treatment plans. This conservative strategy aligns with the principle of minimizing risks associated with interventions, especially in the context of pediatric patients, where preserving spinal integrity and minimizing potential complications are paramount. However, a thorough understanding of the underlying factors, such as lesion location, symptom severity, and patient health, is essential to effectively determine the appropriateness of conservative management in each case.

Conservative approaches and operative measures in the management of spinal subdural hematomas in the pediatric population have significant implications. The conservative approach, which includes symptomatic management with analgesia or observation, has yielded positive results in some cases. Especially in cases with mild or non-disruptive symptoms, this approach is able to achieve stable improvement and avoid the risks associated with surgical intervention. On the other hand, operative measures, such as pterional, laminectomy, durotomy, and subdural irrigation, have proven successful in managing cases with significant neurological deficits and other acute symptoms. Nevertheless, these measures should be considered carefully, due to the potential risks and complications inherent in surgical intervention, especially in pediatric patients.

The decision between conservative and operative approaches should be based on a thorough evaluation of the severity of symptoms, lesion location, medical history, as well as any special factors affecting the patient.^{24,25} It should be emphasized that each case is unique, and the approach chosen should be tailored to

the patient's individual characteristics. Close collaboration between the medical team of surgeons, neurologists and other experts is essential in deciding the best approach for each case. Further studies and accumulation of clinical evidence will help direct more detailed guidelines and treatment protocols for spinal subdural hematoma in the pediatric population.

CONCLUSION

Analysis of data from 14 literatures concluded a variety of etiologies, including cystic disorders, tumors, minor trauma, and bleeding disorders such as hemophilia. Clinical manifestations include symptoms of severe back pain, limb weakness, as well as sensory disturbances and urinary incontinence. Diagnosis is supported by the use of imaging techniques such as MRI and CT scans. Treatment of spinal subdural hematoma cases in children involves various approaches including laminectomy, and conservative approaches through the use of analgesia or blood clotting therapy can also be

applied depending on the patient's condition. The success rate of treatment varies, with some patients having a good recovery after surgical intervention or conservative therapy, while others have a poor recovery, especially in cases involving comorbidities such as hemophilia. This underscores the complexity in the diagnosis and case management of spinal subdural hematoma in the pediatric population, as well as the importance of a tailored approach to individual patient characteristics.

Competing interests

The authors declare no competing interest.

Authors' contributions

All the authors read and approved the final version of this manuscript.

Acknowledgements

We would like to thank All SMF Neurosurgery Saiful Anwar Malang Hospital team during the preparation of this scoping review.

Table 1. Summary of the results from the literature review: cases of spinal subdural hematoma in pediatric

Author and year	Age/Sex	Etiology	Diagnosis strategy	Location	Presenting symptoms	Surgery	Conservative	Outcome
Lohani et al., 2013 ⁸	11/M	cyst	MRI & CT scan	L4-S1	severe back pain radiating to the back of his thighs	None	oral steroids	Good Outcome
Ma et al., 2014 ⁹	14/F	subdural schwannoma	MRI & CT scan	C4	bilateral upper extremities weakness	bilateral pterional craniotomy	N/A	complete excision of her original spinal lesion but a large amount of fluid collection (pseudomeningocele) around the surgical site
Köksal & Özdemir, 2015 ¹⁸	20/M	from minor head trauma	MRI & CT scan	Th 10-11 level and extending to lower areas intradurally	pain occurred in the lumbar region and in both legs	None	None	Resolved in 1 month
Ben Nsir et al., 2016 ¹⁰	13/F	congenital von Willebrand, desmopressin treatment since the age of three	MRI	T7-T9	severe back pain centered in her thoracic spine without any precipitating factor such as sports or trauma	laminectomy	None	Good Outcome

Lee & Barker, 2016 ¹¹	7/M	Arachnoid cysts	MRI	fat-saturated T1 and C7	lower back pain	None	managed conservatively with analgesia	Stable conditions
Rangwala et al., 2017 ¹⁹	2/M	nonaccidental injury, specifically, domestic child abuse	MRI & CT scan	C2–C3	10 episodes of postprandial emesis, ecchymosis to the right ear, and mild edema	None	managed conservatively	none
Satyarthee & Ahmad, 2018 ¹²	14/M	N/A	MRI	L4–S2	Cranial and spinal SDH in thoracolumbar region	N/A	conservative	Good Outcome
Baruah et al., 2018 ¹³	N/A	Dengue Fever Presenting with Cervicodorsal	MRI	C3 to C6	acute onset quadriparesis and urinary incontinence	Durotomy C6 to D4	N/A	poor recovery
Farzan, 2019 ¹⁴	7/F	no previous disease,	MRI	T2 to T6	limping and pain in lower extremities and acute paraplegia	laminectomy from T2 to T5		Good Outcome
Hong et al., 2019 ²⁶	5-month-old boy	nonaccidental trauma	MRI	T4-L5	poor neurologic examination limited to extremity withdrawal	L3-5 laminectomies, durotomy, and subdural irrigation	none	none
Sareharto et al., 2021 ¹⁵	15-month	severe hemophilia	MRI	1 st cervical to 1st lumbar spine	lower motor neuron lesion	laminectomy	replacement therapy of factor VIII	poor recovery due to hemophilia
Abou-Madawi et al., 2022 ¹⁶	11/M	aplastic anemia	MRI & CT scan	C2	headache and persistent vomiting and neck and back pain	none	conservative	clinically symptoms free
Ahrari et al., 2023 ²¹	16/M	no positive history for any recent trauma	MRI & MRA	C2 to C6	rapid progressive weakness of the left side extremities	decompression by C3–C7 conservative laminectomy	none	Good Outcome
Michon de Marais et al., 2023 ¹⁷	14/F	comorbidities secondary to multiple congenital malformations	MRI	T3 to L4	N/A	complete L3 laminectomy	None	Good Outcome

Notes: N/A= Not available; MRI= Magnetic Resonance Imaging; MRA= Magnetic resonance angiography; CT= Comuted Topography; C=Cervical; T= Thoracal; L= Lumbalis

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