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Overcoming vasospasm. Timely chemical angioplasty in ruptured right posterior communicating aneurysm

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ABSTRACT
This article presents a case report detailing the endovascular management of severe vasospasm in a 55-year-old patient following the rupture of a right posterior communicating aneurysm. Initially presenting with a Fisher grade 4 subarachnoid haemorrhage, the patient underwent embolization treatment, which resulted in good condition. However, on the 9th day, the patient experienced a sudden deterioration, marked by severe vasospasm and neurological deficits.

Diagnostic procedures, including cerebral angiography, revealed extensive vasospasm affecting multiple cerebral arteries. In response, endovascular therapy was initiated, consisting of the intra-arterial administration of Milrinone and Nimodipine. This intervention aimed to alleviate vasospasm and enhance cerebral perfusion. Angiographic imaging post-intervention demonstrated significant improvement in vascular perfusion, correlating with a rapid neurological response. Notably, the patient exhibited immediate improvement in motor deficits and dysarthria following treatment.

This case underscores the critical importance of timely recognition and intervention in managing complications post-aneurysmal rupture, particularly severe vasospasm, which poses significant risks of neurological sequelae. The successful application of endovascular techniques, including chemical angioplasty, highlights the evolving landscape of neurointerventional procedures in addressing complex cerebrovascular pathology.

The case further emphasizes the necessity of a multidisciplinary approach, involving collaboration between neurosurgery, interventional radiology, and neurocritical care, to optimize patient outcomes in cerebrovascular emergencies. Early detection, prompt intervention, and vigilant post-procedural monitoring remain pivotal in mitigating the risks associated with cerebral aneurysm rupture and its sequelae.

Keywords
chemical angioplasty, vasospasm management, milrinone infusion, endovascular treatment, angiographic monitoring, aneurysm embolization

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1. INTRODUCTION

Vasospasm following ruptured brain aneurysms represents a pivotal challenge in neurocritical care, significantly affecting outcomes by predisposing patients to delayed cerebral ischemia. This condition underscores the necessity of a nuanced understanding of cerebral vasculature responses post-rupture and the strategic application of interventions to prevent ischemic complications. The literature emphasizes the imperative of timely and aggressive management strategies to improve patient prognosis, focusing on the initial stabilization of life-threatening conditions, meticulous control of blood pressure, maintenance of fluid and electrolyte balance, and the prophylactic administration of nimodipine.

Early intervention is crucial, with strategies encompassing the rapid repair of the ruptured aneurysm via surgical clipping or endovascular coiling to secure the aneurysm and prevent rebleeding. Such prompt actions are supported by studies showing the correlation between the timing of treatment post-rupture and the incidence of complications such as rebleeding, cerebral infarcts, and mortality. Specifically, treatments administered within the critical first hours after rupture can significantly reduce the risk of subsequent vascular events, highlighting the importance of early diagnosis and intervention.

Beyond the initial surgical interventions, the management of vasospasm involves a sophisticated regimen of pharmacological agents aimed at vasodilation to restore adequate cerebral blood flow. Nimodipine, a calcium channel blocker, is widely recognized for its efficacy in preventing vasospasm and improving neurological outcomes. Its role is augmented by the selective use of intraarterial vasodilators, including papaverine, nicardipine, and verapamil, particularly in refractory cases where conventional treatments fail to alleviate the vasospasm.

The utilization of vasodilators extends to a diverse array of agents, each with specific mechanisms of action tailored to counteract the pathological constriction of cerebral vessels. Among these, magnesium sulfate acts as a non-selective calcium channel blocker and has neuroprotective properties. Clazosentan, an endothelin receptor antagonist, and milrinone, a phosphodiesterase III inhibitor, represent newer therapeutic avenues being explored for their potential to reduce vasospasm-induced complications in clinical trials.

The literature review further explores chemical angioplasty with milrinone and nimodipine as an innovative treatment modality. This approach targets the underlying pathophysiological mechanisms of vasospasm, offering a multimodal strategy to enhance cerebral vasodilation and blood flow. Clinical studies have documented the effectiveness of this therapy in reducing vasospasm severity and improving neurological outcomes, suggesting its value as a complementary treatment in the neurocritical care arsenal.

The study by Labeyrie et al. on distal balloon angioplasty emphasizes its efficacy in decreasing the risk of delayed cerebral infarction, highlighting the importance of endovascular interventions. Bashir et al.'s work on intra-arterial nimodipine points to its beneficial influence on clinical outcomes, reinforcing the role of targeted pharmacological therapies. These references, along with foundational research like Aaslid et al.'s evaluation of cerebrovascular spasm with Doppler ultrasound and Allen GS et al.'s trial on nimodipine, underscore the multifaceted approach required to manage vasospasm, combining diagnostic precision, prophylactic pharmacotherapy, and innovative endovascular techniques to improve patient outcomes. Integrating these findings into the management strategy provides a comprehensive and evidence-backed framework for treating vasospasm after brain aneurysm rupture.

Safety considerations are paramount, with the literature indicating that while these pharmacological interventions are generally well-tolerated, careful monitoring for potential adverse effects, such as hypotension, is essential. The goal is to achieve a delicate balance between therapeutic efficacy and safety, optimizing dosing and administration protocols to maximize patient benefits while minimizing risks.

Future research directions are poised to refine our understanding of vasospasm management, with ongoing investigations into the optimal timing, duration, and patient selection criteria for these interventions. The evolution of treatment protocols, informed by robust clinical evidence, promises to enhance the quality of care for patients suffering from the aftermath of ruptured brain aneurysms.

In sum, the management of vasospasm following ruptured brain aneurysms encapsulates a multidisciplinary effort, integrating surgical, pharmacological, and supportive strategies to mitigate the risk of delayed cerebral ischemia and optimize patient outcomes. Through the judicious application of established and emerging therapies, the neurocritical care community continues to advance the frontier of care for this complex and challenging condition.

2. Materials and methods

Patient underwent comprehensive diagnostic assessments upon admission to evaluate their neurological status and identify underlying vascular abnormalities. The diagnostic protocol involved cerebral angiography to visualize the vascular anatomy and embolization of the ruptured posterior communicating aneurysm in the first case and severe vasospasm following meningitis hemorrhage in the second case.

Therapeutic interventions involved meticulous preparation for endovascular procedures, including femoral artery puncture and the insertion of catheters and guides. In the first procedure, platinum coil embolization via a coaxial system occluded the aneurysm, followed by angiographic confirmation. In the second procedure, intra-arterial chemical angioplasty with Milrinone and Nimodipine alleviated severe vasospasm, monitored through angiographic imaging. Post-procedural care encompassed manual femoral artery closure, compressive dressing, and cerebral CT scans for outcome assessment and complication detection. Patients received intravenous Heparin bolus during procedures to prevent thrombotic events.

3. Case report

3.1. Presentation in ED and embolization

A 55-year-old female known to have hypertension, type 2 diabetes mellitus, presented to the emergency department with a Fisher 4 subarachnoid hemorrhage caused by rupture of the right posterior communicating aneurysm. At admission, the patient has a GCS of 15 without neurological deficits.

The patient was transferred to the interventional neuroradiology unit, where cerebral angiography with digital subtraction (DSA) was performed, which revealed a ruptured giant posterior communicating aneurysm. Embolization of the aneurysm was performed with platinum coils, the intervention proceeded without complications. Post-procedurally, the woman woke up without neurological deficits, with normal cardiovascular values. Vasospasm prevention therapy with Nimodipine was initiated.

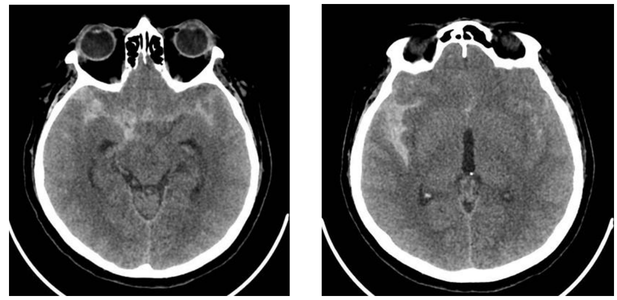

Figure 1. Cranio-cerebral native CT scan in the ED (a-b) subarachnoid haemorrhage with quantitatively greater extension at the level of the right sylvian fissure.

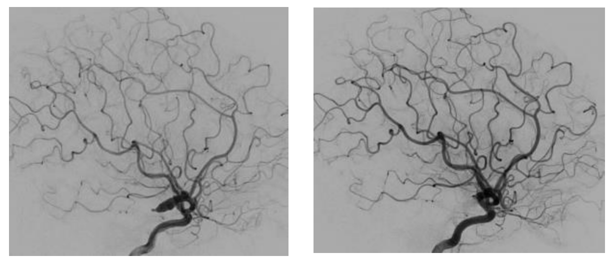

Figure 2. Digital subtraction angiogram (DSA) in lateral view of the right internal carotid artery: (a) Giant posterior communicating saccular aneurysm; (b) DSA control after endovascular embolization with platinum coils.

3.2 Clinical deterioration on the 9th day

In the morning of the 9th day, the patient shows mild fatigue. An interdisciplinary consultation is requested for a complete neurological examination which is normal, without changes. A native cranio-cerebral CT scan is performed, which reveals a small hypodense area at the right frontal sylvian level (Figure 3a). A few hours later, the patient presents, with progressive worsening, left hemiparesis, up to hemiplegia and dysarthria. An emergency cranio-cerebral MRI examination is performed, which highlights an ischemic area in the territory of the right middle cerebral artery (Figure 3b).

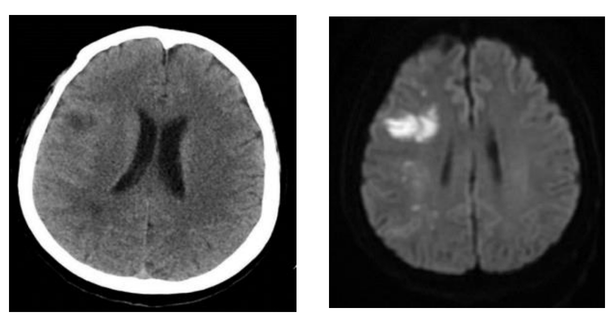

Figure 3. Brain imagistic investigations at the time of first neurological symptoms onset: (a) Cranial CT scan performed as

routine - the patient complains of mild fatigability; (b) Brain MRI performed after the onset of left hemiplegia and dysarthria.

3.3 Chemical angioplasty with Milrinone and Nimodipine for vasospasm therapy

DSA highlighted a severe vasospasm at the level of the right carotid termination, right A1, segment M1 and M2 of the right Sylvian artery. The right sylvian branches have a filiform appearance with very delayed parenchymography.

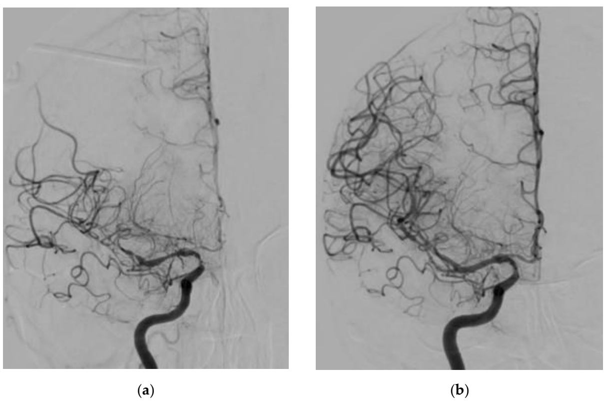

Figure 4. DSA in frontal view of the right internal carotid artery: (a) Severe vasospasm at the level of the right carotid termination, right A1, segment M1 and M2; (b) After the selective intra-arterial injection of vasodilators, a reduction in vascular spasm is observed with a net improvement of cerebral perfusion.

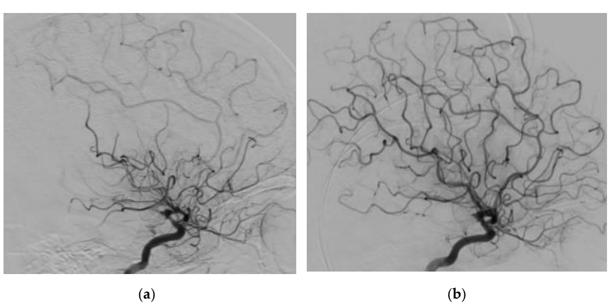

Figure 5. DSA in lateral view of the right internal carotid artery: (a) Severe vasospasm at the level of the right carotid termination, right A1, segment M1 and M2; (b) After the selective intra-arterial injection of vasodilators, a reduction in vascular spasm is observed with a net improvement of cerebral perfusion.

4. Discussion

The efficacy of chemical angioplasty using Milrinone and Nimodipine in managing severe vasospasm following the rupture of a posterior communicating aneurysm has been a subject of significant research interest. It is imperative to analyze how these medications act synergistically to induce cerebral vasodilation and improve cerebral blood flow, leading to rapid symptom relief and enhanced neurological recovery.

Timely recognition and intervention are paramount in managing complications post-aneurysmal rupture, particularly severe vasospasm. Long-term neurological outcomes and follow-up strategies for patients undergoing chemical angioplasty require thorough evaluation. Continued surveillance and monitoring, along with the potential role of advanced imaging modalities and functional assessments, are crucial in detecting and managing any late complications or recurrence of vasospasm.

A multidisciplinary approach involving neurosurgery, interventional radiology, and neurocritical care is essential for optimizing patient outcomes. As highlighted by our example, a coordinated multidisciplinary approach enables comprehensive evaluation, timely intervention, and vigilant post-procedural monitoring, ultimately enhancing the quality of care and patient safety.

Comparing chemical angioplasty to traditional management strategies raises important considerations regarding efficacy, safety, and patient outcomes. While Milrinone and Nimodipine have shown promise in reducing the incidence of delayed cerebral ischemia and facilitating functional recovery, rigorous comparative studies are essential. These studies would offer clearer insights into the benefits of chemical angioplasty over standard treatments, including the use of oral or intravenous vasodilators and the implementation of Triple-H therapy (hypertension, hypervolemia, and hemodilution).

Considering the generalizability of findings from case reports to broader clinical practice is essential. Proposing avenues for future research, including larger prospective studies and randomized controlled trials, can further elucidate the optimal timing, dosing, and patient selection criteria for chemical angioplasty in managing vasospasm after brain aneurysm rupture.

Exploring patient-specific factors that may influence the response to chemical angioplasty is necessary for personalized treatment strategies. Additionally, addressing ethical and legal considerations, enhancing patient education and counseling, and understanding the mechanisms of action of Milrinone and Nimodipine are vital aspects of optimizing vasospasm management.

The exploration of genetic and molecular biomarkers associated with vasospasm susceptibility represents an exciting frontier in neurocritical care. Such advancements could lead to tailored treatment strategies that account for individual variability in response to therapy. Additionally, addressing disparities in treatment outcomes across different patient populations could further enhance the effectiveness and equity of vasospasm management.

5. Conclusion

This case underscores the critical need for timely intervention in managing complications post-aneurysmal rupture, particularly severe vasospasm. Chemical angioplasty with Milrinone and Nimodipine led to significant improvements in vascular perfusion and neurological deficits, reflecting advancements in neurointerventional procedures. A multidisciplinary approach involving neurosurgery, interventional radiology, and neurocritical care proved vital in optimizing patient outcomes. Early detection, swift intervention, and vigilant post-procedural monitoring are essential for mitigating risks associated with cerebral aneurysm rupture and its sequelae.

References

1. Distal Balloon Angioplasty of Cerebral Vasospasm Decreases the Risk of Delayed Cerebral Infarction. M.-A. Labeyrie, S. Gaugain, G. Boulouis, A. Zetchi, J. Brami, J.-P. Saint-Maurice, V. Civelli, S. Froelich, E. Houdart; American Journal of Neuroradiology Aug 2019, 40 (8) 1342-1348; DOI: 10.3174/ajnr.A6124
2. Bashir A, Andresen M, Bartek J Jr, Cortsen M, Eskesen V, Wagner A (2016) Intra-arterial nimodipine for cerebral vasospasm after subarachnoid haemorrhage: influence on clinical course and predictors of clinical outcome. Neuroradiol J 29:72–81
3. Aaslid R, Huber P, Nornes H (1984) Evaluation of cerebrovascular spasm with transcranial Doppler ultrasound. J Neurosurg 60:37–41
4. Allen GS, Ahn HS, Preziosi TJ, Battye R, Boone SC, Boone SC, Chou SN, Kelly DL, Weir BK, Crabbe RA, Lavik PJ et al (1983) Cerebral arterial spasm—a controlled trial of nimodipine in patients with subarachnoid hemorrhage. N Engl J Med 308:619–624
5. Arakawa Y, Kikuta K, Hojo M, Goto Y, Ishii A, Yamagata S (2001) Milrinone for the treatment of cerebral vasospasm after subarachnoid hemorrhage: report of seven cases. Neurosurgery 48:723–728, discussion 728–730
6. Barker FG 2nd, Ogilvy CS (1996) Efficacy of prophylactic nimodipine for delayed ischemic deficit after subarachnoid hemorrhage: a metaanalysis. J Neurosurg 84:405–414
7. Bele S, Proescholdt MA, Hochreiter A, Schuierer G, Scheitzach J, Wendl C, Kieninger M, Schneiker A, Brundl E, Schodel P, Schebesch KM et al (2015) Continuous intra-arterial nimodipine infusion in patients with severe refractory cerebral vasospasm after aneurysmal subarachnoid hemorrhage: a feasibility study and outcome results. Acta Neurochir (Wien) 157:2041–2050
8. Cindea C-N, Saceleanu V, Saceleanu A. Intraoperative Rupture of an Intracranial, Extradural Hydatid Cyst: Case Report and Treatment Options. Brain Sciences. 2021; 11(12):1604. https://doi.org/10.3390/brainsci11121604
9. Biondi A, Ricciardi GK, Puybasset L, Abdennour L, Longo M, Chiras J, Van Effenterre R (2004) Intra-arterial nimodipine for the treatment of symptomatic cerebral vasospasm after aneurysmal subarachnoid hemorrhage: preliminary results. AJNR Am J Neuroradiol 25:1067–1076
10. Chalouhi N, Tjoumakaris S, Thakkar V, Theofanis T, Hammer C, Hasan D, Starke RM, Wu C, Gonzalez LF, Rosenwasser R, Jabbour P (2014) Endovascular management of cerebral vasospasm following aneurysm rupture: outcomes and predictors in 116 patients. Clin Neurol Neurosurg 118:26–31
11. Cindea C, Mihăilă R, Săceleanu V. Thrombosis Generation Abnormalities In Spontaneous Intracerebral Haemorrhage. Romanian Neurosurgery; 2019. p. 33.
12. Khajavi K, Ayzman I, Shearer D, Jones SC, Levy JH, Prayson RA, Skibinski CI, Hahn JF, Chyatte D (1997) Prevention of chronic cerebral vasospasm in dogs with milrinone. Neurosurgery 40:354–362, discussion 362–353
13. Lannes M, Zeiler F, Guichon C, Teitelbaum J (2016) The use of milrinone in patients with delayed cerebral ischemia following subarachnoid hemorrhage: a systematic review. Can J Neurol Sci 1–9
14. Sherif C, Wambacher B, Loyoddin M, Karaic R, Krafft P, Valentin A, Tscholakoff D, Kleinpeter G (2015) Repeated combined endovascular therapy with milrinone and nimodipine for the treatment of severe vasospasm: preliminary results. Acta Neurochir Suppl 120:203–207
15. Zeiler FA, Silvaggio J (2015) Early angiographic resolution of cerebral vasospasm with high dose intravenous milrinone therapy. Case Rep Crit Care 2015:164597
16. Diringer M. N., Bleck T. P., Hemphill J. C., III, et al. Critical care management of patients following aneurysmal subarachnoid hemorrhage: recommendations from the Neurocritical Care Society's Multidisciplinary Consensus Conference. Neurocritical Care. 2011;15(2):211–240. doi: 10.1007/s12028-011-9605-9. - DOI - PubMed
17. Meyer R., Deem S., David Yanez N., Souter M., Lam A., Treggiari M. M. Current practices of triple-H prophylaxis and therapy in patients with subarachnoid hemorrhage. Neurocritical Care. 2011;14(1):24–36. doi: 10.1007/s12028-010-9437-z. - DOI - PubMed
18. Dabus G., Nogueira R. G. Current options for the management of aneurysmal subarachnoid hemorrhage-

induced cerebral vasospasm: a comprehensive review of the literature. Interventional Neurology. 2013;2(1):30–51. doi: 10.1159/000354755. - DOI - PMC - PubMed
19. Baggott C. D., Aagaard-Kienitz B. Cerebral vasospasm. Neurosurgery Clinics of North America. 2014;25(3):497–528. doi: 10.1016/j.nec.2014.04.008. - DOI - PubMed
20. Hollingworth M., Chen P. R., Goddard A. J., Coulthard A., Söderman M., Bulsara K. R. Results of an international survey on the investigation and endovascular management of cerebral vasospasm and delayed cerebral ischemia. World Neurosurgery. 2015;83(6):1120.e1–1126.e1. doi: 10.1016/j.wneu.2015.01.036.

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Occipital intradiploic epidermoid cyst. Case report

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ABSTRACT
Intradiploic epidermoid cysts are rare intracranial tumours, with an estimated prevalence of less than 1% of all cranial tumours. Most of the intradiploic cysts are asymptomatic; however, clinical findings consist of headache and tenderness. We presented a case of a 21-year-old female who consulted the neurosurgery department for a period of three years about a mass in the occipital region, which was growing gradually. The patient was treated with surgical removal without complications. Intradiploic epidermoid cysts are infrequent intracranial tumours that primarily affect adults. This tumour has a wide spectrum of symptoms. Radiologic findings on computed tomography (CT) and magnetic resonance imaging (MR) are the cornerstone for the diagnosis, which is finally confirmed by histopathological studies. Surgical management with a complete resection of the cyst and capsule is the most commonly used treatment.

Keywords
epideroidl cyst,
occipital,
posterior cranial fossa,
bone tumo

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INTRODUCTION

Intradiploic epidermoid cysts are rare intracranial tumors, with an estimated prevalence of less than 1% of all cranial tumors. (1) The origin is controversial but generally attributed to congenital origin, with defects in neural tube closure that give rise to inclusions of ectodermal cells. The area's most frequently affected are the frontal, parietal, cranial sutures, and cranial bases (2, 3). These defects are more common in men than women. (2, 4) In addition, epidermoid tumors occur most likely in the third and fourth decades of life. (4)

Most of the intradiploic cysts are asymptomatic; however, clinical findings consist of headache and tenderness. (3) Less common symptoms include traumatic rupture, focal neurological signs, intracranial hypertension, and seizures; furthermore, these findings are most likely to be present in large cysts. (3) The definitive treatment is a complete surgical resection, including the capsule to prevent recurrence. (1, 3)

CASE REPORT

A 21-year-old female with no prior medical history consulted the neurosurgery department for a period of three years of gradual enlargement of a tumor in the occipital region. On a physical exam, a mass on the right occipital region was palpable and had characteristics of soft texture and non-mobile consistency.

Cranial computed tomography (CT) and brain magnetic resonance imaging (MRI) conducted in other health institutions revealed an osteolytic lesion in the right occipital cranial diploe. This lesion, located near the junction of the transverse sinus with the sigmoid sinus at the ponto-cerebellar angle, did not exhibit contrast enhancement. Additionally, there is a potential presence of a fistulous trajectory. The patient was treated with surgical removal. The surgery commenced with making an incision in the occipital region at the level of the superior nuchal line, careful desperiotization, and decortication. Subsequently, an intradiploic lesion was identified and dissected until a complete lesion was achieved. Various fistulous tracts were discovered along the midline, which are necessary to be reamed and resected. The cessation and occlusion of venous bleeding originating from a tributary branch is necessary. Ultimately, the bone deficiency is remedied through the utilization of a circular plate that is securely affixed in place using screws. The treatment was successfully concluded without any difficulties.

The patient received analgesic treatment, and a control cranial CT reported post-surgical changes in the right occipital region with osteosynthesis material, edema, and emphysema of soft tissues in the right occipital region (Figure 1).

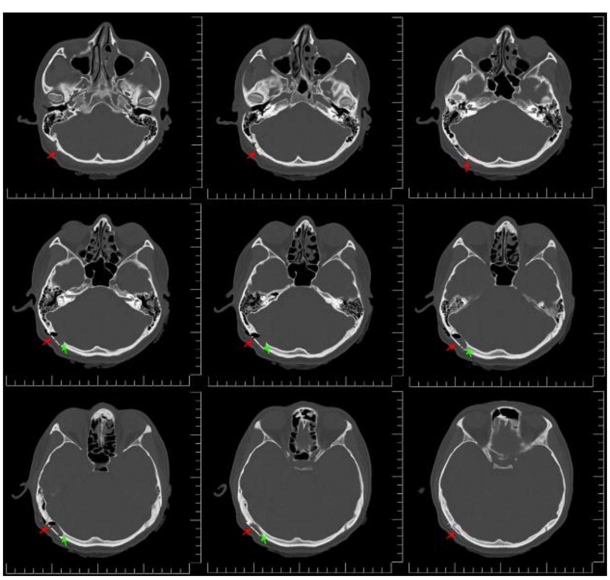

Figure 1. A CT of the head showing a rounded area with well-delineated sclerotic margins of bone destruction (green arrows) and post-surgical changes with osteosynthesis material covering the defect (red arrows).

A histopathological test confirmed the diagnosis of an intradiploic epidermoid cyst (Figure 2). Finally, the patient was discharged to continue outpatient care.

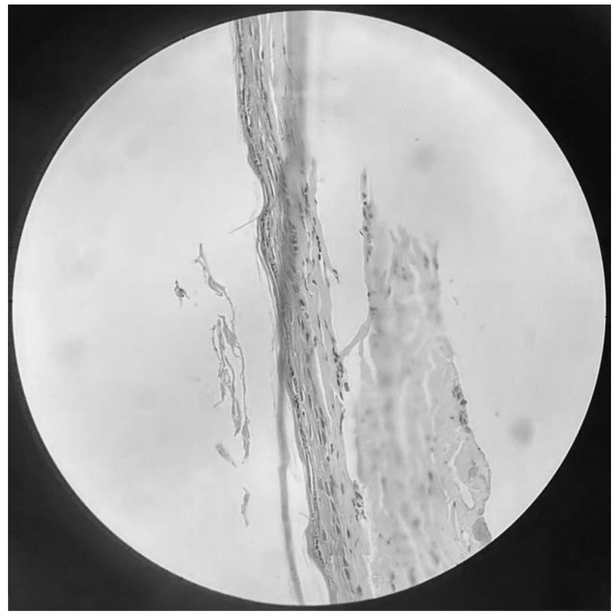

Figure 2. Hematoxylin-eosin staining of the tissue specimen removed during the surgical procedure shows the presence of a cyst with epithelial cells without atypia and containing lamellar keratin compatible with an intradiploic epidermoid cyst.

Discussion

Since the first description of an intradiploic cyst in 1922, there have been little more than two hundred cases reported in the literature. (4, 5) The ectodermal cysts have a capsule of stratified squamous epithelium with keratin, cholesterol, and cellular debris, and they do not include any dermal elements, which is the main difference with dermoid tumors. (5)

Regarding diagnosis, a CT scan or MR images are the cornerstone to detecting this rare anomaly. In a CT scan, they have low density, so they are hypodense without any enhancement. (5) The MRI can report hypointense lesions in T1, hyperintense lesions in T2, and fluid-attenuated inversion recovery (FLAIR) without enhancement upon application of intravenous contrast. According to Law EK et al. (2015), epidermoid and cysts can have atypical imaging findings, being able to be T1 hyperintense and T2 hypointense with a lack of restricted diffusion. (6) The opposite pattern of a typical epidermoid cyst can be present due to the T1 and T2 weighted MRI signals being strongly influenced by protein content, which also explains the lack of restricted diffusion. (6)

The radiological differential diagnoses include primarily dermoid cysts and arachnoid cysts; abscesses and metastasis are less frequent. (6, 7) Classically epidermoid cysts are described as soft lessons that are conforming brain structures or insinuating between them with the classic T1-hypointense and T2-hyperintense patterns. (7) On the other hand, arachnoid cysts are isointense with the cerebrospinal fluid (CSF) in all sequences, and they do not restrict on diffusion-weighted images. The dermoid cysts are usually located along the midline and appear like fat, not CSF. (7) The definitive diagnosis is by histopathological study, which reported stratified epithelium that it is desquamative on keratin. (1) Our patient´s lesion showed these histopathological findings, confirming the diagnosis.

The optimal course of treatment is a surgical approach that prioritizes the excision of the cyst and full tumour capsule. This procedure aims to alleviate brain congestion and facilitate subsequent histopathological examinations. Certain tumors have intracranial involvement affecting various intraparenchymal structures, resulting in incomplete resection. (8,9,10) The recurrence rate ranges from 1% to 54% and can potentially be mitigated by devitalizing the remaining capsule fragments during the surgical procedure. (11)

Conclusion

Intradiploic epidermoid cysts are infrequent intracranial tumours that primarily affect adults within the age range of the second to fourth decades of life. This tumour has a wide spectrum of symptoms. Radiologic findings on CT and MR are the cornerstone for the diagnosis, which is finally confirmed by histopathological studies. Surgical management with a complete resection of the cyst and capsule is the most commonly used treatment.

Abbreviations

CSF: cerebrospinal fluid
CT: computed tomography
FLAIR: fluid-attenuated inversion recovery
MRI: magnetic resonance imaging

References

1. Zambrano DA, Reyes EO, Chacín JP, Pérez BV, Stock F, Petrosino P, et al. Quiste epidermoide intradiploico parietal izquierdo. A propósito de un caso y revisión de la literatura. Avances en biomedicina 2018; 7(2):129–34.
2. Khalid S, Khan SA, Aurangzeb A, Muhammad G, Afridi EAK, Muhammad D. Intradiploic epidermoid cyst of the skull. Journal of Ayub Medical College Abbottabad 2021;33(2):349–51.
3. Han GY, Won YS, Young J, Choi CS. Intradiploic Epidermoid Cyst of the Skull. Journal of Korean Neurosurgical Society 2005;38(1): 68-70.
4. Oommen A, Govindan J, Peroor D, Azeez C, Rashmi R, Abdul Jalal M. Giant occipital intradiploic epidermoid cyst. Asian Journal of Neurosurgery 2018;13:514–517
5. Cushing H. A large epidermal cholesteatoma of the parietotemporal region deforming the left hemisphere without cerebral symptoms. 8th ed. Surgery, Gynecology and Obstetrics, 1922.
6. Law EKC, Lee RKL, Ng AWH, Siu DYW, Ng H-K. Atypical Intracranial Epidermoid Cysts: Rare Anomalies with Unique Radiological Features. Case Reports in Radiology 2015;2015:1–4.
7. Osborn AG, Preece MT. Intracranial Cysts: Radiologic-Pathologic Correlation and Imaging Approach. Radiology 2006;239:650–664.
8. Zhao F, Liu Q, Lan Y. A case of intradiploic epidermoid cyst. Quantitative Imaging in Medicine and Surgery 2023;13:5451–5455.
9. Kim CS, Yoon SH, Oh JW, Lee KC. Epidermoid cyst in temple area with skull perforation. Archives of Craniofacial Surgery 2020;21:137–140
10. Gaivas S, Rotariu D, Dumitrescu G, Iliescu B, Apetrei C, Poeata I. Intradiploic epidermoid cyst of the skull: Case report. Romanian Neurosurgery 2011;18(2).
11. Patibandla M, Yerramneni V, Mudumba V, Manisha N, Addagada G. Brainstem epidermoid cyst: An update. Asian Journal of Neurosurgery 2016;11:194–200.

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Solitary intracerebral Langerhans cell histiocytosis. An unusual presentation

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ABSTRACT

Background: Langerhans cell histiocytosis is an uncommon proliferative histiocytic disorder which can affect any organ. It is common in children and can rarely occur in adults. In the central nervous system, the hypothalamic-pituitary axis is most commonly involved. Brain parenchyma is rarely affected.

Case summary: We report a case of a 13-year-old male who presented with chief complaints of headache and swelling over the right frontal region. On imageology, a clinical diagnosis of meningioma was considered. The tumor was excised and on histopathological examination diagnosis of Langerhans cell histiocytosis was considered

Conclusion: Intracranial Langerhans cell histiocytosis is a rare condition which can mimic primary neoplasms of the central nervous system such as glioma, meningioma and metastatic deposits on imageology. Histopathology is the gold standard for diagnosis.

Keywords
Langerhans cell histiocytosis,
intracerebral,
histiocytosis

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INTRODUCTION

Langerhans cell histiocytosis (LCH) is a rare disease caused by clonal proliferation of myeloid precursors which differentiates into (CD)1a+/CD207+(Langerin) cells in lesion. [1] It commonly affects the children with incidence of 4 – 5 cases/ year/ million children with age less tha15 years. [2]

Incidence in adults is reported as 1-2/ million adults/ year. [3] LCH can affect any system or organ, but most frequently affects bone, lung, skin, spleen, liver, pituitary, lymph nodes, hematopoietic system and central nervous system. [4] Most common location of intracranial LCH is hypothalamic-pituitary axis and the brain parenchyma is rarely affected. [5] We are presenting a case of LCH involving brain parenchyma at the right frontal convexity and adjacent frontal bone which was clinically diagnosed as meningioma on imageology.

CASE REPORT

A 13 years old male patient presented with chief complaints of head ache and swelling over the right frontal region of head since 1 month, which was gradually increasing in size. There was no history of fever, trauma, ear or nose bleed/ vomiting/ blurring of vision, speech and smell disturbances. General examination revealed pulse rate - 81/minute, blood pressure- 118/80mm Hg, respiratory rate – 141/min. Glasgow Coma Scale (GCS) scored 15 (E4V5M6). Haematological investigations were with in normal limits.

MRI with contrast study revealed well defined extra axial dural based altered signal intensity lesion measuring 3.2X1.6cms involving right frontal convexity, parasagittal location. The lesion is heterogeneously iso intense to grey matter on T1, T2, FLAIR showing peripheral restricted diffusion with no evidence of blooming. Peripheral post contrast enhancement with dural tail is present. Lesion is infiltrating lateral wall of superior sagittal sinus and mildly extending across midline to left side. Adjacent frontal bone is also involved by lesion. Based on the above findings radiological diagnosis of meningioma was considered.

Patient underwent right frontal craniotomy with excision of tumor. We received 2 grey brown soft tissue bits together measuring 1.3X0.5X0.5cms. Microscopic examination revealed lesion composed of sheets of histiocytes surrounded by eosinophils and lymphocytes (Figure 2). Histiocytes have moderate to abundant pale eosinophilic cytoplasm with elongated nuclei and indistinct nucleoli. Some of them show prominent nuclear grooves (Figure 3). Immunohistochemistry (IHC) showed histiocytes with cytoplasmic positivity for Langerin and membranous positivity with CD1a. Morphology and IHC favoured diagnosis of Langerhans cell histiocytosis

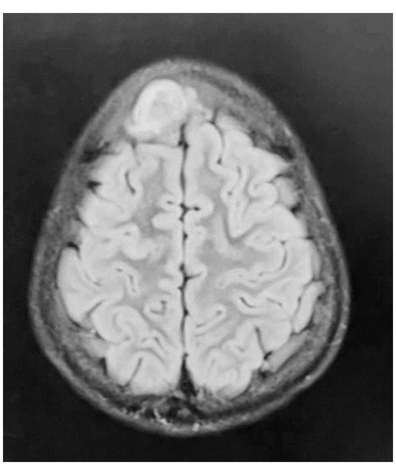

Figure 1. MRI scan showing well defined extra axial iso intense lesion broad base towards dura noted infrontal convexity showing peripheral enhancement.

Discussion

LCH is an uncommon disease involving hypothalamic-pituitary axis in brain, but involvement of the brain parenchyma is infrequent. According to the reviewed literature less than 30 cases have been reported in Pub med data base. [5] The etiology of LCH is still unknown. The histiocytic cells in this lesion stain positive for CD1a and S100 and also form Birbeck granules which is similar to that of Langerhans cells, a specialized dendritic cells found in mucosa and skin. But these cells do not exhibit morphology of dendritic cells. [6]

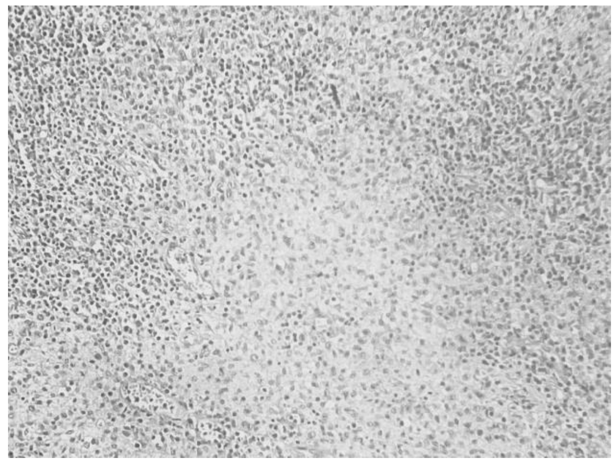

Figure 2. Lesion composed of sheets of histiocytes surrounded by eosinophils and lymphocytes (H&E,X100).

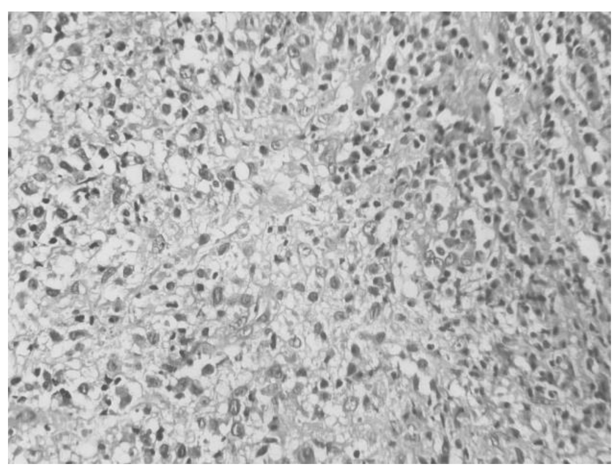

Figure 3. Lesion composed of sheets of histiocytes surrounded by eosinophils and lymphocytes. Histiocytes have moderate to abundant pale eosinophilic cytoplasm with elongated nuclei and some of them are showing nuclear grooves (H&E,X400).

LCH is a disease entity composed of 3 distinct clinical syndrome with indistinguishable histology characterized by presence of Langerhans cells which stain positively with S-100 and CD1a. Clinical syndromes include Hand Schuller-christian disease, Letterer-Siwe disease and Eosinophilic granuloma. Hand-Schuller-christian disease is characterised by extraskeletal involvement of reticuloendothelial system and multifocal bone lesions. Lettere-Siwe disease is characterized by disseminated involvement of reticuloendothelial systems and has fulminant course in children with age less than 2 years. Eosinophilic granuloma are seen in 5 – 15 years old patients and are limited to bone.

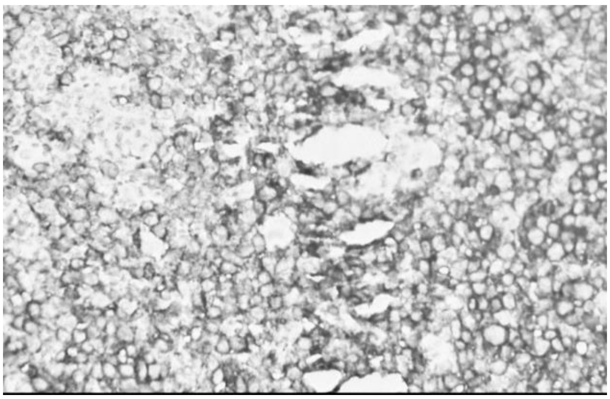

Figure 4. Immunohistochemistry showing membranous positivity with CD1a (CD1a,X400).

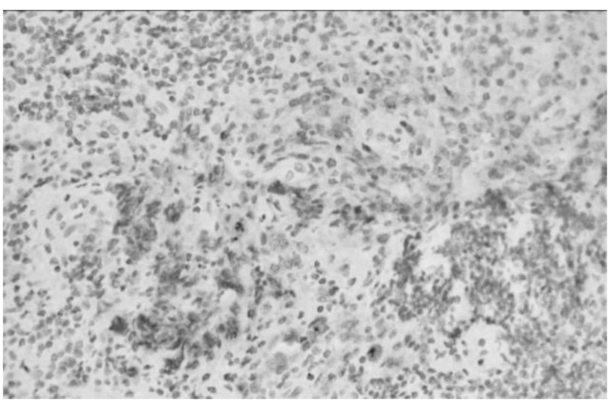

Figure 5. Immunohistochemistry showing cytoplasmic positivity with Langherin (Langherin,X400).

Pathogenesis of LCH is controversial. Cell of origin of LCH is not the Langerhans cell, but a myeloid dendritic cell which expresses CD1a and CD207. Some studies suggest that LCH is a reactive disorder as there was increase in levels of various cytokines in the blood of patients, which indicates possibility of immune response. There were also upregulation of genes associated with T cell recruitment and regulatory T cell expansion. [7] However recent evidences suggest that LCH is a myeloid neoplasia. Many studies have suggested that the oncogenic BRAF V600E mutation was found in high percentage LCH cases in children. Cases with these mutations were having increased relapse. [8,9] LCH patients with BRAF mutations are associated with more aggressive form of disease and poor short term response to therapy. [10]

According to the literature, intracranial LCH are mostly part of systemic disease and only 40% of intracranial LCH are solitary, isolated to brain. [11] Patients presented with headache, polyuria and polydipsia indicating diabetes insipidus in patients with tumors infiltrating posterior pituitary, gait disturbances or ataxia, nausea and/or vomiting, visual impairment and seizures. Other rare symptoms were lethargy, anorexia, and chronic eczema. [12]

Imaging characteristics of LCH on Magnetic Resonance Imaging (MRI) are isointense on T1 weighted MRI and iso to hyper intense on T2 weighted images. On post contrast MRI, lesion is diffusely and homogenously enhancing. On Contrast Tomography (CT) imaging, lesion appears isodense and presents as destructive lesion when involving bone. [12]

Histopathological examination of the lesion is required for the diagnosis. Differential diagnosis of LCH are juvenile Xanthogranulomatosis, Erdheim Chester disease and Rosai Dorfman disease. Juvenile xanthogranulomatosis is a benign lesion often affecting the skin. Histiocytic cells in this lesion are CD68 positive, negative for S-100 and CD1a. They also do not have Birbeck granules. Erdheim Chester disease is characterised by fibrosis surrounding the histiocytes which are positive for CD68 and CD 163 but are negative for CD1a. In Rosai Dorfman disease, multinucleated histiocytes with emperipolesis are seen. Histiocytes in this lesion are S-100 positive and negative for CD1a or CD207. [13]

No specific treatment has been suggested but therapeutic measures implemented were surgical resection, with low dose radiotherapy and combination chemotherapy. [11] Prognosis depends on initial presentation of disease. If the presentation is low risk with isolated involvement of skin, lymphnodes, or pituitary gland, then the mortality is low and is less than 5%. If presents as high-risk disease involving liver, spleen, bone marrow or skeleton, mortality is 50% or more with more wide spread disease. [14]

Conclusion

Intracranial LCH is a rare condition which can mimic primary CNS neoplasms such as glioma, xanthogranuloma, meningioma on imaging and should be considered as one of the differential diagnosis in children. Histopathological examination is the gold standard for diagnosis. Standard treatment protocol is not available due to limited data.

References

1. Rodriguez-Galindo C, Allen CE. Langerhans cell histiocytosis. Blood.2020;135:1319-1331
2. Krooks J, Minkov M, Weatherall AG. Langerhans cell histiocytosis in children: History, classification, pathobiology, clinical manifestations and prognosis. J Am Acad Dermatol. 2018;78:1035-1044
3. CS Muller E. Janssen, R. Schmaltz, H.Korner, T.Vogt, C.Pfohlers. Multisystemic Langerhans cell histiocytosis presenting as chronic scalp eczema. Clinical management and current concepts. J Clin Oncol 2011;29:e539-e542
4. Haupt R, Minkov M, Astigarraga I, Schafer E, Nanduri V, Jubran R, Egeler RM, Janka G, et al. Langerhans cell histiocytosis (LCH): guidelines for diagnsosi, clinical; work-up and treatment for patients till the age of 18 years. Pediatr Blood Cancer. 2013;60:175-184
5. Han-Xiang Liang, Yue-Long-Yang, Qing Zhang, Zhixia, En-Tao Liu and Shu-Xia Wang. Langerhans cell histiocytosis presenting as an isolated brain tumor: A case report. World J Clin Cases. 2022;10(4):1423-1431
6. L.Mihova, M.Yaneva, M.Sopadjieva, V.Andreev, I. Nejtcheva. Primary solitary eosinophilic granuloma of the brain and post-operative radiotherapy: a clinical case. J buon 2007;12:125-128.
7. B.Senechal, G.Elain, E.Jeziorski, V.Grondin, Patey-Mariacid de serre N, Jaubert F. et al. Expansion of regulatory T cells in patient with Langerhans cell histiocytosis. PLoS Med 2007;4:e253
8. M.L.Berres, K.P.Lim, T.Peters, J.Price, H.takizawa, H.Salmon et al. BRAF-V200E expression in precursor versus differentiated dendritic cells defines clinically distinct LCH risk groups. J Exp Med 2015;212:281
9. K.Zeng, K. Ohshima, Y.Liu, W.Zhang, L.Wang, L.Fan et al. BRAF-V200E and MAP2K1 mutations in Langerhans cell histiocytosis occur predominantly in children. Hematol Oncol 2017;35:845-851
10. S.Heritier, J.F. Emile, M.A. Barkaoui, C.Thomas, S.Fraitag, S.Boudjemaa et al. BRAF mutation correlates with High-risk Langerhans cell Histiocytosis and increased tresistance to first –line therapy. J Clin Oncol 2016;34:3023-3030
11. F.Perren, L.Fankhauser, B.Thievent, J.C.Pache, J. Delavelle, T. Rochet et al. Late adult onset of Langerhans cell histiocytosis mimicking glioblastoma multiforme. J Neurol Sci 2011;301:96-99
12. Zachary C. Gersey, Ian Zheng, Amade Bregy, Nitin Agarwal, Ricardo J.Komotar. Intracranial Langerhans cell histiocytosis: A review. Interdisciplinary Neurosurgery 2020;21:100729
13. J.F.Emile, O.Abla, S. Fraitag, A.Horne, J.Haroche, J.Donadien et alRevised classification of histiocytosis and neoplasms of the macrophage-DENDRITIC CELL LINEAGES. Blood 2016;127:2672-2681
14. Tillotson CV, Anjum F, Patel BC. Langerhans Cell Histiocytosis. [Updated 2023 Jul 17]. In: StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing; 2023 Jan-. Available from: https://www.ncbi.nlm.nih.gov/books/NBK430885/

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Neurosarcoidosis: overview of management and differentiation from fungal aetiologies

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ABSTRACT
Neurosarcoidosis, a rare inflammatory condition, poses a diagnostic challenge due to its various clinical presentations and potential mimics. This comprehensive review delves into the complexities of neurosarcoidosis, emphasizing the importance of a thorough diagnostic workup and the consideration of alternative conditions, such as fungal mimics. The study explores the intricacies of the diagnostic process, particularly the role of histopathology, imaging, and laboratory tests. The current state of neurosarcoidosis management is examined, such as the use of corticosteroids as well as novel therapies including Rituximab and JAK-STAT inhibitors. The clinical spectrum is described in detail for both the peripheral and central nervous systems, offering insights into the many presentations, which include ocular manifestations and syndromes like Heerfordt's syndrome. The complexities of neurosarcoidosis necessitate further research in its diagnosis, pharmacotherapy, and management. The inclusion of information on ongoing research and clinical trials underscores the need for tailored therapeutic approaches.

Keywords
neurosarcoidosis,
fungal mimickers,
management,
workup

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INTRODUCTION

Sarcoidosis is an inflammatory condition that affects multiple systems and is identified by the development of granulomas, which can emerge in various organs. Neurosarcoidosis, which involves the nervous system, impacts 5–10% of individuals and has the potential to result in severe consequences [1-5].

Typical manifestations of neurosarcoidosis encompass cranial neuropathies, leptomeningeal disease, intraparenchymal lesions, and myelitis. Nevertheless, there have been documented instances of initial presentations involving stroke, seizures, cerebral vasculopathy, intracranial masses, hypopituitarism, neuropsychiatric symptoms, and encephalopathy [1,2]. Neurosarcoidosis frequently impacts the pulmonary system, lymph nodes, eyes, and skin as the most common systemic sites affected in patients [1].

Diagnosing the condition can be challenging because of the diverse range of clinical symptoms, the fluctuating nature of concurrent systemic ailments, and the difficulties in obtaining a central nervous system (CNS) biopsy for a conclusive diagnosis. To diagnose neurosarcoidosis, according to existing guidelines, the patient should exhibit a neurological clinical presentation consistent with the condition, and other potential causes must be ruled out. Patients meeting these criteria can be categorized as having a "possible" diagnosis of neurosarcoidosis[6].

A biopsy revealing granulomatous inflammation is required to diagnose definite neurosarcoidosis (via nervous system biopsy) and probable neurosarcoidosis (via biopsy of a systemic site). However, this alone is not conclusive for diagnosis, as various granulomatous diseases, including infections, autoimmune conditions, and neoplastic disorders, can mimic sarcoidosis and initially respond to corticosteroid treatment. In cases where patients with a confirmed diagnosis of systemic sarcoidosis undergo cranial neuropathies or exhibit leptomeningeal disease indicative of neurosarcoidosis, there is a potential risk of overlooking other possible causes. It is crucial to recognize that these patients do not automatically fulfill the criteria for "probable" neurosarcoidosis without considering mimicking conditions. Other potential diagnoses, such as atypical infection and malignancy, especially in light of treatment-related complications, should be taken into account. Common mimics of neurosarcoidosis include tuberculosis, cryptococcus, primary angiitis, granulomatosis with polyangiitis, IgG4-related disease, and primary central nervous system lymphoma. Fundamentally, any granulomatous infections infiltrating the central nervous system can imitate neurosarcoidosis. These infections encompass atypical bacteria (such as mycobacterial, syphilis, Whipple's disease, brucellosis, nocardiosis, and actinomycosis), fungi (including aspergillosis, cryptococcosis, and endemic mycoses), and parasites (such as toxoplasmosis, schistosomiasis, neurocysticercosis, and toxocariasis)[7,8].

Although many of these infections are uncommon and demand a heightened suspicion for diagnosis, it is crucial to rule them out before initiating immunosuppressive therapies. A comprehensive exposure history and examination can guide diagnostic testing. Notably, mycobacterial and fungal infections frequently mimic sarcoidosis and should be assessed in all individuals suspected of having neurosarcoidosis.

Several current randomized controlled trials (RCTs) are assessing novel therapeutic compounds, innovative targets for treatment, and alternative regimens to steroids in sarcoidosis, and several of them have shown positive results in early phases[8,9].

Clinical presentation

The presentation of neurosarcoidosis is known to be quite variable and non-specific, which may make diagnosing this disease difficult. Firstly, neurosarcoidosis can affect either the central nervous system (CNS), the peripheral nervous system (PNS), or both[10]. The most frequent manifestations are onset of cranial nerve-palsies and neuropathies; however, other manifestations include aseptic meningitis, parenchymal brain lesions, hydrocephalus, headache, seizure, neuropsychiatric abnormalities, neuroendocrine dysfunction, myelopathy, and peripheral neuropathy[10-17]. Fritz et al. reported that, in a meta-analysis and systematic review, 55% (572/1047) of patients with neurosarcoidosis presented with cranial neuropathy, and of the cranial nerves, the facial nerve (24%) and optic nerve (21%) were involved the most frequently[1]. It was similarly reported that sensory and motor abnormalities (hemiparesis, paraparesis), spinal cord abnormalities, and PNS involvement (polyneuropathy, myopathy) are other common presenting features. Sarcoidosis-associated facial nerve palsy may be unilateral or bilateral[6,10,18]. Other studies have reported that approximately 50% of cohorts reported CNS involvement and that potentially affected areas include brain parenchyma with multiple masses as well meninges with hypertrophic pachymeningitis; vascular disease with associated stroke also may be an affect area but is rare[19-40]. Clinical symptoms may manifest in an acute fashion or progress chronically; however, spontaneous regression is more common than progressive neurological deterioration[41-44].

The main CNS clinical manifestations of neurosarcoidosis can be further divided into the various systems affected: brain, spinal cord, and meningeal disease[19]. Brain involvement can be differentiated into parenchyma manifestations, which may result in the symptoms such as headaches, hormonal disturbances, SIADH, focal deficits, behavioral/cognitive changes, seizures, visual changes, and vascular manifestations, which may result in the symptoms such as strokes, confusion, and cognitive impairment. Meningeal disease can similarly present with symptoms such as headaches, cognitive changes, gait dysfunction, and hydrocephalus; spinal cord manifestations can also similarly present with symptoms such as gait changes, sensory changes, weakness, and bowel/bladder disturbances.

Conversely, the main PNS clinical manifestations can be further divided into various neuropathies, namely, cranial neuropathy, small fiber neuropathy, and large fiber neuropathy[19]. Cranial neuropathy may present as symptoms such as anosmia, decreased visual acuity, facial numbness, hearing loss, dysarthria, dysphagia, and hiccups[45,46]. Small fiber neuropathy may cause painful paresthesia and dysautonomia (GI, orthostasis), whereas large fiber neuropathy may cause polyneuropathy, mononeuritis multiplex, radiculopathy, plexopathy, paresthesia, weakness, and gait disturbance. Figure 1 depicts the various clinical manifestations of neurosarcoidosis.

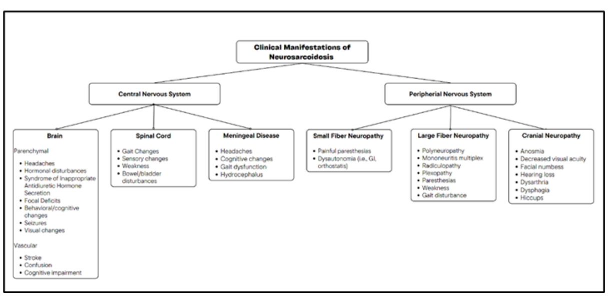

Figure 1. Clinical Manifestations of Neurosarcoidosis.

One syndrome highly suggestive of sarcoidosis is Heerfordt's syndrome, a cranial neuropathy (primarily facial nerve) with uveitis, parotid-gland enlargement, and fever[47,48]. Additionally, Horner syndrome, Argyll-Robertson pupil, and Adie's pupil has been described in sarcoidosis[42,49-52]. Another common ocular manifestation of neurosarcoidosis is optic neuritis which typically presents with blurred vision, a change of color vision, or visual field deficit[10,11]. Optic neuritis related to neurosarcoidosis is a neuro-ophthalmic emergency because it may result in permanent vision loss if there is no immediate intervention. Additionally, common findings indicating neurosarcoidosis on ophthalmologic examination include papilledema or optic nerve head edema[11].

Fungal mimickers

Rare in non-immunodeficient individuals and more present in immunocompromised patients, central nervous system (CNS) fungal infections have the following main etiologies: mucormycosis, endemic mycoses, *Aspergillus* meningitis (Aspergillosis), and Cryptococcal meningitis *(C. gattii, C. neoformans*)[53]. Manifestations of CNS fungal infections involve intracranial granuloma formation, a central clinical finding in neurosarcoidosis presentation[54]. In that regard, it is essential to rule out fungal mimics when a patient presents with neurosarcoidosis symptoms for effective treatment.

Mucormycosis (*Apophysomyces*)

Mucormycosis is an infrequent fungal infection that occurs in individuals with compromised immune systems, with the rhinocerebral variant being the most prevalent form of presentation[55]. Patients with rhinocerebral mucormycosis exhibit symptoms such as fever, lethargy, black nasal secretions, headache, orbital pain, orbital cellulitis, proptosis, and may experience sudden vision loss, often accompanied by a characteristic necrotic ulcer in the palate or nasal mucosa. Additionally, they may display signs of palsies involving cranial nerves III, IV, V, and VI, such as ptosis, mydriasis, diplopia, and loss of sensation on the ipsilateral side of the face due to local infiltration into the cavernous sinus. While facial paralysis is a rare occurrence, it has been reported in the past[56]. Sarcoidosis, which can manifest as basal meningitis, brainstem and hypothalamus parenchymal involvement, cranial neuropathies, and is associated with systemic features like erythema nodosum and pulmonary symptoms, can mimic mucormycosis[57].

Endemic Mycoses

Coccidioides species belong to the dimorphic fungi category within the Ascomycete division[58]. The two species identified as causing human disease are *Coccidioides immitis* and *Coccidioides posadasii*[59,60]. While most individuals infected with coccidioidomycosis do not show symptoms, those who do experience symptoms typically exhibit mild flu-like manifestations, muscle and joint pain, rash, and pulmonary symptoms[60,61]. Disseminated coccidioidomycosis is observed in around 1% of infected individuals, and its most severe manifestation is meningitis[60]. Central nervous system (CNS) involvement can happen in as many as 50% of individuals experiencing disseminated coccidioidomycosis, typically emerging within weeks to months after the primary infection[62]. The prevalent manifestation is basilar meningitis, which might be accompanied by complications like hydrocephalus and vascular infarcts[61,63]. Failure to recognize CNS coccidioidomycosis promptly can have severe consequences; hence, early identification and treatment are crucial to minimize mortality and morbidity[61].

After analyzing 71 cases of coccidioidal meningitis, it was observed that 42% were immunocompromised, and 45% reported a prior illness indicative of pulmonary coccidioidomycosis[63]. The primary symptom of CM is typically a headache, accompanied by other symptoms such as fever, neck stiffness, nausea, and vomiting[60,62]. In rare instances, patients may undergo changes in personality, cognitive abnormalities, decreased consciousness levels, and focal neurologic symptoms. Notably, in 50% of cases, an MRI may reveal no abnormalities[59,60,64]. A positive cerebrospinal fluid (CSF) culture for *Coccidioides* or the presence of CSF coccidioidal IgG antibodies is nearly confirmatory for coccidioidal meningitis. The most dependable diagnostic tests include serology using ELISA for initial screening, followed by immunodiffusion tests for IgM and IgG, and complement fixation for IgG[59,60]. In cases where results are inconclusive, but suspicion remains high, polymerase chain reaction (PCR) of CSF can assist in confirming the diagnosis of coccidioidomycosis[65,66]. Additionally, the utilization of 1,3-Beta-D-Glucan testing in CSF may serve as a valuable tool for excluding CM, particularly in immunocompromised patients with potential delays in antibody production[67,68].

Aspergillosis

The increased concern for CNS Aspergillosis infection is present in both immunocompromised and immunocompetent individuals. Like Cryptococcal meningitis, *Aspergillus* meningitis is recognized as one of the most common CNS fungal infections. More prevalent in immunocompetent patients than immunocompromised, the infection can be detected through PCR methodology of collected CSF[69]. Although fungal cultures of collected CSF can be used, they are not the most effective detection method as they tend to be negative in 70% of *Aspergillus* meningitis infections[70].

Cryptococcal meningitis

Cryptococcal meningitis is a cerebral infection resulting from the presence of the fungus cryptococcus, either in the form of *Cryptococcus neoformans* or *Cryptococcus gattii*. It stands out as one of the common causes of meningitis, especially in individuals with compromised immune systems, particularly those affected by Human Immunodeficiency Virus/Acquired Immune Deficiency Syndrome (HIV/AIDS)[71].

Typical meningeal symptoms like headaches and neck stiffness are commonly observed in classic cryptococcal meningitis. However, additional systemic indications of widespread infection, such as pneumonia and dermatological symptoms, may also manifest[71]. Consequently, it is crucial to assess immunocompetent patients with subacute to chronic meningitis for the presence of *Cryptococcus neoformans*. While serum cryptococcal antigen and radiographic imaging aid in identifying CM, a lumbar puncture is indispensable for a definitive diagnosis[71,72]. Elevated opening pressure during the lumbar puncture, predominantly mononuclear cells, the visualization of encapsulated yeast using India ink, and a positive CSF culture of the organism are characteristic findings that confirm the diagnosis[72].

Invasive cryptococcosis involves two fungi, *C. neoformans* and *C. gatti*, both of which are encapsulated yeasts. Notably, *C. neoformans* is linked to immunocompromised hosts, while *C. gatti* is known to occur in individuals with intact immune systems[73,74]. Cryptococcus species tend to affect the central nervous system, especially in individuals with compromised immune systems, owing to their numerous virulence factors. Nevertheless, the occurrence of cryptococcal meningitis in immunocompetent patients remains challenging to elucidate. Potential reasons for this occurrence may include exposure to a highly pathogenic strain of Cryptococcus, a significant level of exposure to the pathogen, or subtle and undetectable immune deficiencies. These deficiencies could be linked to factors such as alcoholism, diabetes mellitus, or autoimmune conditions. In immunocompetent individuals, the cryptococcus species are more inclined to lead to pulmonary cryptococcosis compared to immunocompromised individuals. Likewise, neuroimaging results are more confined and may involve hydrocephalus in immunocompetent patients[73,74].

The clinical presentation of cryptococcal meningitis in immunocompetent patients typically exhibits characteristic features like fever, stiff neck, headache, vomiting, or altered mental status. This contrasts with immunocompromised individuals, who typically display only subtle clinical features[75]. Imaging may reveal observations such as cerebral infarction, granulomas, and pseudocysts. One case report described a case involving a 29-year-old immunocompetent woman with no known comorbidities, experiencing intermittent headache and vomiting. Ultimately, she was diagnosed with cryptococcal meningitis. Despite her neuroimaging results deviating from the typical findings in CM cases, the diagnosis was confirmed through a cryptococcal antigen test. The neuroimaging results did not indicate the presence of hydrocephalus; instead, they revealed a ring-enhancing lesion resembling the characteristics observed in the colloidal vesicular stage of neurocysticercosis. However, contrary to the favorable prognosis indicated in the literature, she passed away during her hospitalization[75].

Table 1 lists the fungal mimics of neurosarcoidosis including similarities to neurosarcoidosis and distinct features.

	Shared CNS features	Shared systemic features	Distinguishing features	Diagnostic testing
Tuberculosis	• Predilection for the skull base (basilar meningitis) • Leptomeningeal enhancement • Cranial neuropathies • Dural masses • Initial steroid response	• Pulmonary disease • Lymphadenopathy • Ocular inflammation • Constitutional symptoms • Arthropathy	• More likely to cause clinical meningitis, basilar exudates on neuroimaging, caseating granulomas on biopsy	• CSF AFB smear, culture and PCR
Cryptococcus	• Leptomeningeal enhancement • Cranial neuropathies • Dural masses • Initial steroid response	• Pulmonary disease • Lymphadenopathy • Ocular inflammation • Constitutional symptoms	• More likely to cause meningitis and hydrocephalus • Pulmonary presentation can cause acute pneumonia or ARDS	• Serum cryptococcal antigen testing by LAF CSF culture
PACNS	• White matter lesions • Leptomeningeal enhancement • Vasculitis with noncaseating granulomas on biopsy • Steroid response	• No systemic features	• No systemic features • More likely than neurosarcoidosis to cause CNS vasculitis	• CNS biopsy
GPA	• White matter lesions • Steroid response • Pachymeningeal enhancement • Ocular inflammation	• Pulmonary disease • Lymphadenopathy • Ocular inflammation • Sinusitis • Constitutional symptoms • Arthropathy	• More likely to cause diffuse alveolar hemorrhage, rapidly progressive glomerulonephritis, vasculitic skin rashes	• Biopsy of CNS or other systemic organ • ANCA, anti-MPO, anti-PR3
IgG4-RD	• Pachymeningeal enhancement • Intraparenchymal mass • Cranial neuropathies • Steroid response	• Lymphadenopathy • Ocular inflammation with or without pseudotumor • Sinusitis • Constitutional symptoms	• More likely to cause pancreatitis, retroperitoneal fibrosis, and kidney infiltration • Vasculitis more frequently seen	• CNS biopsy, staining for IgG4 plasma cells, looking for evidence of storiform fibrosis and obliterative phlebitis

Table 1. Fungal mimics of neurosarcoidosis with shared and distinguishing features.

Overview of Management

Diagnostic workup

Neurosarcoidosis is an inflammatory disorder that clinically manifests in multiple body systems, identified by the presence of non-caseating granulomatous lesions[5]. Retrospective studies and case reviews have demonstrated that approximately half of patients with systemic sarcoidosis likewise have neurological symptoms, demonstrating the distinct need for a full neurosarcoidosis workup when assessing patients in clinical settings[76,77]. Patients with neurosarcoidosis experience lesions and subsequent dysfunction of nerve, brain, spinal cord, meningeal, and muscular tissue, resulting in common findings of frequent headaches, ataxia, visual disturbances, facial nerve palsy, fatigue, and somato-sensory disturbances[77]. Diagnosis is difficult due to the myriad possible causes of granulomatosis, including bacterial CNS infections, inflammatory diseases, and lymphomas[4]. As a result, ruling between differential diagnosis and definite neurosarcoidosis necessitates the identification of accordant clinical scenarios, histological determination of non-caseating granulomas in tissue, and imaging/laboratory testing supporting diagnosis, as noted by Zajicek et al[5].

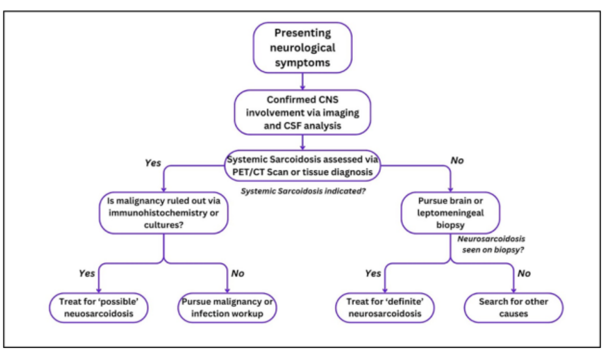

Figure 2. Neurosarcoidosis workup.

The 1999 joint statement on sarcoidosis by the American Thoracic Society (ATS), the European Respiratory Society (ERS), and the World Association of Sarcoidosis and Other Granulomatous Disorders (WASOG) established the primary diagnostic and treatment modalities for sarcoidosis and subsequent neurosarcoidosis[78]. More recently, the Neurosarcoidosis Consortium Consensus Group leveraged novel guidelines for diagnosing neurosarcoidosis, suggesting 'possible,' 'probable,' and 'definite' diagnostic criteria for diagnosis[76]. Stern et al. proposed a 'possible' neurosarcoidosis diagnosis in situations with established clinicoradiological findings but lacking histological evidence; a "probable" diagnosis when existing clinicoradiological results are supported by pathologic indication of granulomatous disease; and 'definite' for instances where nervous system biopsy confirms neurosarcoidosis[76]. Figure 2 illustrates the workup for neurosarcoidosis.

Imaging

Clinical disease manifestations in patients most commonly appear as cranial neuropathies, optic neuropathies, endocrine/hypothalamic dysfunction, seizures, meningitis, myelopathies, myopathy, peripheral neuropathy, and intracranial masses[79]. Subsequent imaging for diagnosing neurosarcoidosis involves the usage of computed tomography (CT) and Gadolinium-enhanced magnetic resonance imaging (MRI), the latter being the current gold standard for assessing the brain parenchyma, meninges, and spinal cord[80]. The most common MRI finding is basilar leptomeningeal involvement, presenting as diffuse thickening of the dural meninges; but focal masses, persistent pseudotumor changes, and involvement of hypothalamus/pituitary and cranial nerves are also noted in neurosarcoidosis[81,82]. CT scans may show hydrocephalus, intracranial calcification, and enhancing nodules, but they lack the sensitivity of MRI modalities[76].

Due to the multi-organ nature of sarcoidosis and subsequent neurosarcoidosis, chest radiography is an indicated tool for ruling out pulmonary disease, as the lungs are the most affected organ, and most frequently present with hilar lymphadenopathy[76,83]. Although the decreased sensitivity of chest radiographs presents an inherent drawback in diagnosing neurosarcoidosis, chest radiography was involved in correct diagnoses 71% of the time in observational cohort studies by Zajicek et al[5]. The use of fluorodeoxyglucose positron emission tomography (FDG-PET) can likewise assist in differentiating granulomatous lesions in neurosarcoidosis from potential malignancy and have been noted as a more useful modality for targeting hypermetabolic lesions for biopsy than CT and MRI[84]. These modalities are seldom used, however, due to their limited availability and cost. To be noted, the use of Gallium-67 scintigraphy and similar radioisotopic imaging studies have been noted within the literature; these studies can aid in detecting perfusion defects indicative of diminished circulation, as well as sarcoidosis of the lacrimal and parotid glands denoted as the "panda sign"[78,82].

Laboratory and CSF studies

Those who are suspected of neurosarcoidosis should have a cerebral spinal fluid (CSF) analysis. While the CSF analysis is not very specific to diagnosing neurosarcoidosis, the testing could be potentially helpful to determine if there is a malignancy or infection that is mimicking the clinic manifestations of neurosarcoidosis[19,85]. Abnormalities in the CSF are a frequent occurrence in neurosarcoidosis, with one study finding CSF abnormalities in over 80% of cases[5]. Commonly found elevated in the CSF of patients with neurosarcoidosis was an increased ratio of lymphocytes C4/CD8 of greater than 5[82]. Proteins levels, IgG levels, and glucose levels are either normal or low[19,82]. Angiotensin converting enzyme (ACE) is often used in terms of raised protein levels, however the significance of the raised ACE levels in the CSF is yet to be understood[5,19].

Studies have shown that ACE has low specificity and sensitivity for neurosarcoidosis and the levels of ACE in CSF are not likely a key player in diagnosing neurosarcoidosis[86,87]. Another component that may also be taken into account when making a diagnosis is the elevated levels of CSF interleukin 2 receptor. Petereit et al. found that the increase in the levels of interleukin 2 receptor in CSF was associated with the disease activity[85]. Overall CSF analysis could potentially be useful in eliminating other diagnoses, but it does not provide a definitive answer for the diagnosis of neurosarcoidosis. The continued advancement of medical technologies and research have produced novel techniques for improving neurosarcoidosis diagnosis. Future considerations for physicians should include multiplex or broad-range universal PCR and agnostic metagenomic next-generation sequencing for use in specialized laboratory settings; these emerging diagnostic modalities have demonstrated promise in improving diagnosis compared to standard CSF culture[19,88].

Histopathology

Biopsy of leptomeningeal tissue is pursued when assessing a patient for neurosarcoidosis; however, due to the high-risk and invasive nature of targeting brain and intracranial tissue, it is often not performed[76]. Nevertheless, brain or cerebrospinal meningeal biopsy remains the gold standard for confirming a definite neurosarcoidosis diagnosis[82]. Peripheral nerve biopsies are also used for patients who may have diabetes mellitus to rule out the role of diabetes in the diagnosis, due to the similarity in symptomatology and the possibility of patients without symptoms[19].

Another option that was previously available was the Kveim-Siltzbach test or Kevin skin test. This modality involves inoculating a patient with a sarcoidal spleen tissue intradermally for about 5 to 6 weeks after which a skin biopsy is taken[5]. The test was found to have a high specificity of 95% for neurosarcoidosis and also a sensitivity of 79%[89]. However, the Kveim skin test is not used anymore due to safety concerns over the transmission of diseases and the material used for this test, specifically the inoculation material that was obtained from human spleen specimens that is no longer available[83,90].

Treatment

Much of our understanding of neurosarcoidosis comes from autopsy and retrospective studies assessing neurosarcoidosis investigation, treatment, and disease course[83]. Historically, the treatment of neurosarcoidosis has been subject to similar immunopathogenic targeting as seen in systemic manifestations of the disease[19]. Current first-line treatment indicates the use of corticosteroids, although its usage as a monotherapy has become less indicated due to the increased risk of relapse and the contraindications of high dose corticosteroid use. Second-line treatment includes the use of synthetic disease-modifying antirheumatic drugs (csDMARDs), including methotrexate, azathioprine, mycophenolate, hydroxychloroquine, and leflunomide[19,79,81].

Methotrexate remains the most utilized second-line treatment, due to its associations with decreased disease-relapse in comparison to the less commonly used azathioprine, mycophenolate, and hydroxychloroquine[91]. Third-line treatments like anti-tumor necrosis factor drugs (anti-TNF) and cytotoxic agent have historically been used only after the aforementioned failed, yet recent use of infliximab and adalimumab have shown promise in clinical cohort studies[91,92]. Third-line cytotoxic agents like cyclophosphamide have decreased in usage in recent years due to their high toxicity, yet observational studies like Joubert et al, retain that it may still be useful in severe neurological presentations for neurosarcoidosis, such as in stroke[20]. Overall, the literature indicates first-line corticosteroid administration benefits from being paired with a second-line treatment like methotrexate, improving the drug response and reducing the drug-toxicity of corticosteroid usage alone[4]. Figure 3 depicts the respective lines of treatment for neurosarcoidosis.

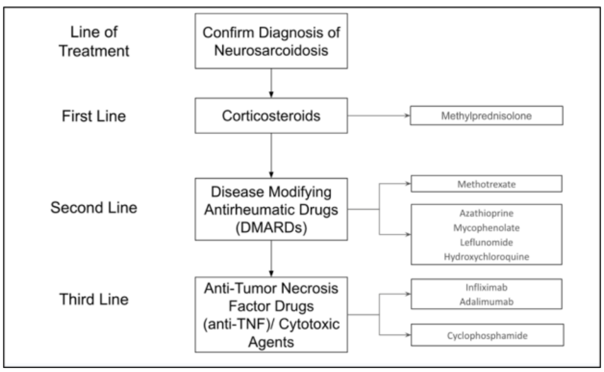

Figure 3. Neurosarcoidosis lines of treatment for neurosarcoidosis.

Emerging Treatment

Neurosarcoidosis, being a relatively rare and understudied manifestation of sarcoidosis, lacks the relevant literature needed to prove the efficacy of pharmacological treatments. Consequently, there are no FDA-approved pharmacotherapies on the market indicated for neurosarcoidosis—only off-label uses of other therapies. On the other hand, the use of prednisone and repository corticosteroid injections (RCI) have been FDA-approved for general sarcoidosis. Current literature regarding the therapy of neurosarcoidosis is composed of retrospective studies and case studies, and thus far, no randomized controlled trials concerning treatment strategies have been completed[93]. Generally, treatment options are derived from studies with regards to the care of pulmonary or general sarcoidosis[94]. Due to the variability of clinical manifestation, severity, and causes, it is imperative that treatments are studied and developed specifically to target neurosarcoidosis, and a few emerging treatments look to do so.

As mentioned previously, repository corticotropin injections (RCI), marketed as Acthar Gel, is an FDA-approved treatment for sarcoidosis and several other conditions[95]. In patients with both general and pulmonary sarcoidosis, RCI use has been shown to reduce the burden of corticosteroids and displayed therapeutic benefit in several studies[96-98]. A study reviewing the use of RCI in patients with sarcoidosis, including neurosarcoidosis, showed improvements in objective measures after three months of RCI use as well as a reduction in prednisone dosage[97].

A clinical trial by the Cleveland Clinic aimed to assess the use of Acthar therapy for neurosarcoidosis, but was withdrawn due to difficulty of recruitment, reaffirming the rarity of this disease (NCT02920710). Another exploratory therapy is rituximab, a monoclonal antibody that targets and depletes CD20+ B-cells[99]. In refractory cases or when steroid use is contraindicated, case reports have shown the effectiveness of rituximab in the therapy of neurosarcoidosis[100-102].

Single-institution retrospective reviews evaluating the use of rituximab in refractory sarcoidosis demonstrated symptomatic relief in the case of granulomatous disease of the eye and a generally positive prognosis[103,104]. Cibinetide (ARA290) is an amino acid peptide derived from erythropoietin and acts by reducing inflammatory and fibrotic responses. These therapeutic targets make it advantageous in targeting sarcoidosis-associated small nerve fiber loss (SNFL), as a prevalent hypothesis behind its etiology is systemic inflammation[105]. Literature has shown that it is not only effective in reversing SNFL but also increasing the density of corneal nerve fibers[106]. Along with these pathological markers, Dahan et al. noted improved patient-reported outcomes and increased exercise capacity using the 6-minute walk test[106].

Double-blinded, phase 2 studies with regular administration of cibinetide in sarcoidosis patients have established safety and shown significant improvements in neuropathic symptoms and a decrease in pain intensity[107,108]. The use of randomized controlled trials in the studies of cibinetide and their positive results make it promising in the development of neurosarcoidosis-specific therapy regimens. JAK-STAT inhibitors have also shown some potential in the treatment of neurosarcoidosis. Genes associated with the JAK-

STAT signaling pathway were differentially expressed between sarcoidosis patients and healthy controls, indicating that JAK-STAT may be implicated in the pathogenesis of sarcoidosis[109]. Specifically, Rosenbaum et al. revealed that granulomas in the lymph nodes of sarcoidosis patients expressed higher levels of STAT1 compared to control levels. Considering the possible immunologic basis for sarcoidosis, this is a possible therapeutic target. Recent studies have shown that the use of Janus kinase inhibitors have resulted in the clinical remission of lesions associated with sarcoidosis[110,111]. Damsky et al. looked at the use of tofacitinib, a JAK inhibitor, in the treatment of one patient with multiorgan sarcoidosis which resulted in the resolution of inflammation from granulomas and a reduction in disease biomarkers[111]. All in all, a lack of conclusive RCTs and general literature regarding neurosarcoidosis therapy remains a major barrier to developing comprehensive treatment strategies.

Conclusion

In conclusion, neurosarcoidosis stands as a challenging and multifaceted entity within the spectrum of inflammatory disorders. The intricacies of its clinical presentation, diagnostic hurdles, and potential mimics necessitate a meticulous approach to ensure accurate identification and appropriate management. As highlighted in this review, advancements in diagnostic tools, ranging from imaging modalities to laboratory studies, play a pivotal role in differentiating neurosarcoidosis from its fungal etiologies. Treatment strategies, currently anchored in corticosteroids and disease-modifying antirheumatic drugs, are witnessing the emergence of novel therapeutic options, offering hope for more specific and efficacious interventions.

The current understanding of neurosarcoidosis presented in this review highlights the need for controlled trials to further the knowledge base surrounding diagnosis and treatment. As we navigate the evolving landscape of diagnostic and therapeutic approaches, this exploration provides a foundation for continued advancements in the understanding and management of neurosarcoidosis.

References

1. Fritz D, van de Beek D, Brouwer MC. Clinical features, treatment and outcome in neurosarcoidosis: systematic review and meta-analysis. BMC Neurol. 2016;16(1):220. Published 2016 Nov 15. d186/s12883-016-0741-x
2. Barreras P, Stern BJ. Clinical features and diagnosis of neurosarcoidosis - review article. J Neuroimmunol. 2022;368:577871. doi:10.1016/j.jneuroim.2022.577871
3. Kidd DP. Neurosarcoidosis: clinical manifestations, investigation and treatment. Pract Neurol. 2020;20(3):199-212. doi:10.1136/practneurol-2019-002349
4. Bradshaw MJ, Pawate S, Koth LL, Cho TA, Gelfand JM. Neurosarcoidosis: Pathophysiology, Diagnosis, and Treatment. Neurol Neuroimmunol Neuroinflamm. 2021;8(6):e1084. Published 2021 Oct 4. doi:10.1212/NXI.0000000000001084
5. Zajicek JP, Scolding NJ, Foster O, et al. Central nervous system sarcoidosis--diagnosis and management. QJM. 1999;92(2):103-117. doi:10.1093/qjmed/92.2.103
6. Stern BJ, Royal W 3rd, Gelfand JM, et al. Definition and Consensus Diagnostic Criteria for Neurosarcoidosis: From the Neurosarcoidosis Consortium Consensus Group. JAMA Neurol. 2018;75(12):1546-1553. doi:10.1001/jamaneurol.2018.2295
7. Challa S. Granulomatous diseases of the central nervous system: Approach to diagnosis. Indian J Pathol Microbiol. 2022;65(Supplement):S125-S134. doi:10.4103/ijpm.ijpm_1067_21
8. Zumla A, James DG. Granulomatous infections: etiology and classification. Clin Infect Dis. 1996;23(1):146-158. doi:10.1093/clinids/23.1.146
9. Crouser ED, Smith RM, Culver DA, et al. A Pilot Randomized Trial of Transdermal Nicotine for Pulmonary Sarcoidosis. Chest. 2021;160(4):1340-1349. doi:10.1016/j.chest.2021.05.031
10. Nozaki K, Judson MA. Neurosarcoidosis. Curr Treat Options Neurol. 2013 Aug;15(4):492-504. doi: 10.1007/s11940-013-0242-9. PMID: 23703311.
11. Terushkin V, Stern BJ, Judson MA, Hagiwara M, Pramanik B, Sanchez M, Prystowsky S. Neurosarcoidosis: presentations and management. Neurologist. 2010 Jan;16(1):2-15. doi: 10.1097/NRL.0b013e3181c92a72. Erratum in: Neurologist. 2010 Mar;16(2):140. PMID: 20065791.
12. Chapelon C, Ziza JM, Piette JC, et al. Neurosarcoidosis: signs, course and treatment in 35 confirmed cases. Medicine (Baltimore) 1990; 69:261–76.
13. Aksamit, A. (2008). Neurosarcoidosis. CONTINUUM Lifelong Learning in Neurology, 14(1), 181-196. https://doi.org/10.1212/01.CON.0000299992.09447.2b
14. Berek K, Kiechl S, Willeit J, Birbamer G, Vogl G, Schmutzhard (1993) Subarachnoid haemorrhage as presenting feature of isolated neurosarcoidosis. Clin Investig 71:54–56
15. Kieff DA, Boey H, Schaefer PW, Goodman M, Joseph MP (1997) Isolated neurosarcoidosis presenting as anosmia and visual changes. Arch Otolaryngol Head Neck Surg 117:183–186

16. Mafee MF, Dorodi S, Pai E (1999) Sarcoidosis of the eye, orbit, and central nervous system. Role of MR imaging. Radiol Clin North Am 37:73–87
17. Mayock RL, Bertrand P, Morrison LE, Scott JH (1963) Manifestations of sarcoidosis. Am J Med 35:67–89
18. Allen RK, Sellars RE, Sandstrom PA. A prospective study of 32 patients with neurosarcoidosis. Sarcoidosis Vasc Diffuse Lung Dis. 2003;20(2):118– 25.
19. Gosselin, J., Roy-Hewitson, C., Bullis, S.S.M. et al. Neurosarcoidosis: Phenotypes, Approach to Diagnosis and Treatment. Curr Rheumatol Rep 24, 371–382 (2022). https://doi.org/10.1007/s11926-022-01089-z
20. Joubert B, Chapelon-Abric C, Biard L, Saadoun D, Demeret S, Dormont D, Resche-Rigon M, Cacoub P. Association of Prognostic Factors and Immunosuppressive Treatment With Long-term Outcomes in Neurosarcoidosis. JAMA Neurol. 2017 Nov 1;74(11):1336-1344. doi: 10.1001/jamaneurol.2017.2492. PMID: 29052709; PMCID: PMC5710577.
21. Herring AB, Urich H. Sarcoidosis of the central nervous system. J Neurol Sci. 1969;9(3):405–22. https://doi.org/10.1016/0022-510x(69)90086-0.
22. Meyer JS, Foley JM, Campagna-Pinto D. Granulomatous angiitis of the meninges in sarcoidosis. AMA Arch Neurol Psychiatry. 1953;69(5):587–600. https://doi.org/10.1001/archneurpsyc.1953.0232029003 9005.
23. Reske-Nielsen E, Harmsen A. Periangiitis and panangiitis as a manifestation of sarcoidosis of the brain: report of a case. J Nerv Ment Dis. 1962;135:399–412. https://doi.org/10.1097/00005053-196211000-00003.
24. Brooks ML, Wang AM, Black PM, Haikal N (1989) Subdural mass lesion secondary to sarcoid granuloma. MR and CT findings and differential diagnosis. Comp
25. Chaix Y, Grouteau E, Sevely A, Boetto S, Delisle MB, Carrière JP (1997) Formes pseudo-tumorales de la neurosarcoïdose chez l'enfant. Rev Neurol (Paris) 153:771–774
26. Clark WC, Acker JD, Dohan FC, Robertson JH (1981) Presentation of central nervous system sarcoidosis as intracranial tumours. Surg Neurol 63:851–856
27. Decker RE, Mardayat M, Marc J, Rasool A (1979) Neurosarcoidosis with computerised tomographic visualisation and transsphenoidal excision of a supra- and intrasellar granuloma. Case report. J Neurosurg 50:814–816
28. Elias WJ, Lanzino G, Reitmeyer M, Jane JA (1999) Solitary sarcoid granuloma of the cerebellopontine angle. A case report. Surg Neurol 51:185–190
29. Grand S, Hoffmann D, Bost F, FrancoisJoubert A, Pasquier B, Le Bas JF (1996) Case report: pseudotumoral brain lesion as the presenting feature of sarcoidosis. Br J Radiol 69:272–275.
30. Healton EB, Zito G, Chauhan P, Brust JCM (1982) Intracranial subdural sarcoid granuloma. Case report. J Neurosurg 56:728–731
31. Jackson RJ, Goodman JC, Huston DP, Harper RL (1998) Parafalcine and bilateral convexity neurosarcoidosis mimicking meningioma: case report and review of the literature. Neurosurgery 42:635–638
32. Krejchi D, Caldemeyer KS, Vakili ST, Michael BP (1998) Neurosarcoidosis resembling meningioma: MRI characteristics and pathologic correlation. J Neuroimaging 8:177–179
33. Larner AJ, Ball JA, Howard RS (1999) Sarcoid tumour: continuing diagnostic problems in the MRI era. J Neurol Neurosurg Psychiatry 66:510–512
34. Lipper MH, Goldstein JM (1998) Neurosarcoidosis mimicking a cerebellopontine angle meningioma. AJR Am J Roentgenol 171:275–276
35. Nataf F, Devaux B, Lamy C, FalletBianco C, Roux FX (1993) Localisation sphéno-caverneuse de la neurosarcoïdose méningée. A propos d'un cas et revue de la literature. Neurochirurgie 39:128–131
36. Osenbach RK, Blumenkopf B, Ramirez Jr H, Gutierrez J (1986) Meningeal neurosarcoidosis mimicking convexity en plaque meningioma Surg Neurol 26:387–390
37. Ranoux D, Devaux B, Lamy C, Mear JY, Roux FX, Mas JL (1992) Meningeal sarcoidosis, pseudo-meningioma, and pachymeningitis of the convexity. J Neurol Neurosurg Psychiatry 55:300–303
38. Seltzer S, Mark AS, Atlas SW (1991) CNS sarcoidosis: evaluation with contrast-enhanced MR imaging. AJNR Am J Neuroradiol 12:1227–1233
39. Skilikorn SA, Garrity RW (1955) Intracranial Boeck's sarcoid tumour resembling meningioma. J Neurosurg 12:407–413
40. Urbach H, Kristof R, Zentner J, Brechtelsbauer D, Solymosi L, Wolf HK (1997) Sarcoidosis presenting as an intra- or extra-axial cranial mass: report of two cases. Neuroradiology 39:516–519
41. Chen RC, McLeod JG (1989) Neurological complications of sarcoidosis. Clin Exp Neurol 26:99–112
42. Delaney P (1977) Neurological manifestations in sarcoidosis: review of the literature, with report of 23 cases. Ann Intern Med 87:336–345
43. Luke RA, Stern BJ, Krumholz A, Johns CJ (1987) Neurosarcoidosis: the longterm clinical course. Neurology 37:461–463
44. Sharma OP, Sharma AM (1991) Sarcoidosis of the nervous system: a clinical approach. Arch Intern Med 151:1317–1321
45. S. Pawate, H. Moses, S. Sriram, Presentations and outcomes of neurosarcoidosis: a study of 54 cases, QJM: An International Journal of Medicine, Volume 102, Issue 7, July 2009, Pages 449–460, https://doi.org/10.1093/qjmed/hcp042
46. Tavee JO, Stern BJ. Neurosarcoidosis. Clin Chest Med. 2015 Dec;36(4):643-56. doi: 10.1016/j.ccm.2015.08.007. Epub 2015 Sep 26. PMID: 26593139.
47. Bandyopadhyay T, Das D, Das SK, Ghosh A. A case of neurosarcoidosis presenting with multiple cranial nerve palsy. J Assoc Physicians India. 2003 Mar;51:328-9. PMID: 12839373.

48. Palacios E, Rigby PL, Smith DL. Cranial neuropathy in neurosarcoidosis. Ear Nose Throat J. 2003 Apr;82(4):251-2. PMID: 12735154.
49. DeBroff BM, Donahue SP. Bilateral optic neuropathy as the initial manifestation of systemic sarcoidosis. Am J Ophthalmol. 1993 Jul 15;116(1):108-11. doi: 10.1016/s0002-9394(14)71759-3. PMID: 8328532.
50. James DG, Zatouroff MA, Trowell J, Rose FC. Papilloedema in sarcoidosis. Br J Ophthalmol. 1967 Aug;51(8):526-9. doi: 10.1136/bjo.51.8.526. PMID: 6035953; PMCID: PMC506439.
51. Karma, A., Huhti, E., & Poukkula, A. (1988). Course and outcome of ocular sarcoidosis. American journal of ophthalmology, 106(4), 467-472.
52. Westlake WH, Heath JD, Spalton DJ. Sarcoidosis Involving the Optic Nerve and Hypothalamus. Arch Ophthalmol. 1995;113(5):669–670. doi:10.1001/archopht.1995.01100050137044
53. Shen J, Lackey E, Shah S. Neurosarcoidosis: Diagnostic Challenges and Mimics A Review. Curr Allergy Asthma Rep. 2023 Jul;23(7):399-410. doi: 10.1007/s11882-023-01092-z. Epub 2023 May 31. PMID: 37256482; PMCID: PMC10230477.
54. Sharma BS, Khosla VK, Kak VK, Banerjee AK, Vasishtha RK, Prasad KS, Sharma SC, Mathuriya SN, Tewari MK, Pathak A. Intracranial fungal granuloma. Surg Neurol. 1997 May;47(5):489-97. doi: 10.1016/s0090-3019(96)00209-1. PMID: 9131036.
55. Riley TT, Muzny CA, Swiatlo E, Legendre DP. Breaking the Mold: A Review of Mucormycosis and Current Pharmacological Treatment Options. Ann Pharmacother. 2016;50(9):747-757. doi:10.1177/1060028016655425
56. Meas T, Mouly S, Kania R, et al. Zygomycosis: an uncommon cause for peripheral facial palsy in diabetes. Diabetes Metab. 2007;33(3):227-229. doi:10.1016/j.diabet.2006.12.001
57. Nagendra V, Thakkar KD, Prasad Hrishi A, Prathapadas U. A Rare Case of Rhinocerebral Mucormycosis Presenting as Garcin Syndrome and Acute Ischemic Stroke. Indian J Crit Care Med. 2020;24(11):1137-1138. doi:10.5005/jp-journals-10071-23643
58. Kirkland TN, Fierer J. Coccidioides immitis and posadasii; A review of their biology, genomics, pathogenesis, and host immunity. Virulence. 2018;9(1):1426-1435. doi:10.1080/21505594.2018.1509667
59. Galgiani JN, Ampel NM, Blair JE, et al. 2016 Infectious Diseases Society of America (IDSA) Clinical Practice Guideline for the Treatment of Coccidioidomycosis. Clin Infect Dis. 2016;63(6):e112-e146. doi:10.1093/cid/ciw360
60. Johnson R, Ho J, Fowler P, Heidari A. Coccidioidal Meningitis: A Review on Diagnosis, Treatment, and Management of Complications. Curr Neurol Neurosci Rep. 2018;18(4):19. Published 2018 Mar 13. doi:10.1007/s11910-018-0824-8
61. Tan LA, Kasliwal MK, Nag S, O'Toole JE, Traynelis VC. Rapidly progressive quadriparesis heralding disseminated coccidioidomycosis in an immunocompetent patient. J Clin Neurosci. 2014;21(6):1049-1051. doi:10.1016/j.jocn.2013.07.040
62. Ho J, Fowler P, Heidari A, Johnson RH. Intrathecal Amphotericin B: A 60-Year Experience in Treating Coccidioidal Meningitis. Clin Infect Dis. 2017;64(4):519-524. doi:10.1093/cid/ciw794
63. Drake KW, Adam RD. Coccidioidal meningitis and brain abscesses: analysis of 71 cases at a referral center. Neurology. 2009;73(21):1780-1786. doi:10.1212/WNL.0b013e3181c34b69
64. Lo Re V 3rd, Gluckman SJ. Eosinophilic meningitis. Am J Med. 2003;114(3):217-223. doi:10.1016/s0002-9343(02)01495-x
65. Stockamp NW, Thompson GR 3rd. Coccidioidomycosis. Infect Dis Clin North Am. 2016;30(1):229-246. doi:10.1016/j.idc.2015.10.008
66. Bamberger DM, Pepito BS, Proia LA, et al. Cerebrospinal fluid Coccidioides antigen testing in the diagnosis and management of central nervous system coccidioidomycosis. Mycoses. 2015;58(10):598-602. doi:10.1111/myc.12366
67. Stevens DA, Zhang Y, Finkelman MA, Pappagianis D, Clemons KV, Martinez M. Cerebrospinal Fluid (1,3)-Beta-d-Glucan Testing Is Useful in Diagnosis of Coccidioidal Meningitis. J Clin Microbiol. 2016;54(11):2707-2710. doi:10.1128/JCM.01224-16
68. Lang R, Stokes W, Lemaire J, Johnson A, Conly J. A case report of Coccidioides posadasii meningoencephalitis in an immunocompetent host. BMC Infect Dis. 2019;19(1):722. Published 2019 Aug 16. doi:10.1186/s12879-019-4329-0
69. Antinori S, Corbellino M, Meroni L, Resta F, Sollima S, Tonolini M, Tortorano AM, Milazzo L, Bello L, Furfaro E, Galli M, Viscoli C. Aspergillus meningitis: a rare clinical manifestation of central nervous system aspergillosis. Case report and review of 92 cases. J Infect. 2013 Mar;66(3):218-38. doi: 10.1016/j.jinf.2012.11.003. Epub 2012 Nov 21. PMID: 23178421; PMCID: PMC7112586.
70. Sonneville R, Magalhaes E, Meyfroidt G. Central nervous system infections in immunocompromised patients. Curr Opin Crit Care. 2017 Apr;23(2):128-133. doi: 10.1097/MCC.0000000000000397. PMID: 28169858.
71. Abassi M, Boulware DR, Rhein J. Cryptococcal Meningitis: Diagnosis and Management Update. Curr Trop Med Rep. 2015;2(2):90-99. doi:10.1007/s40475-015-0046-y
72. Temfack E, Rim JJB, Spijker R, et al. Cryptococcal Antigen in Serum and Cerebrospinal Fluid for Detecting Cryptococcal Meningitis in Adults Living With Human Immunodeficiency Virus: Systematic Review and Meta-Analysis of Diagnostic Test Accuracy Studies. Clin Infect Dis. 2021;72(7):1268-1278. doi:10.1093/cid/ciaa1243
73. Pappas PG. Cryptococcal infections in non-HIV-infected patients. Trans Am Clin Climatol Assoc. 2013;124:61-79.
74. Poley M, Koubek R, Walsh L, McGillen B. Cryptococcal Meningitis in an Apparent Immunocompetent Patient. J Investig Med High Impact Case Rep.

2019;7:2324709619834578. doi:10.1177/2324709619834578

75. Regmi BU, Pathak BD, Subedi RC, et al. Neuro-cryptococcosis in an immunocompetent individual with radiologically atypical findings: a case report and review of literature. Oxf Med Case Reports. 2023;2023(3):omad016. Published 2023 Mar 25. doi:10.1093/omcr/omad016
76. Stern BJ, Krumholz A, Johns C, Scott P, Nissim J. Sarcoidosis and its neurological manifestations. Arch Neurol. 1985 Sep;42(9):909-17. doi: 10.1001/archneur.1985.04060080095022. PMID: 3896208.
77. Joseph FG, Scolding NJ. Neurosarcoidosis: a study of 30 new cases. J. Neurol. Neurosurg. Psychiatry. 2009;80(3):297–304.
78. Hunninghake GW, Costabel U, Ando M, Baughman R, Cordier JF, du Bois R, Eklund A, Kitaichi M, Lynch J, Rizzato G, Rose C, Selroos O, Semenzato G, Sharma OP. ATS/ERS/WASOG statement on sarcoidosis. American Thoracic Society/European Respiratory Society/World Association of Sarcoidosis and other Granulomatous Disorders. Sarcoidosis Vasc Diffuse Lung Dis. 1999 Sep;16(2):149-73. PMID: 10560120.
79. Lacomis D. Neurosarcoidosis. Curr Neuropharmacol. 2011 Sep;9(3):429-36. doi:10.2174/157015911796557975. PMID: 22379457; PMCID: PMC3151597.
80. Williams D. W. D., Elster A. D., Kramer S. I.Neurosarcoidosis: gadolinium-enhanced MR imaging. J. Comput. Assist. Tomogr.141990704707
81. Lower EE, Broderick JP, Brott TG, Baughman RP. Diagnosis and management of neurological sarcoidosis. Arch Intern Med. 1997 Sep 8;157(16):1864-8. PMID: 9290546.
82. Hebel, R., Dubaniewicz-Wybieralska, M. & Dubaniewicz, A. Overview of neurosarcoidosis: recent advances. J Neurol 262, 258–267 (2015). https://doi.org/10.1007/s00415-014-7482-9
83. Ibitoye RT, Wilkins A, Scolding NJ. Neurosarcoidosis: a clinical approach to diagnosis and management. J Neurol. 2017 May;264(5):1023-1028. doi: 10.1007/s00415-016-8336-4. Epub 2016 Nov 22. PMID: 27878437; PMCID: PMC5413520.
84. Segal BM (2013) Neurosarcoidosis: diagnostic approaches and therapeutic strategies. Curr Opin Neurol 26:307–313
85. Petereit, HF., Reske, D., Tumani, H. et al. Soluble CSF interleukin 2 receptor as indicator of neurosarcoidosis. J Neurol 257, 1855–1863 (2010). https://doi.org/10.1007/s00415-010-5623-3
86. Bridel C, Courvoisier DS, Vuilleumier N, Lalive PH. Cerebrospinal fluid angiotensin-converting enzyme for diagnosis of neurosarcoidosis. J Neuroimmunol. 2015;285:1–3. https://doi.org/10.1016/j.jneuroim.2015.05.020.
87. Chopra A, Kalkanis A, Judson MA. Biomarkers in sarcoidosis. Expert Rev Clin Immunol. 2016;12(11):1191–208. https://doi.org/10.1080/1744666x.2016.1196135.
88. Simner PJ, Miller S, Carroll KC. Understanding the Promises and Hurdles of Metagenomic Next-Generation Sequencing as a Diagnostic Tool for Infectious Diseases. Clin Infect Dis. 2018;66(5):778–88.
89. Hirsch JG, Cohn ZA, Morse SI, Schaedler RW, Siltzbach LE, Ellis JT, et al. Evaluation of the Kveim reaction as a diagnostic test for sarcoidosis. N Engl J Med. 1961;265:827–830. doi: 10.1056/NEJM196110262651703.
90. Marangoni, S., Argentiero, V. & Tavolato, B. Neurosarcoidosis. J Neurol 253, 488–495 (2006). https://doi.org/10.1007/s00415-005-0043-5
91. Gelfand JM, Bradshaw MJ, Stern BJ, Clifford DB, Wang Y, Cho TA, et al. Infliximab for the treatment of CNS sarcoidosis: a multi-institutional series. Neurology. 2017;89(20):2092–100.
92. Hutto SK, Kyle K, Cavanagh JJ, Reda H, Venna N. Adalimumab for CNS sarcoidosis: single-center experience and literature review. J Neurol. 2022;269(4):2064–72. https://doi.org/10.1007/s00415-021-10793-2.
93. Fritz D, Voortman M, van de Beek D, Drent M, Brouwer MC. Many faces of neurosarcoidosis: from chronic meningitis to myelopathy. Curr Opin Pulm Med. 2017 Sep;23(5):439-446. doi: 10.1097/MCP.0000000000000401. PMID: 28598872.
94. Soto-Gomez N, Peters JI, Nambiar AM. Diagnosis and Management of Sarcoidosis. Am Fam Physician. 2016 May 15;93(10):840-8. PMID: 27175719.
95. Obi ON, Saketkoo LA, Russell AM, Baughman RP. Sarcoidosis: Updates on therapeutic drug trials and novel treatment approaches. Front Med (Lausanne). 2022 Oct 12;9:991783. doi: 10.3389/fmed.2022.991783. PMID: 36314034; PMCID: PMC9596775.
96. Chopra I, Qin Y, Kranyak J, Gallagher JR, Heap K, Carroll S, Wan GJ. Repository corticotropin injection in patients with advanced symptomatic sarcoidosis: retrospective analysis of medical records. Ther Adv Respir Dis. 2019 Jan-Dec;13:1753466619888127. doi: 10.1177/1753466619888127. PMID: 31722624; PMCID: PMC6856972.
97. Baughman RP, Barney JB, O'Hare L, Lower EE. A retrospective pilot study examining the use of Acthar gel in sarcoidosis patients. Respir Med. 2016 Jan;110:66-72. doi: 10.1016/j.rmed.2015.11.007. Epub 2015 Nov 19. PMID: 26626451.
98. Mirsaeidi M, Baughman RP. Repository Corticotropin Injection for the Treatment of Pulmonary Sarcoidosis: A Narrative Review. Pulm Ther. 2022 Mar;8(1):43-55. doi: 10.1007/s41030-022-00181-0. Epub 2022 Feb 3. PMID: 35113366; PMCID: PMC8861221.
99. Sweiss NJ, Lower EE, Mirsaeidi M, Dudek S, Garcia JG, Perkins D, Finn PW, Baughman RP. Rituximab in the treatment of refractory pulmonary sarcoidosis. Eur

Respir J. 2014 May;43(5):1525-8. doi: 10.1183/09031936.00224513. Epub 2014 Jan 31. PMID: 24488568; PMCID: PMC4167390.

100. Bomprezzi R, Pati S, Chansakul C, Vollmer T. A case of neurosarcoidosis successfully treated with rituximab. Neurology. 2010 Aug 10;75(6):568-70. doi: 10.1212/WNL.0b013e3181ec7ff9. PMID: 20697110.
101. Earle B, Wolf DS, Ramsay ES. Novel Use of Rituximab in Treatment of Refractory Neurosarcoidosis in an 11-Year-Old Girl. J Clin Rheumatol. 2019 Sep;25(6):e101-e103. doi: 10.1097/RHU.0000000000000900. PMID: 30247223.
102. Zella S, Kneiphof J, Haghikia A, Gold R, Woitalla D, Thöne J. Successful therapy with rituximab in three patients with probable neurosarcoidosis. Ther Adv Neurol Disord. 2018 Oct 26;11:1756286418805732. doi: 10.1177/1756286418805732. PMID: 30386436; PMCID: PMC6204624.
103. Lower EE, Baughman RP, Kaufman AH. Rituximab for refractory granulomatous eye disease. Clin Ophthalmol. 2012;6:1613-8. doi: 10.2147/OPTH.S35521. Epub 2012 Oct 5. PMID: 23055686; PMCID: PMC3468281.
104. Cinetto F, Compagno N, Scarpa R, Malipiero G, Agostini C. Rituximab in refractory sarcoidosis: a single centre experience. Clin Mol Allergy. 2015 Sep 1;13(1):19. doi: 10.1186/s12948-015-0025-9. PMID: 26330764; PMCID: PMC4556310.
105. Uçeyler N, Kafke W, Riediger N, He L, Necula G, Toyka KV, Sommer C. Elevated proinflammatory cytokine expression in affected skin in small fiber neuropathy. Neurology. 2010 Jun 1;74(22):1806-13. doi: 10.1212/WNL.0b013e3181e0f7b3. PMID: 20513817.
106. Dahan A, Dunne A, Swartjes M, Proto PL, Heij L, Vogels O, van Velzen M, Sarton E, Niesters M, Tannemaat MR, Cerami A, Brines M. ARA 290 improves symptoms in patients with sarcoidosis-associated small nerve fiber loss and increases corneal nerve fiber density. Mol Med. 2013 Nov 8;19(1):334-45. doi: 10.2119/molmed.2013.00122. Erratum in: Mol Med. 2016 Oct 20;22:674. PMID: 24136731; PMCID: PMC3883966.
107. Heij L, Niesters M, Swartjes M, Hoitsma E, Drent M, Dunne A, Grutters JC, Vogels O, Brines M, Cerami A, Dahan A. Safety and efficacy of ARA 290 in sarcoidosis patients with symptoms of small fiber neuropathy: a randomized, double-blind pilot study. Mol Med. 2012 Nov 15;18(1):1430-6. doi: 10.2119/molmed.2012.00332. PMID: 23168581; PMCID: PMC3563705.
108. Culver DA, Dahan A, Bajorunas D, Jeziorska M, van Velzen M, Aarts LPHJ, Tavee J, Tannemaat MR, Dunne AN, Kirk RI, Petropoulos IN, Cerami A, Malik RA, Brines M. Cibinetide Improves Corneal Nerve Fiber Abundance in Patients With Sarcoidosis-Associated Small Nerve Fiber Loss and Neuropathic Pain. Invest Ophthalmol Vis Sci. 2017 May 1;58(6):BIO52-BIO60. doi: 10.1167/iovs.16-21291. PMID: 28475703.
109. Rosenbaum JT, Pasadhika S, Crouser ED, Choi D, Harrington CA, Lewis JA, Austin CR, Diebel TN, Vance EE, Braziel RM, Smith JR, Planck SR. Hypothesis: sarcoidosis is a STAT1-mediated disease. Clin Immunol. 2009 Aug;132(2):174-83. doi: 10.1016/j.clim.2009.04.010. Epub 2009 May 22. PMID: 19464956; PMCID: PMC2733945.
110. Wang A, Singh K, Ibrahim W, King B, Damsky W. The Promise of JAK Inhibitors for Treatment of Sarcoidosis and Other Inflammatory Disorders with Macrophage Activation: A Review of the Literature. Yale J Biol Med. 2020 Mar 27;93(1):187-195. PMID: 32226347; PMCID: PMC7087061.
111. Damsky W, Young BD, Sloan B, Miller EJ, Obando JA, King B. Treatment of Multiorgan Sarcoidosis With Tofacitinib. ACR Open Rheumatol. 2020 Feb;2(2):106-109. doi: 10.1002/acr2.11112. Epub 2020 Jan 9. PMID: 31916703; PMCID: PMC7011417.

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Neurofibroma of C2 root. A series of cases

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ABSTRACT
Background: Intra and extradural neurofibromas of C2 root is a challenging pathology, usually with indolent evolution, that is why the onset symptoms are neurologic deficit just like upper cervical myelopathy symptoms and explains the late diagnosis of giant tumours with severe spinal cord compression with involvement and distortion of great vessels anatomy. These facts make surgeries more difficult. The follow-up of this type of surgery must be very close because CSF fistula can often occur.
Case description: The present article reports a series of three cases of neurofibromas, two of them are giant dumbbell-shaped C2 neurofibromas and the third one is a case of neurofibromatosis type 1 of C2 roots bilaterally, C3 root unilateral with unusual postoperative course. Dural reconstruction was necessary in all cases.
Conclusions: The patients in this series were very symptomatic with good recovery. The surgical procedures were challenging, total tumour removal was possible, and the reconstruction of dural defects was needed in all cases. In the case of NF1, the postoperative period was practically just the follow-up of complications and addressing them. This fact stresses the importance of meticulous preoperative planning and close follow-up. Postoperative quality of life was better than preoperative in all the cases. The purpose of the surgical treatment is the decompression of the spinal cord, tumour removal and prophylaxis of CSF fistula by closing the dural defects. Overall, the surgical C2 root neurofibromas resection is a safe procedure and is associated with good clinical outcomes.

Keywords
neurofibroma,
C2 root,
dumbbell-shaped tumour

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INTRODUCTION

Neurofibromas arise mainly from the C2 root [5,3]. C2 neurofibromas can grow to a large size while remaining asymptomatic and extend via the intervertebral foramina to achieve a dumbbell shape [5,3]. C2 neurofibroma has specific characteristics, such as multiplicity, a dumbbell shape, a relationship with the vertebral artery and particular associated surgical problems [5,3,8,13]. Peripheral nerve sheath tumors arising from the second cervical nerve root are relatively common and constitute approximately 15% of all spinal peripheral nerve sheath tumors [5]. Neurofibromas account for about 2-5% of all primary spinal tumors [9,10,2], including neurofibromatosis type 1 (NF1, Von Recklinghausen's disease) [11]. Neurofibromas have a high prevalence at the C2 level in patients with and without NF1. [5,1,4,7,12].

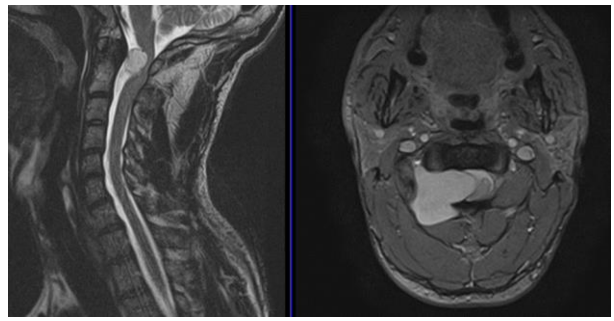
Surgical procedure

The posterior approach was selected in all patients, using a midline incision, exposing occiput, C1, C2, C3 posterior elements. A C1 laminectomy and C2 hemilaminectomy was performed and extended laterally to expose the tumor and the dural tube. The posterior dural wall of the tumor was coagulated and incised, and intra tumoral debulking was performed. The dura was cut in a T shape, longitudinal and the perpendicular incision to the tumor side. The involved C2 root was resected together with the tumor, avoiding vascular structures. The venous bleeding was the main sources of hemorrhage during surgery: careful coagulation and the use of hemostatic foam associated with gentle compression reduces the bleeding. Reconstruction of dural defect was performed if needed. Fixations and fusions were not necessary.

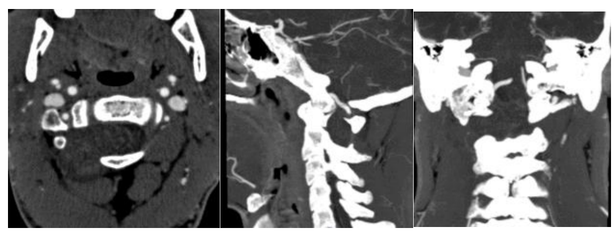
According to Atul Goel, C2 neurinomas arise in the region of the C2 ganglion, and despite the fact that some achieve a large size, they remain confined within the dura. Radical tumor resection can be achieved by working within the layers of the dural cover. Bone removal and opening of spinal dura for tumor exposure and resection can be avoided [6]. Unfortunately, in our cases it was not possible, we considered dural opening safer and we recommend the nuchal ligament as good plastic material for dural reconstruction. Each patient has sufficient size of ligament, it is easy to choose a good layer, and it is strong and resistant, there are no difficulty to suture it.

Case 1

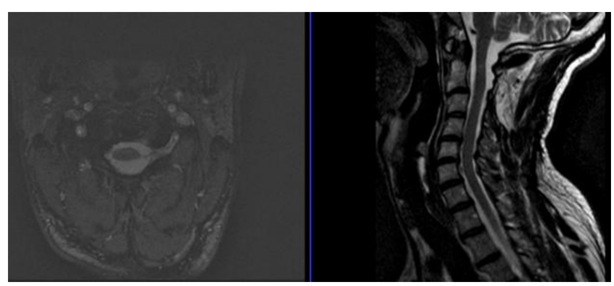
42 years old man, presented with spastic tetra paresis at the admission time, but still maintaining autonomy (Karnofsky 80). First sign was right hand weakness, rapidly progressing to other limbs. No history of previous diseases, no smoking. MRI revealed severe spinal cord compression by dumbbell-shaped extramedullary, intra, extradural tumor (Figure 1 A). For preoperative planning and in order to study the vascular anatomy, contrast enhanced CT scan was performed, that showed impingement of VA upwards (Figure 1 B). The patient was selected for removal of the tumor through median posterior approach, as described previously. At the end of the surgery, the reconstruction of the dural defect was performed. As material for reconstruction was used the nuchal ligament, previously harvested during the approach. Postoperative period was uneventful, with excellent neurological and functional recovery. Pathologic anatomy was neurofibroma grade I (WHO), Three-year postoperative MRI confirmed no sign of residual tumor, right C2 root amputation, slight intramedullary T2 hypersignal.



A: Preoperative MRI revealing severe spinal cord compression by dumbbell-shaped extramedullary, intra, extradural tumor.



B: Contrast enhanced CT scan, revealing right C1-C2 foramina enlargement and relationship with vertebral artery.



C: Postoperative MRI, identifying good spine cord decompression, right C2 root amputation, slight intramedullary hypersignal.

Figure 1. Right sided dumbbell-shaped neurofibroma of the right C2 root.

Case 2

31 years old African man with a two-week history of paresthesia of inferior limbs with rapid progression to tetra paresis and subsequent inferior paraplegia (Karnofsky 50). CT scan revealed right-sided, dumbbell-shaped C2 root tumor with severe spine cord compression. He was operated on, the tumor

was removed totally through posterior medial approach as well, the tumor was growing from C2 root, at the end of the surgery also a dural reconstruction was needed. The patient's postoperative recovery was good, the only sequel remained is right hand proximal weakness, still recovering. Postoperative CT scan excluded local complication.

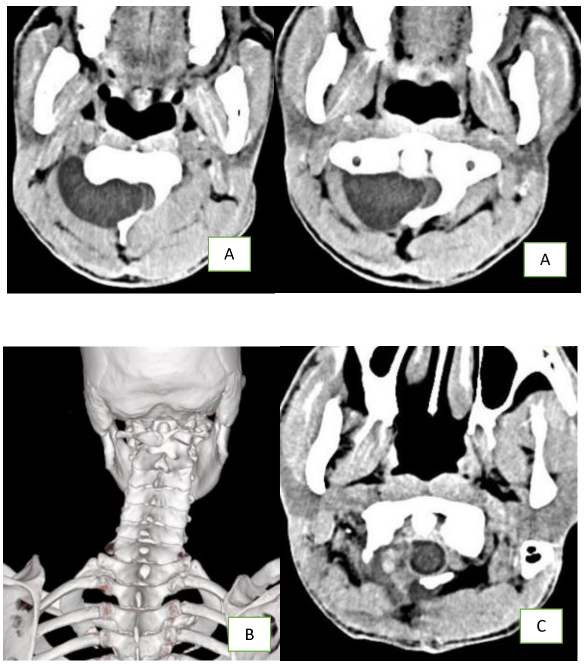
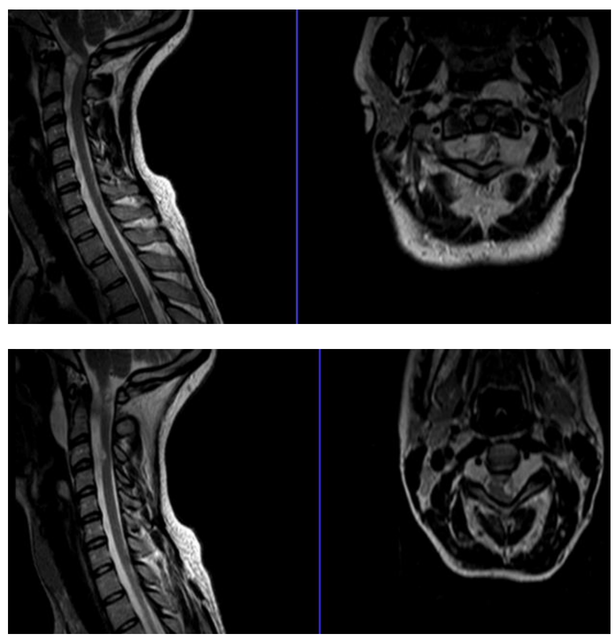


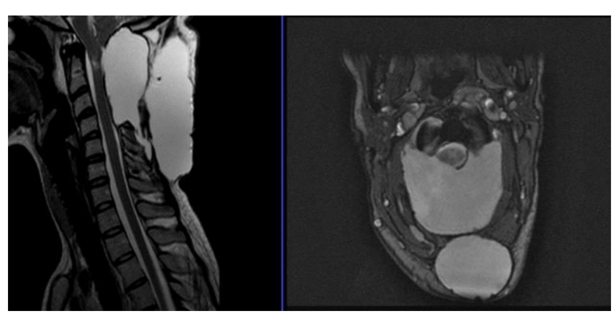
Figure 2. **A**. Preoperative CT scan; **B**. CT scan reconstruction revealing C1 and C2 lamina erosion C. Postoperative CT scan.

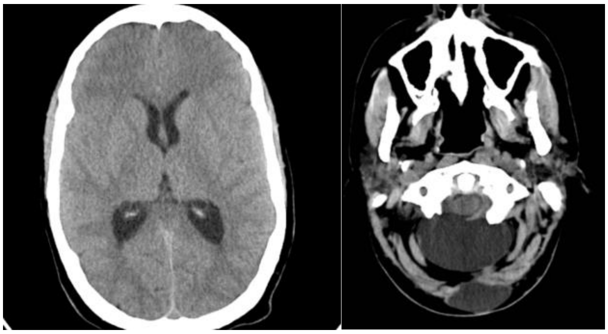
Case 3

34 years old lady, with NF1 diagnosed since the age of 18 years, admitted because of unstable gait (Karnofsky 80). MRI revealed bilateral C2 roots tumors with severe bilateral compression of the spinal cord, spinal cord is squeezed in between C2 bilateral tumors and C3 root left sided tumor (Figure 3 A). She was operated, it was performed removal of tumors with extra, intradural growth through posterior approach through C2 laminectomia with subsequent dural reconstruction also with nuchal ligament harvested during the approach. In the postoperative period she developed a huge, tense, subaponeurotic CSF collection (Figure 2 B), solved only after inserting de ventriculoperitoneal shunt with the use of navigation, because of small ventricles (Figure 3 C). Two years after the neurofibroma removal she was bothered by neck pain and fixed position in anterior flexion of the head. X-Ray, MRI diagnosed post laminectomy regional kyphosis C2-C3 with anterior luxation. She was operated: circumferential arthrodesis (ACDF C3-C4, C4-C5, posterior mass lateral fixation C2-C6 on the right side, C2, C3, C5, C6 on the left side) with good recovery and pain relief (Figure 3 D). Three years after she started to be bothered by upper limb paresthesia and MRI revealed initial cervical syringomyelia. One year later her gait was progressively more unstable and MRI showed significant syringomyelia progression (Figure 3 E) and next surgery was performed: siringopleural shunt insertion trough upper thoracic laminectomy Th1, Th2 and unilateral intralaminar fixation C7-Th3 was performed at the end of the surgery (Figure 3 F). The decision to fix C7-Th3 with intralaminar unilateral screws was dictated by previous experience with cervical instability and weak muscles of the patient. The postoperative period was uneventful, the gait improved significantly.

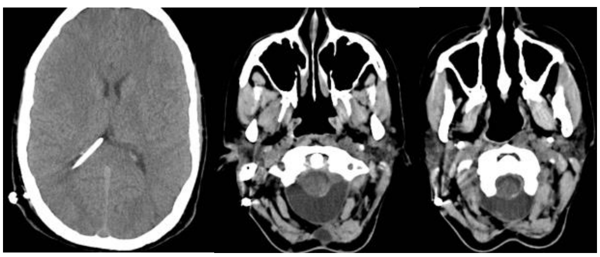


A: MRI revealing bilateral C2 root tumor with severe bilateral spine cord compression and C3 unilateral tumor.

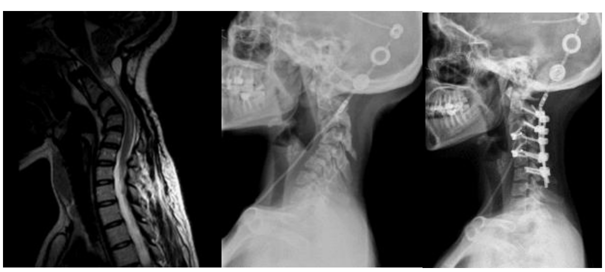




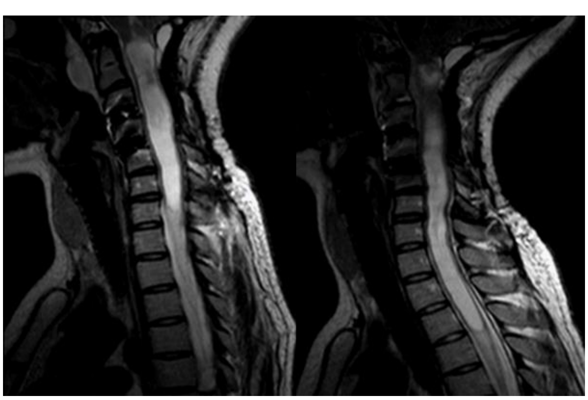
B: MRI and CT scan showing huge, postoperative pseudomeningocele, no signs of hydrocephalus, no signs of residual tumors.



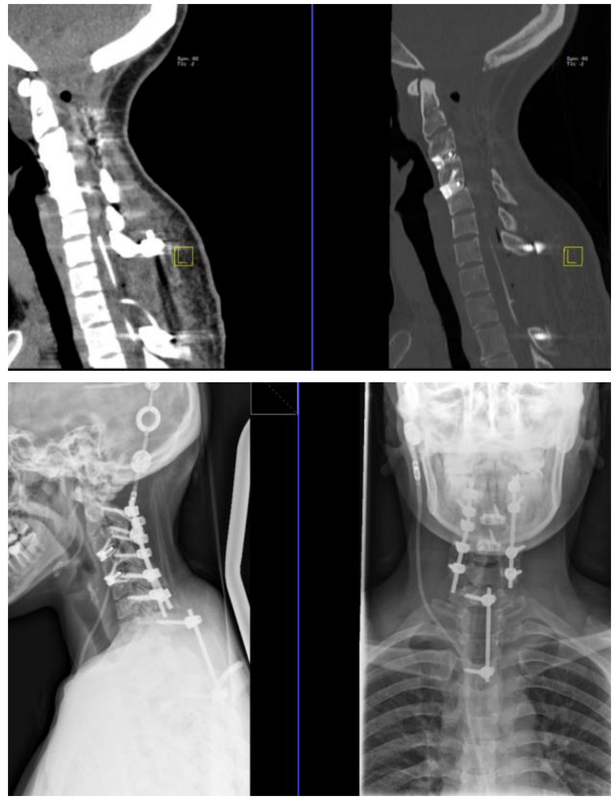
C: Serial CT scan after ventriculoperitoneal shunting, meningocele diminished on serial CT scan.



D: MRI revealing upper cervical post laminectomy regional kyphosis, syringomyelia, no signs of meningocele. X-Ray before and after 360-degree arthrodesis.



E: Serial MRI with 1-year time difference, showing syringomyelia progression to upper thoracic spine cord.



F: CT scan, X-Ray after syringopleural shunting

Conclusion

The patients in this series were very symptomatic with good recovery. The surgical procedures were challenging, total tumor removal was possible, the reconstruction of dural defects was needed in all cases. In the case of NF1, the postoperative period was practically just the follow up of complications and addressing them. This fact stresses the importance of meticulous preoperative planning and close follow up. Postoperative quality of life was better than preoperative in all the cases. The purpose of the surgical treatment is the decompression of the spinal cord, tumor removal and prophylaxis of CSF fistula by closing the dural defects. Over all, the surgical C2 root neurofibromas resection is a safe procedure and associated with good clinical outcomes.

Abbreviations

NF1: neurofibromatosis type 1;
WHO: World Health Organization;
VA: vertebral artery;
CSF: cerebral spinal fluid;
ACDF: anterior cervical decompression and fusion.

References

1. Abe J, Takami T, Naito K, Yamagata T, Arima H, Ohata K: Surgical management of solitary nerve sheath tumors of the cervical spine: a retrospective case analysis based on tumor location and extension. Neurol Med Chir (Tokyo) 54:924-929, 2014
2. Campian J, Gutmann DH: CNS tumors in neurofibromatosis. J Clin Oncol. 2017, 35:2378-85.10.1200/JCO.2016.71.7199
3. El-Sissy M.H., Mahmoud M., C2 root nerve sheath tumors management, Acta Neurochir. (Wien) 155 (5) (2013) 779-784.
4. El-Sissy MH, Mahmoud M: C2 root nerve sheath tumors management. Acta Neurochir (Wien) 155:779-784, 2013
5. Goel A., Muzumdar D., Nadkarni T., Desai K., Dange N., Chagla A., Retrospective analysis of peripheral nerve sheath tumors of the second cervical nerve root in 60 surgically treated patients, J. Neurosurg. Spine 8 (2) (2008) 129-134.
6. Goel Atul, Kaswa Amol, Shah Abhidha, Rai Survendra, Gore Sandeep, Dharurkar Pralhad. Extraspinal-Interdural Surgical Approach for C2 Neurinomas-Report of an Experience with 50 Cases. World Neurosurg. (2018) 110:575-582. http://dx.doi.org/10.1016/j.wneu.2017.08.191
7. Leonard JR, Ferner RE, Thomas N, Gutmann DH: Cervical cord compression from plexiform neurofibromas in neurofibromatosis 1. J Neurol Neurosurg Psychiatry 78:1404-1406, 2007
8. Maurya P., Singh K., Sharma V., C1 and C2 nerve sheath tumors: analysis of 32 cases, Neurol. India 57 (1) (2009) 31-35.
9. North K: Neurofibromatosis type 1. Am J Med Gene. 2000, 97:119-27. 10.1002/1096-8628(200022)97:23C119::AID-AJMG33E3.0.CO;2-3
10. Ruggieri M, Polizzi A, Spalice A, et al.: The natural history of spinal neurofibromatosis: a critical review of clinical and genetic features. Clin Genet. 2015, 87:401-10. 10.1111/cge.12498
11. Sadeh M, Farhat H (July 24, 2022) Severe High Cervical Cord Compression Due to Large Bilateral Neurofibromas in a Patient with Neurofibromatosis Type 1: A Case Report and Review of Literature. Cureus 14(7): e27211. DOI 10.7759/cureus.27211
12. Taleb FS, Guha A, Arnold PM, Fehlings MG, Massicotte EM: Surgical management of cervical spine manifestations of neurofibromatosis Type 1: long-term clinical and radiological follow-up in 22 cases. J Neurosurg Spine 14:356-366, 2011
13. Zuowei Wanga, Xingwen Wanga, Hao Wua, Zan Chena, Qingguo Yuanb,Fengzeng Jian, C2 dumbbell-shaped peripheral nerve sheath tumors: Surgicalmanagement and relationship with venous structures. Clinical Neurology and Neurosurgery, 151 (2016) 96-101.

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Microsurgical excision of intracranial arteriovenous malformation. An institutional study

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ABSTRACT

Objectives: Brain Arteriovenous malformations are high-flow cerebrovascular lesions with dysplastic vascular nidus, fed by arteries and drained by veins without intervening capillaries. Prevalence is 0.2% and is an important cause of intracerebral haemorrhage in about 38% of young adults. The objective of this study is to analyze surgically managed Intracranial AV malformations with respect to their demographic features, varied clinical presentations, imaging features Spetzler Martin grading and outcome.

Methods: A study of 48 patients with Intracranial Arteriovenous malformations who underwent microsurgical excision at the Institute of Neurosurgery, Madras Medical College and Rajiv Gandhi Government General Hospital, Chennai over a period of 5 years from July 2018 to June 2022 and extracted their data including demographic characteristics, clinical presentations, Spetzler-Martin (SM) grades, complications and outcome were assessed.

Results: Of the 48 patients treated with microsurgery, the most common 51% belongs to the age group between 21 to 40years, left-sided is slightly more common with headache major symptom, involving Parietooccipital lobe 33% commonly, 28 (62.2%) patients initially presented with haemorrhage.

Anterior circulation artery feeders was common 68.8% and mostly drainage involving superficial venous drainage system. Based on the Spetzler-Martin (SM) grading system, the patients were graded as follows: 6(13 %) Grade I, 10(21%) Grade II, 25(52%) Grade III, 3 (6%) Grade IV and 4(8%) Grade V. Overall, 35(73%) patients had a favorable outcome, most commonly seen in Grade I, II and Grade III. Almost complete obliteration of the AVMs were achieved in all favorable outcome cases.

Conclusion: Microsurgical excision is the gold standard treatment of choice for low grade AVMs and certain high-grade AVMs with increased risk of rupture. The Spetzler-Martin grading system is a simple and effective method to estimate the risk of surgery and to evaluate the prognosis. Proper patient selection combined with appropriate preoperative evaluation, meticulous surgical technique and postoperative care all lead to reduced mortality and morbidity.

Keywords
AVM,
Spetzler Martin,
microsurgery,
ARUBA,
haemorrhage

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INTRODUCTION

Brain Arteriovenous malformations (AVM) are high flow cerebrovascular lesions with dysplastic vascular nidus, fed by arteries and drained by veins without intervening capillaries. Prevalence is 0.2%, and is an important cause of intracerebral hemorrhage of about 38% in young adults between 20 and 40 years old (11). AVMs account for 1 to 2% of all causes of strokes, 3% of strokes in young adults, 9% SAH subarachnoid hemorrhages, and 4% of all primary intracerebral hemorrhages, but as much as one third in young adults (3). The Most common clinical presentations of AVMs are intracranial hemorrhage and seizures typically before the age of 40 years old. (4) Focal neurologic deficits occur in 1% to 40% of patients with intracranial AVMs, which can be transient, persistent or progressive. The natural history of AVM is poorly understood and its management is still controversial. Current treatment options include conservative management, surgical resection, stereotactic radiosurgery (SRS), endovascular embolization, or combinations of these treatments (multimodal therapy). Microsurgical resections remain the most effective and immediate treatment for AVMs. (15) The ARUBA, A Randomized trial of Unruptured Brain AVMs trial concluded that medical management alone is superior to medical management with interventional therapy for the prevention of death or stroke in patients with unruptured brain arteriovenous malformations followed up for 33 months. But in experienced hands, microsurgery proved to have better results, compared to other treatments which is not in line with the conclusion of ARUBA trial.

Objectives

The Objective of this study is to analyze surgically managed Intracranial AV malformations with respect to their demographic features, varied clinical presentations, imaging features and its management outcome.

Methods

A study of 48 patients with Intracranial Arteriovenous malformations underwent microsurgical excision at Institute of Neurosurgery, Madras Medical College and Rajiv Gandhi Government General Hospital, Chennai over a period of 6 years from July 2018 to June 2022

The data included demographic characteristics, clinical presentations, Spetzler-Martin (SM) grades, complications and Outcome was assessed. All the patients were followed for up minimum period 1 year for rebleed/ recurrence and new deficit. Exclusion criteria - arteriovenous fistulas, vein of Galen malformations, or spinal vascular malformations were excluded.

Results

Of the 48 patients treated with microsurgery, most common age group was between 21 to 40 years (48 %) as shown in chart 1, more commonly seen in Males 68% as shown in chart 2, left sided is slightly more common with headache major symptom as shown in chart 3 and 4, involving most commonly Parietal lobe 31% as shown in chart 5, 28 (62.5 %) patients initially presented with hemorrhage as shown in chart 6 and chart 7. Anterior circulation artery feeders were common 69 % and most involved superficial venous drainage system. Based on the Spetzler-Martin (SM) grading system, the patients were graded as follows: 6(13 %) Grade I, 10(33%) Grade II, 25(44%) Grade III, 3 (6%) Grade IV and 2(4%) Grade V as shown in chart 8. Overall, 37(77%) patients had a favorable outcome, most commonly seen in Grade I, II and Grade III. Out of 48 cases AVM 4 case was associated aneurysm (8.5%) in which 3 case flow related aneurysm. Almost complete obliteration of the AVMs was achievable in all favorable outcome cases. New postop deficit was seen in 8 patients (17.7%) and death in 4 patients (8%) as shown in chart 9.

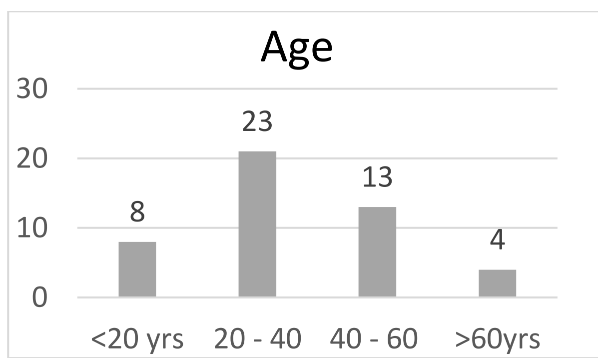
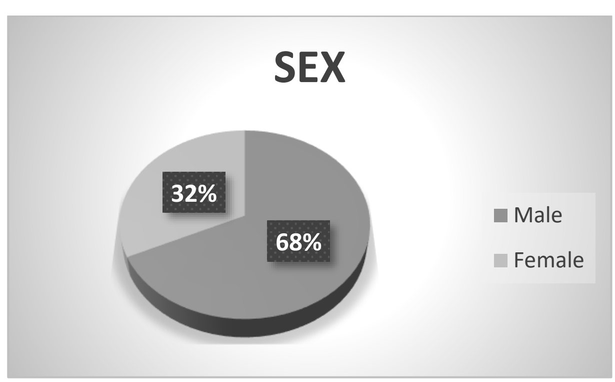


Chart 1: Age Wise Distribution. **Chart 2**: Sex Distribution



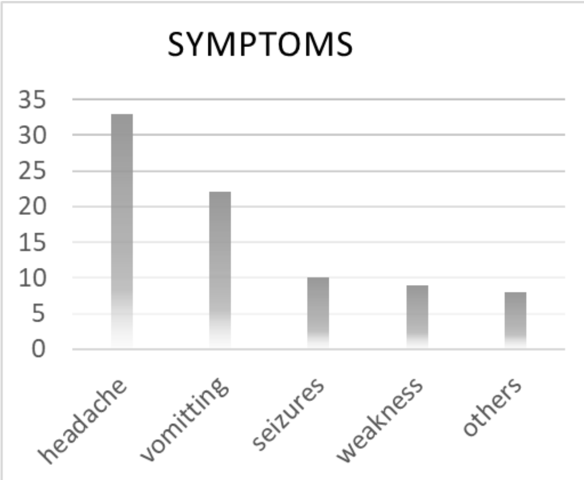


Chart 3: Symptom Wise Distribution. **Chart 4:** Side Involved.

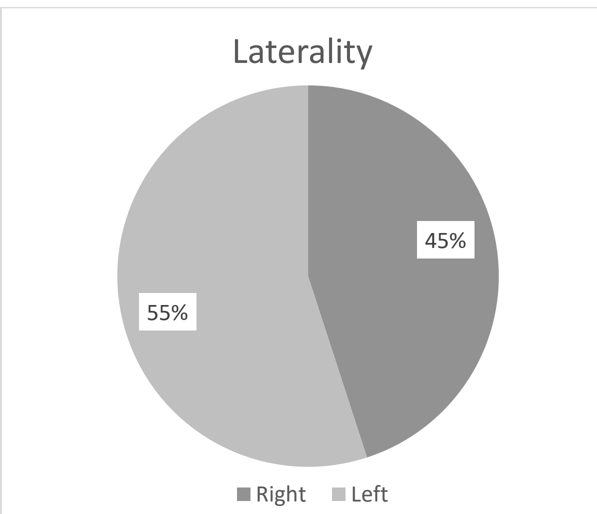


Chart 5: Location Wise Distribution

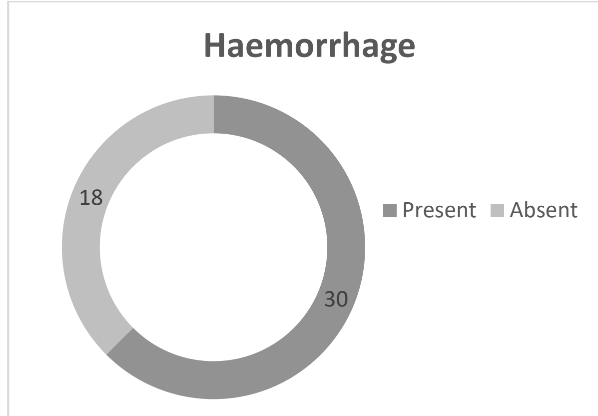


Chart 6: Incidence of Hemorrhage

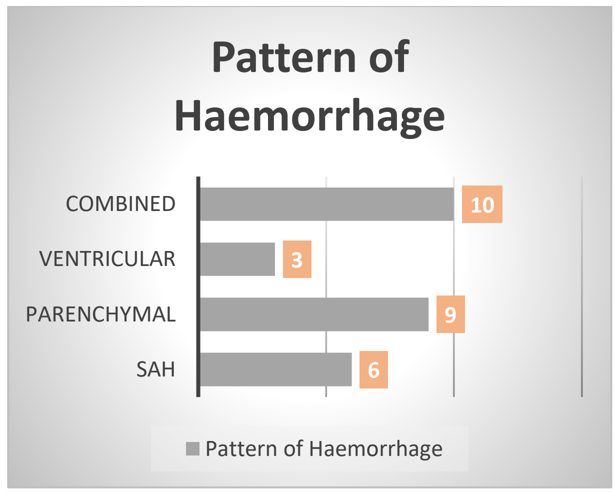


Chart 7: Hemorrhage Pattern

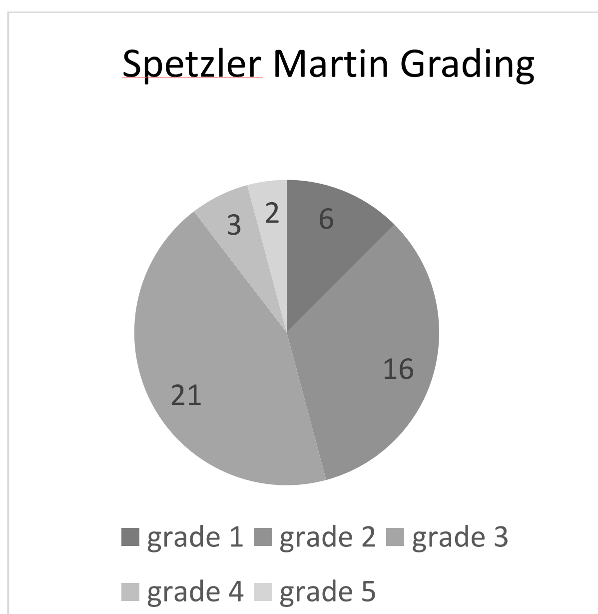


Chart 8: Spetzler Martin Grading

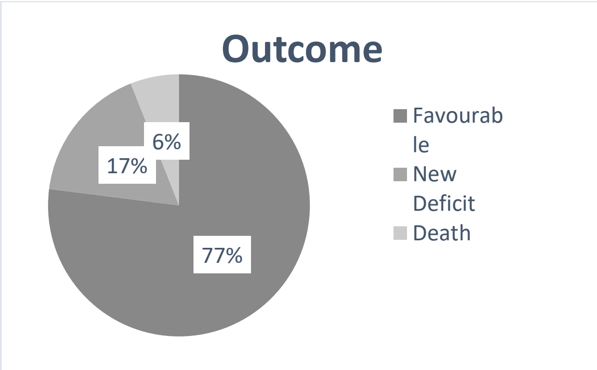


Chart 9: Outcome

Discussion

Incidence of AVM is 1 per 100000, In our study male sex is commonly affected which is similar to study conducted by Zhao et al in 2005(16). Most common age group was between 20 to 40 yrs which was consistent with other studies (9). The incidence of brain AVM presenting with intracranial hemorrhage is approximately 30% to 70% (4, 7, 8,) which was similar to our study. Combined hemorrhage followed by parenchymal bleed which is similar with other study (11). Based on our results headache is more common complaint. Approximately 6% to 14% of patients with AVMs present with chronic headache without hemorrhage. A number of series have evaluated the annual risk of hemorrhage varies from 2 to 4%. Theofanis et al study 264 patients underwent microsurgery and showed rates of permanent morbidity and mortality of 1.9% and 2.7% respectively. In our study comprising 48 patients treated with microsurgical resections in a large single center, and illustrated permanent postoperative morbidity of 17.7% and a mortality of 8%. It includes even minor complications like postop hydrocephalus or a small visual field defects as deficit. All deaths were seen in patients who presented as ruptured AVM with low Glasgow coma scale underwent emergency surgery.

A Randomized trial of Unruptured Brain Arteriovenous malformations (ARUBA) is a non-blinded, multicenter, randomized trial aimed to evaluate the risk of patients with an unruptured AVM treated with medical management alone compared with interventional therapy/ micro excision surgery (17). But the results of ARUBA have provoked many debates over concerns in study design, treatment modality offered, follow-up length, and study validity [18 - 21]. Of 223 patients with interim analysis when ARUBA was halted, 114 assigned for interventional therapy and 109 for medical management, only 5 patients were treated with standalone microsurgical excision. It's criticized that only few patients were treated surgically when 76 patients had an SM grade of 1 or 2.[18] In our study around 45% patients with SM Grade 1 or 2 received microsurgical resections and 80% had good outcome, 44% SM grade 3 underwent surgery with 70% favorable outcome.

In ARUBA Out of a total of 223 patients with a mean follow-up of 33.3 months, the primary endpoint of death from any cause or stroke occurred in 11 of 109 (10.1%) patients in the medical group compared with 35 of 114 (30.7%) in the interventional group. Almost more than threefold increased risk of stroke and death after the initiation of interventional therapy compared with medical management alone in patients with an unruptured brain arteriovenous malformation (12). In our study, the incidence of primary outcome events after microsurgical excision was favorable. Criticisms of the ARUBA study included short follow up period, lack of patient heterogeneity, lack of standardization of the treatment arm, suspected selection bias, lack of subgroup analysis, and inappropriately drawn conclusions (13). The data concerning the disparity in outcomes should affect standard specialist practice and the information presented to patients. The future AVM research and clinical trials that will continue to refine the neurosurgical treatment of this disease for the benefit of our patients.

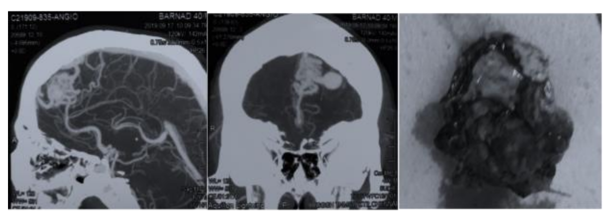


Figure 1: A case of grade 1 left frontal AVM with postop excision image.

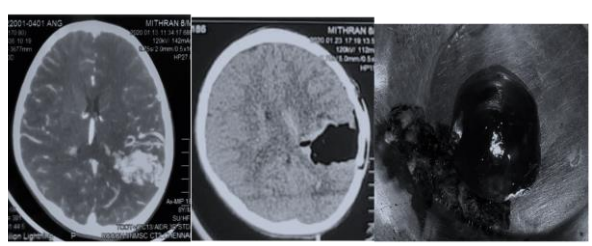


Figure 2: A case of grade 3 left parietal AVM preop and postop image.

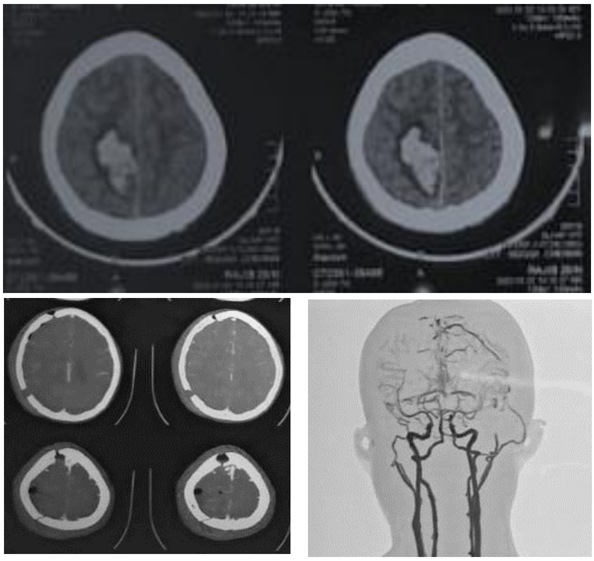


Figure 3: A case of grade 4 right frontoparietalAVM with post op complete excision image.

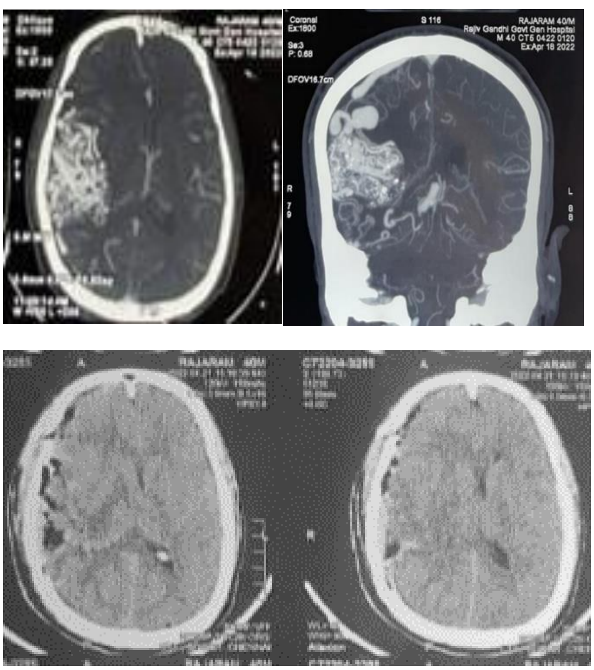


Figure 4: A case of grade 5 right frontotemporal AVM with post op complete excision image.

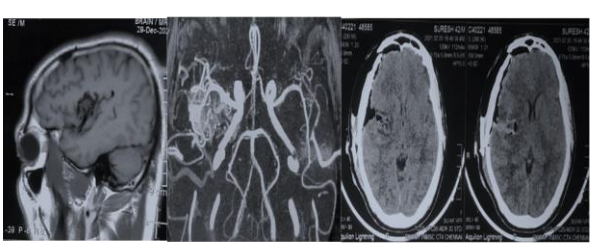


Figure 5: A case of grade 3 right insular AVM with post op complete excision image.

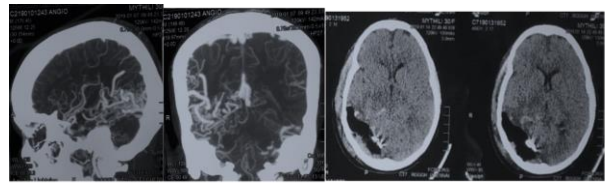


Figure 6: A case of grade 3 right occipital AVM with post op complete excision image.

Conclusion

Microsurgical excision is the gold standard treatment of choice for low grade AVMs and for high grade AVMs with progressive deficit, recurrent rupture. However, all the patients should be well informed about the available alternative mode of treatment and their associated risks. The Spetzler-Martin grading system is a simple and effective method to estimate the risk of surgery and to evaluate the prognosis. Proper patient selection combined with appropriate preoperative evaluation, meticulous surgical technique and postoperative care all lead to reduced mortality and morbidity.

Abbreviations

NF1: neurofibromatosis type 1;

WHO: World Health Organization;

VA: vertebral artery;

CSF: cerebral spinal fluid;

ACDF: anterior cervical decompression and fusion.

References

1. Ruiz-Sandoval JL, Cantu C, Barinagarrementeria F. Intracerebral hemorrhage in young people: analysis of risk factors, location, causes, and prognosis. Stroke; a journal of cerebral circulation. 1999;30(3):537–41.
2. Al-Shahi R, Bhattacharya JJ, Currie DG, Papanastassiou V, Ritchie V, Roberts RC, et al. Prospective, population-based detection of intracranial vascular malformations in adults: the Scottish Intracranial Vascular Malformation Study (SIVMS). Stroke; a journal of cerebral circulation. 2003;34(5):1163–9.
3. Al-Shahi R, Warlow C. A systematic review of the frequency and prognosis of arteriovenous malformations of the brain in adults. Brain: a journal of neurology. 2001;124(Pt 10):1900–26.
4. Da Costa L, Wallace MC, TerBrugge KG, O'Kelly C, Willinsky RA, Tymianski M. The natural history and predictive features of hemorrhage from brain arteriovenous malformations. Stroke; a journal of cerebral circulation. 2009;40(1):100–5.

5. Arteriovenous malformations of the brain in adults. The New England journal of medicine. 1999;340(23):1812–8. pmid:10362826.
6. Graf CJ, Perret GE, Torner JC. Bleeding from cerebral arteriovenous malformations as part of their natural history. Journal of neurosurgery. 1983;58(3):331–7. pmid:6827317
7. Gross BA, Du R. Natural history of cerebral arteriovenous malformations: a meta-analysis. Journal of neurosurgery. 2013;118(2):437–43. pmid:23198804
8. Stapf C, Mast H, Sciacca RR, Choi JH, Khaw AV, Connolly ES, et al. Predictors of hemorrhage in patients with untreated brain arteriovenous malformation. Neurology. 2006;66(9):1350–5. pmid:16682666
9. Fleetwood IG, Steinberg GK. Arteriovenous malformations. Lancet (London, England). 2002;359(9309):863–73.
10. Perret G, Nishioka H. Report on the cooperative study of intracranial aneurysms and subarachnoid hemorrhage. Section VI. Arteriovenous malformations. An analysis of 545 cases of cranio-cerebral arteriovenous malformations and fistulae reported to the cooperative study. Journal of neurosurgery. 1966;25(4):467–90. pmid:5925721.
11. Hofmeister C, Stapf C, Hartmann A, Sciacca RR, Mansmann U, terBrugge K, et al: Demographic, morphological, and clinical characteristics of 1289 patients with brain arteriovenous malformation. Stroke 31: 1307-1310, 2000.
12. Mohr JP Parides MK Stapf C et al.Medical management with or without interventional therapy for unruptured brain arteriovenous malformations (ARUBA): a multicentre, non-blinded, randomised trial. Lancet. 2014; 383: 614-621.
13. Chen W, Choi EJ, McDougall CM, Su H. Brain arteriovenous malformation modeling, pathogenesis, and novel therapeutic targets. Transl Stroke Res. 2014 Jun;5(3):316-29.
14. Moftakhar P, Hauptman JS, Malkasian D, Martin NA. Cerebral arteriovenous malformations. Part 2: physiology. Neurosurg Focus. 2009 May;26(5): E11.
15. Elhammady MS, Heros RC. Editorial: The ARUBA study: where do we go from here? J Neurosurg. 2017 Feb;126(2):481-485.
16. Zhao J, Wang S, Li J, Qi W, Sui D, Zhao Y. Clinical characteristics and surgical results of patients with cerebral arteriovenous malformations. Surgical neurology. 2005;63(2):156–61; discussion 61. 10.1016/j.surneu.2004.04.021.
17. Mohr JP, Parides MK, Stapf C, Moquete E, Moy CS, Overbey JR, et al. Medical management with or without interventional therapy for unruptured brain arteriovenous malformations (ARUBA): a multicentre, non-blinded, randomised trial. Lancet (London, England). 2014;383(9917):614–21.
18. Russin J, Spetzler R. Commentary: The ARUBA trial. Neurosurgery. 2014;75(1):E96–7. 10.1227/NEU.0000000000000357
19. Nerva JD, Mantovani A, Barber J, Kim LJ, Rockhill JK, Hallam DK, et al. Treatment outcomes of unruptured arteriovenous malformations with a subgroup analysis of ARUBA (A Randomized Trial of Unruptured Brain Arteriovenous Malformations)-eligible patients. Neurosurgery. 2015;76(5):563–70; discussion70; quiz 70.10.1227/NEU.0000000000000663
20. Starke RM, Sheehan JP, Ding D, Liu KC, Kondziolka D, Crowley RW, et al. Conservative management or intervention for unruptured brain arteriovenous malformations. World neurosurgery. 2014;82(5): e668–9. 10.1016/j.wneu.2014.07.001
21. Lawton MT, Abla AA. Management of brain arteriovenous malformations. Lancet (London, England). 2014;383(9929):1634–5.
22. Warlow C. Management of brain arteriovenous malformations. Lancet (London, England). 2014;383(9929):1632–3.
23. Gross BA, Scott RM, Smith ER. Management of brain arteriovenous malformations Lancet.
24. A case series of Occipital AVMs operated over duration of one year – An Institutional study in a single unit. Raghavendran R, NihalAhemad.
25. Posterior Circulation vascular lesions – An Institutional experience. Kesavan G, Balamurugan S, Raghavendran R.
26. Annals of the Tamilnadu Association of Neurological Surgeons, Inaugural issue TANS 2019– Institute of Neurosurgery, Madras Medical College, Chennai.
27. Al-Shahi Salman R. Management of brain arteriovenous malformations. Lancet (London, England). 2014;383(9929):1633–4.
28. Solomon RA, Connolly ES Jr.. Management of brain arteriovenous malformations Lancet (London, England). 2014;383(9929):1634.

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Comparative study of thoracolumbar fractures posterior fixations between long segment and short segment involving the fractured vertebra

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Abstract

Background. Thoracolumbar fractures are among the most common and unstable traumatic injuries to the spine. They require a rigid fixation. However, there are controversies in the choice of fixation types. This study aimed to compare long-segment posterior fixation (LSPF) bridging the injured vertebra and short-segment fixation with screws in the fractured vertebra (SSFFV).

Methods. This was an analytical study of 22 patients admitted to the Kinshasa University Teaching Hospital from 2020 to 2023 with thoraco-lumbar fractures. Variables of interest included: sex, age, occupation, cause of fracture, ASIA score, injured vertebra, Magerl fracture types, Sagittal Cobb angle (SCA), and level of fixation. Data were analysed using SPSS 26 software.

Results. Ten patients (45.4%) had SSFFV and 12 (54.6%) had LSPF. Overall, the sex ratio was 4.5 and, the mean age was 35.27±9.88 years. Road accidents accounted for 72.7% of causes, fracture of L1 (50%), ASIA A (41%) and Magerl B (54,5%). Pre-operative features did not show a difference between the two fixations. No difference was observed in function values before surgery (p=0.863) and at one year postoperatively (p=0.914). The mean SCA was 15.57 ± 5.90° before surgery, and 12.60±5.94° one year after surgery showing a significant correction of local kyphosis of 3° (P <0.001). There was no significant difference in the degrees of correction of local kyphosis immediately postoperatively (p=0.591) and at one year postoperative (p=0.819) and also in the degrees of loss of local kyphosis (p=0.870) between SSFFV and LSPF.

Conclusion. This study did not show a significant difference in functional recovery, reduction and loss of correction of traumatic kyphosis between the two fixations. The SSFFV therefore appears to be an effective alternative to LSPF.

Keywords
thoracolumbar fracture,
long-segment fixation,
short-segment fixation,
cobb's angle

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Introduction

Spinal fractures are among the most feared injuries by patients and doctors, and their consequences can be devastating, ranging from complete paralysis to death [1]. The thoracolumbar region is the transition from the rigid thoracic spine to the movable lumbar spine, and it is considered biomechanically to be the weakest part of the spine.

This characteristic makes it vulnerable to various high-energy injuries resulting from road accidents and falls [2]. Nearly 60-70% of all traumatic spinal injuries occur in this region [3,4]

Treatment of traumatic spinal cord injury can be conservative or surgical. In the majority of cases, surgical management may be warranted in unstable fractures, as is the case with the majority of thoracolumbar fractures, and those associated with neurological deficit [5]. Surgical approaches can be anterior, posterior, or a combination of anterior and posterior surgery. There is an abundant literature on different surgical techniques for reducing and stabilizing unstable fractures, but no consensus on the ideal treatment. Finally, the expertise and preference of the surgeon is an important factor.

The primary aims in surgical treatment are: the reduction of segmental kyphosis, the restoration of the stability of the spine and the decompression of the spinal canal, which allows an early mobilization of the patient [6]. In posterior spinal fixations, trans-pedicle screws are usually inserted above and below the fractured level to achieve reduction and control of segmental kyphosis. LSPF consists of attaching 2 levels above and 2 levels below the fractured vertebra. Short-segment posterior fixation (SSPF) fixes one level above and one level below the lesional focus. In the latter type of fixation, the screws can also be inserted into the injured vertebra if its pedicles are intact. This is the short-segment fixation involving the fractured vertebra (SSFFV). The number of fixation levels above and below the fracture is still controversial in the literature [2].

Although SSPF can achieve a satisfactory reduction, it often leads to instrumentation failure due to osteoporosis and loss of correction [7]. LSPF is an alternative solution, which can increase the rigidity of the construction and reduce the load on each screw by applying long segmental instrumentation. However, LSPF is unnecessarily extensive and decreases the number of motion segments. Saving the movement segments is an important principle of thoracolumbar spine surgery. In addition, this type of osteosynthesis is often associated with the development of adjacent segment degeneration disease [8–10]. As a result, the SSFFV appears to be an intermediate solution. It limits the number of merge segments and protects adjacent segments from degeneration. It improves the efficacy of SSPF compared to long-term control of kyphosis correction [3]. Many publications focused on comparing LSPF and SSPF, both of which bridge the fractured vertebra [1,5,11,12,13]. Few authors attempted to compare LSPF and SSFFV [14,15].

The purpose of this study is to determine if there is a difference in radiological and neurological outcomes between LSPF and SSFFV.

Methods

Study design and data collection process

This is a quasi-experimental study conducted at the Kinshasa University Teaching Hospital (KUTH) in the Democratic Republic of Congo (DRC) from 2020 to 2023. The intervention group is made up of SSFFV cases. The control group includes cases of LSPF or conventional long-segment fixation. The comparator is functional and radiological outcomes. Included in this study were all cases of unstable thoracolumbar junction fracture (T11-L2) with neurological deficit (ASIA A-D) operated in the Neurosurgery Department of the KUTH during the study period. There were 25 patients, of whom only 22 met our work criteria, 10 received SSFFV and 12 others received LSPF.

All cases of pathological thoracolumbar fractures (osteoporotic, tumor, etc.), fractures with both damaged pedicles and cases with a history of surgery at the thoracolumbar hinge were excluded. Variables of interest included : sex, age (year), dates of entry and discharge, occupation, residence, patient complaints, history, vital signs, cause of fracture, injured vertebra, Magerl fracture types, ASIA score, Sagittal Cobb angle (SCA), fixation level and complications. Data were collected prospectively. The diagnosis was made on the basis of radiological arguments. Patients were evaluated radiologically and clinically prior to surgery, immediately after surgery to assess the angle of correction of kyphosis, and at the end of the first postoperative year to assess loss of correction.

Surgical management

After induction of general anesthesia with endotracheal intubation, each patient was placed prone on a specialized surgical setting in which the upper half of the chest and iliac crests were supported by pads to create a spine hyperextension position and achieve postural reduction. All patients underwent posterior surgery. After incision and dissection of the soft tissues, the surgical procedure consisted of the placement of pedicle screws, followed by a decompression laminectomy, followed by a reduction in displacement and stabilization. For the short assembly with intermediate screws, the technique consisted of placing 6 screws, 2 of which were through the pedicles of the vertebra overlying the fractured vertebra, 2 in the pedicles of the injured vertebra and 2 last screws through the pedicles of the underlying vertebra. The choice of this possibility had to take into account the integrity of the pedicles of the traumatized vertebra and the thickness of the vertebral body.

Regarding osteosynthesis bridging the fractured vertebra, the long-segment set-up consisted of either 8 screws, 4 of which were screwed on 2 vertebrae above the fractured vertebra and 4 screws on 2 other vertebrae below it. The operation continued with the joining of different screws by means of 2 bars on either side of the spine. We used mono and poly-axial screws depending on the case.

Post-operative follow-up

It focused on two components : radiological and clinical. Radiographic evaluation included sagittal Cobb angle (SCA), degree of postoperative reduction, loss of correction at 1 year, and degree of definitive reduction at 1 year. The ACS was calculated from the intersection of two perpendicular lines, one to the plane of the upper plate of the overlying vertebra and the other to the plane of the lower plate of the underlying vertebra (Fig. 1) [16]. The degree of reduction was measured by the difference between the pre-operative and postoperative Cobb angle. And the loss of correction was measured by the difference between the postoperative Cobb angle and that calculated at one year postoperatively. The final degree of correction was the difference between the initial Cobb angle and the one measured at one year.

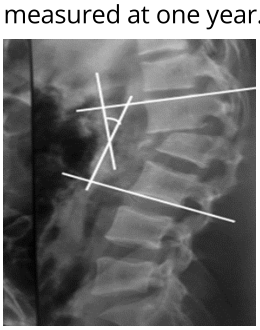

Figure 1. Sagittal Cobb angle : angle formed by the intersection of 2 perpendicular lines, one to the plane of the upper plate of the overlying vertebra and the other to the plane of the lower plate of the underlying vertebra.

Regarding clinical follow-up, daily medical visits were carried out to assess the ASIA score and compare it with the admission scores for the two groups of operated patients.

Statistical analysis of data

For the interpretation of the results, we used SPSS 26 software. The statistical tests performed were : percentage calculation, mean and standard deviation (χ, ±SD). The Pearson Chi-Square Test of Independence was used to compare neurological function using the ASIA score. The independent sample Student's t-test was performed to compare the Cobb angle of two groups of LSPF and SSFFV mounts. A difference was considered statistically significant for a P-value < 0.05.

Results

Pre-operative features of patients

We followed 22 patients with thoracolumbar spinal cord injury, 10 (45.4%) had SSFFV and 12 (54.6%) had LSPF. Overall, the sex ratio was 4.5 and the mean age was 35.27±9.88 years. Road accidents accounted for 72.7% of causes. These were often L1 fracture (50%), ASIA A score (41%) and Magerl B fracture (54.5%). Among the 10 SSFFV, 9 cases (90%) were male versus only one patient (10%) female, for a male/female sex ratio of 9. Patients aged 21 to 40 years accounted for 6 cases, or 60%. The mean age was 35.70±11.52 years. Road accidents were the leading cause of TVM with 8 cases (80%). All patients had a neurological deficit at admission : ASIA A score (40%), ASIA B (30%) and ASIA C (20%) and ASIA D (10). Six traumas (60%) involved the L1 vertebra. The fracture, Magerl type B, accounted for 60% of cases.

Of the 12 LSPF, 9 patients (75%) were male versus 3 (25%) female, i.e. a male/female sex ratio of 3. Eight traumatized patients aged of 21 and 40, 66.6 percent. The mean age was 34.92±8.79 years. Road accidents were the leading cause of TVM, with 8 cases (66.7%), followed by various falls in 4 cases (33.3%). Five patients (41.7%) had ASIA A score and 4 traumatized patients were ASIA B (33.3%). Five traumas (41.7%) had the L1 lesion and 4 (33.3%) had the T12 lesion. Magerl A and B fractures each accounted for 50% of cases. The mean Cobb angle at intake was 15.57±5.90° for the set, 14.89±4.64° for SSFFV, and 16.80±8.19° for LSPF. For all these preoperative features, the difference was not statistically significant between the two groups (Table 1).

Table 1. General data

Parameters	SSFFV N=10 (%)	LSPF N=12 (%)	Total 22 (%)	p-value
Age (years)				
▪ ≤ 20	1(10)	1(8,4)	2(9,1)	0,854
▪ 21 à 40	6(60)	8(66,6)	14(63,7)	
▪ 41 à 60	3(30)	3(25)	6(27,2)	
Mean Age	35,70±11,52	34,92±8,79	35,27±9,88	0,858
Sex				
▪ Male	9(90)	9(75)	18(81,8)	0,364
▪ Female	1(10)	3(25)	4(18,2)	
▪ Sex ratio	9	3	4,5	
Etiology				
▪ MVA	8(80)	8(66,6)	16(72,7)	0,529
▪ Fall	1(10)	4(33,4)	5(22,8)	
▪ Gunshot	1(10)	0(00)	1(4,5)	
ASIA				
▪ A	4(40)	5(41,7)	9(41)	0,863
▪ B	3(30)	4(33,3)	7(31,8)	
▪ C	2(20)	1(8,4)	3(13,6)	
▪ D	1(10)	2(16,6)	3(13,6)	
Injuried Vertebra				
▪ T 11	0(00)	2(16,6)	2(9,1)	0,558
▪ T 12	3(30)	4(33,3)	7(31,8)	
▪ L1	6(60)	5(41,7)	11(50)	
▪ L2	1(10)	1(8,4)	2(9,1)	
Magerl fracture				
▪ A	3(30)	5(41,7)	8(31,8)	0,688
▪ B	6(60)	5(41,7)	11(54,5)	
▪ C	1(10)	2(16,6)	3(13,7)	
SCA				
▪ Mean (°)	14,89±4,64	16,80±8,19	15,57±5,90	0,583

Table 2. Neurological Outcomes

ASIA	SSFFV						LSPF						p-value+	p-value*
	Pre-operative	After 1 year					Pre-operative	After 1 year						
		A	B	C	D	E		A	B	C	D	E	Pre-op	Post-op
A	4	4	0	0	0	0	5	3	2	0	0	0	0,863	0,914
B	3	0	2	1	0	0	4	0	2	1	1	0		
C	2	0	0	0	2	0	1	0	0	0	1	0		
D	1	0	0	0	0	1	2	0	0	0	0	2		
Total	10	4	2	1	2	1	12	3	4	1	2	2		

p-value +: pre-operative ASIA comparison between the two fixations
p-value*: ASIA comparison at one year postoperatively between the two groups.

Table 3. Neurological

SCA		Fixation	Mean (°)	DS (°)	N	p-value*
A	: Pre-operative	SSFFV	14,89	4,64	10	0,583
		LSPF	16,80	8,19	12	

Total		15,57	5,90	22	
B : Immediate pre-operative	SSFFV	8,50	0,70	10	0,618
	LSPF	11,67	7,63	12	
Total		10,40	5,68	22	
C : After 1 Year post-surgery	SSFFV	10,50	0,70	10	0,596
	LSPF	14,00	7,93	12	
Total		12,60	5,94	22	
Post-surgery correction	SSFFV	6,39	3,94	10	0,591
(A – B)	LSPF	5,11	0,56	12	
Total		5,07	0,22	22	
Post-surgery correction loss	SSFFV	2	0,00	10	0,870
(C - B)	LSPF	2,33	0,30	12	
Total		2,26	0,31	22	
Final Correction after 1 Year	SSFFV	4,39	3,94	10	0,819
(A- C)	LSPF	2,8	0,26	12	
Total		2,97	-	22	

N : number
* : Student's t-test for independent samples

Neurological Outcomes

No patients with ASIA A among the SSFFV improved their admission score. Of the 5 LSPF patients with ASIA A, 3 kept the same grade and 2 switched to ASIA B. One out of three patients with ASIA B on admission to the SSFFV group progressed to ASIA C. Similarly, two out of the 4 patients in the LSPF group with ASIA B at the start of hospitalization improved their neurological status, of which 1 went up to ASIA C and 1 to ASIA D. The two traumatized individuals in the SSFFV group with ASIA C at entry were transferred to ASIA D at admission. Similarly, the single ASIA C patient from LSPF was upgraded to ASIA D at the last assessment. The single ASIA D patient from SSFFV and the two ASIA D trauma patients from LSPF all achieved grade E after one year. There were no significant differences in function values before surgery (p=0.863) and at one year postoperatively (p=0.914) between the two groups (Table 2).

Radiological results

For all 22 patients, the mean SCA was 15.57 ± 5.90° before surgery, 12.60±5.94° at one year after surgery showing a significant correction of local kyphosis of 3° (P <0.001). For SSFFV, the mean SCA was 14.89±4.64° before surgery, 10.50±0.70° at one year after surgery with a significant correction of local kyphosis of 4.39 ±3.94 (P=0.049). The mean SCA of LSPF was 16.80±8.19° before surgery, 14.00±7.93° at one year postsurgery with a significant correction of local kyphosis of 2.8 ±0.26 (P=0.017). However, there was no significant difference in the degrees of mean pre-operative SCA (p=0.583), immediate postoperative mean SCA (p=0.618), mean SCA at one year postoperative (p=0.596), correction of local kyphosis in immediate postoperative (p=0.591), one year after surgery (p=0.819) and the degree of loss of this correction (p=0.870) between the two types of fixation (Table 3). Figures 1, 2 and 3 illustrate the evolution of SCA over different time points pre-operative, immediate post-operative, and at one year post-operative for SSFFV.

Fig. 1 : SCA before Surgery **Fig. 2** : SCA Immediate post-surgery **Fig. 3** : SCA 1 year after surgery

Discussion

Pre-operative data

Thoracolumbar fractures are among the most common traumatic injuries to the spine [17]. They frequently affect young male people. They are often caused by violent trauma such as road accidents and falls from very high places [5, 10, 18, 19]. Half of these lesions are unstable [20] and are much more relevant to the L1 [3,6,11,15,18,21]. Burst-type fractures (A3 according AO or to Type B of Denis classification) account for 21% to 58% of all fractures of the thoracolumbar spine [22] and approximately 70% of these fractures occur without immediate neurological injury and, ultimately, 55% remain neurologically intact. Neurological deficit is often incomplete [23]. Previous studies, which compared SSFFV and LSPF, noted that there was no difference in the socio-demographic and pre-operative characteristics of patients [3,11,22].

In our series, socio-demographic and pre-operative characteristics also did not show a significant difference between the two fixations. The sex ratio was 4.5, the mean age 35.27±9.88 years. Road accidents accounted for 72.7%, L1 fracture (50%) followed by T12 (31.8%), ASIA A (41%) and Magerl B (54.5%). Young male people engage in high-risk activities, exposing them to spinal trauma in order to provide for their families, which would justify their predominance. The high frequency of L1 and T12 lesions may highlight the vulnerability of these two hinge vertebrae between the thoracic rigid segment and the movable lumbar portion compared to other vertebrae [23]. The preponderance of Magerl B and ASIA A lesions in this study could be explained by the velocity of the traumatic agent. The majority of our injuries were caused by road accidents.

Neurological outcomes

At the end of one year, there was a significant improvement in neurological function from admission within each group and for all patients in general (p<0.001). No significant differences were observed between the two fixations in function values before surgery (p=0.863) and at one year postoperatively (p=0.914). These results confirm the data in the literature. Apart from ASIA A fractures, the other ASIA types evolve favorably after surgical fixation () in the following order: C>B>D>A [24]. After a rigid correction, many researchers point out that the majority of surgical patients improve their neurological function after a year or more [18]. However, many series claim that the two types of fixation are equivalent in terms of functional recovery [18,19,22].

Radiological outcomes

The primary objectives in the surgical treatment of thoracolumbar fractures, as mentioned above, are: correction or reduction of segmental kyphosis, restoration of spine stability, preservation of mobile segments of the spine, decompression of the spinal canal, which allows early postoperative mobilization of the patient [6, 11, 22].

According to the literature, the closer one is to the fracture site, the easier and better the reduction. Short-segment fixation with or without screws in the fractured vertebra satisfies this requirement and is recognized by some authors as the most suitable instrumentation to better correct local kyphosis while at the same time reducing the number of levels of immobilization [25]. However, other studies show that the difference between short screw fixation in the fractured vertebra and long-segment fixation bridging the fracture focus is not significant [2]. Short fixation has been criticized for not maintaining this correction of segmental kyphosis for a long time compared to long fixation [6]. However, much more recent work has not found a significant difference between the two surgical techniques in terms of loss of correction of local kyphosis after a fairly long setback time. Long-segment fixation is recognized as the most stable setup resulting in less loss of correction of segmental kyphosis due to multiple levels of fixation [6,11,22]. However, this extensive immobilization is often blamed by some authors as the source of subsequent pain and adjacent degeneration segment (ADS), especially in people over 50 years of age, which exposes patients to other surgical procedures [6,22].

However, recent studies have not found a significant difference between the two fixations in terms of stability and correction of segmental kyphosis from the angle of the ACS [13,15,22]. In our series, no significant differences were recorded between the two bindings in terms of correction or loss of correction after one year. The SSFFV achieved a final correction for local kyphosis of 4.39 ±3.94° and LSPF of 2.8 ±0.26° (p=0.583). The SSFFV lost the correction of segmental kyphosis by 2° and the LSPF by 2.33±0.30° (p=0.870). The majority of the literature did not note a final correction or loss of segmental kyphosis greater than 10° [18] and the surgical procedure resulted in a significant correction of the angle [3,15]. In our study, the final reduction at one year was less than 3°, and the final correction of segmental kyphosis was significant for all patients (P <0.001).

Conclusion

This case series did not show a significant difference in functional recovery, reduction and loss of correction of traumatic kyphosis between the two posterior fixations of thoracolumbar fractures. The SSFFV therefore appears to be an effective alternative to LSPF. It satisfactorily reduces traumatic kyphosis and the loss of correction is similar to that of LSPF after one year. This technique may be recommended for older people who have difficulty withstanding long procedures and heavy instrumentation. With the aging of the world's population as described by the WHO, we believe that SSFFV would become a technique of the future. It is also an osteosynthesis suitable for low-income countries that do not have a lot of equipment (screws, bars, plates). But many randomized studies with larger sample sizes are needed to confirm all these hypotheses.

Limits

The monocentric nature and small sample size of this study do not allow the results to be generalized. Some important elements were not calculated : the anterior height of the fractured vertebral body, the vertebral body index, and the spinal canal impingement. But this work has allowed us to get an idea of the neurological and radiological outcomes of these two types of fixation in our environment.

References

1. Filho CAA, Simões FC, PrAdo GO. Thoracolumbar burst fractures, short x long fixation: A metaanalysis. Coluna/Columna. 2016 ;15(1) :78-84
2. Panteliadis P, Musbahi O, Muthian S, Goyal S, Montgomery AS, Ranganathan A. A comparison of three different methods of fixation in the management of thoraco-lumbar fractures. Int J Spine Surg. 2018 ;12(1) :1-7.
3. Xiong C, Huang B, Wei T, Kang H, Feng Xu F. Effect of the short-segment internal fixation with intermediate inclined-angle polyaxial screw at the fractured vertebra on the treatment of Denis type B thoracolumbar fracture. J Orthop Surg Res. 2020 ; 15 : 182.
4. Huang L, Xiong C, Guo Z, Yu Q, Xu F, Kang H. Comparison of monoplanar and polyaxial screw fixation systems in percutaneous intermediate fxation for thoracolumbar fractures. BMC Musculoskeletal Disorders. 2022 ; 23 :172.
5. Rath N, Balain B. Spinal cord injury-The role of surgical treatment for neurological improvement. J Clin Orthop Trauma. 2017;8(2):99-102.
6. Zoccali C, Rossi B, Walter CM, Baaj AA. Short-Segment Versus Long-Segment Stabilization in Thoracolumbar Burst Fracture : A Review of the Literature. J Orthop Spine Trauma. 2017 ; 3(2) : e65649.
7. McLain RF, Sparling E, Benson DR. Early failure of short-segment pedicle instrumentation for thoracolumbar fractures. A preliminary report. J Bone Joint Surg Am. 1993;75(2):162-7.
8. Nagata HSM, Transfeldt EE, Lewis JL. The effects of immobilization of long segments of the spine on the adjacent and distal facet force and lumbosacral motion. Spine (Phila Pa 1976). 1993 ;18(16) :2471–2479.
9. Dekutoski MBSM, Ogilvie JW, Olsewski JM, Wallace LJ, Lewis JL. Comparison of in vivo and in vitro adjacent segment motion after lumbar fusion. Spine (Phila Pa 1976). 1994 ;19(15) :1745–1751.
10. Park PGH, Gala VC, Hoff JT, McGillicuddy JE. Adjacent segment disease after lumbar or lumbosacral fusion : review of the literature. Spine (Phila Pa 1976). 2004 ;29(17) :1938–1944.
11. Tezeren G, Kuru I. Posterior Fixation of Thoracolumbar Burst Fracture Short-Segment Pedicle Fixation Versus Long-Segment Instrumentation. J Spinal Disord Tech. 2005 ;18 :485–488.
12. Waqar M, Van-Popta D, Barone DG, Bhojak M, Pillay R, Sarsam Z. Short versus long-segment posterior fixation in the treatment of thoraco-lumbar junction fractures : a comparison of outcomes. Br J Neurosurg. 2017;31(1):54–57.
13. Biakto KT, Putra LT. Comparison between short dagment screw fixation and long segment pedicle screw fixation for treatment of neglected single level thoraco-lumbar burst fracture. International Journal of Surgery Open. 2020 ; 26 :145-149.
14. Sun C, Guan G, Liu X, Zhang H, Wang B. Comparison of short-segment pedicle fixation with versus without inclusion of fracture level in the treatment of mild thoracolumbar burst fractures. Int J Surg. 2016 ; 36 :352-357.
15. Cetin E, Oner A. Comparison of short segment pedicle screw fixationincluding the fracuredvertebra vesus long segment fixation in thoraco-lumbar fractures. J Acad Res Med. 2020 ; 10(1) :32-5.
16. Keynan O, Fisher CG, Vaccaro A, Fehlings MG, Oner FC, Dietz, et al. Radiographic Measurement Parameters in Thoracolumbar Fractures : A Systematic Review and Consensus Statement of the Spine Trauma Study Group. Spine (Phila Pa 1976). 2006 ;31(5):E156-65.
17. Li K, Li Z, Ren X, Xu H, Zhang W, Luo D, et al. Effect of the percutaneous pedicle screw fixation at the fractured vertebra on the treatment of thoracolumbar fractures. Int Orthop. 2016 ;40(6):1103-10.
18. Lee YS, Sung JK, Long-term Follow-up Results of Short-segment Posterior Screw Fixation for Thoracolumbar Burst Fractures. J Korean Neurosurg Soc. 2005;37:416-421.
19. Aoui M, Sahnoun N, Abid M, Maatoug M, Hsairi M, Hentati Y, et al. Posterior short segment pedicle screw fixation for

the treatment of thoracolumbar fracture. Pan African Medical Journal. 2020;35:102.
20. Santiago FR, Muñoz PT, Sánchez EM, Paniza MR, Martínez AM, Abela ALP. Classifying thoracolumbar fractures: role of quantitative imaging. Quant Imaging Med Surgery. 2016;6(6) :272-284.
21. Choudhury AM, Alam MS, Jonayed S, Dastagir O, Jahan MS. Long-Segment Versus Short-Segment Pedicle Screw Fixation Including Fractured Vertebrae for the Management of Unstable Thoracolumbar Burst Fractures. Cureus. 2023;15(2):e35235.
22. Aly TA. Short Segment versus Long Segment Pedicle Screws Fixation in Management of Thoracolumbar Burst Fractures: Meta-Analysis. Asian Spine J. 2017 Feb;11(1):150-160.
23. Fernández-de Thomas RJ, De Jesus O. Thoracolumbar Spine Fracture. [Updated 2023 Aug 14]. In: StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing; 2023 Jan-. Available from: https://www.ncbi.nlm.nih.gov/books/NBK562204/.
24. Khorasanizadeh M, Yousefefard M, Eskian M, Lu Y, Chalangari M, Harrop JS, et al. Neurological recovery following traumatic spinal cord injury : a systematic review and meta-analysis. J Neurosurg Spine. 2019;15:1-17.
25. Tian JW, Wang L, Xian T, Liu C, Zhao Q, Dong S. Posteriorshort-segmentalfixation combined with intermediate screws vs conventional intersegmental fixationfor monosegmental thoracolumbar fractures. Orthopedics. 2011;34(8):389–396.

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Evaluation of vertebral artery variations and arterial dominance in cervical CT angiographic images in Iranian population

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ABSTRACT

Purpose: The aim of the present study was to determine the characteristics and variations in the origin of vertebral arteries (VA), its level of entry into the transverse foramen, VA diameter, Length of VA, and VA dominance.

Methods: A total of 250 adult patients (143 males and 107 females) were enrolled (Mean age: 60.92±13.44) and scanned with Computerized Tomography angiography (CTA).

Results: The VA entered the C6 transverse foramen in 97.8% of specimens. Abnormal entrance of VA was observed in 4.4% of specimens. The mean length of prevertebral (V1) right and left VA was 81.38±14.38 mm and 82.49±14.16 mm. The mean length of the intraforaminal segment (V2) of the right and left VA was 81.38±14.375mm and 82.49±14.162mm and showed sexual dimorphism. The mean diameter of the right and left VA was 3.297±0.85 and 3.676±0.88, respectively. We found 1(0.4%) left and 1(0.4%) right VA emerging from the aortic arch. The mean right and left VA diameters were 3.28 ± 0.83 mm and 3.6±0.88mm, respectively. A total of 90(0.36) patients were right dominant and 160(0.64) patients were left-dominant. The right VA of aortic arch origin entered the 4th cervical transverse foramina, whereas the left VA entered the 7th cervical transverse foramina. We found that 22(8.8%) of the right and 1 (0.4%) of the left vertebral arteries had distal origin. The results did not show any relationship between gender and origin of VA, diameter of VA, and level of entry. A significant relationship was observed between gender and VA length (P=0.0001).

Discussion: The present study confirms the presence of anomalous in the VA route. Knowledge of such anatomical variations is important in interpreting CTA and may reduce the risk of intraoperative VA injury.

INTRODUCTION

Because of nervous tissue demands, the blood supply of the central nervous system is of special interest. The brain, one of the most metabolically active organs, is reliant on glucose's aerobic metabolism.

The brain, which accounts for only 2% of body weight, receives 17% of the cardiac output and utilizes 20% of the body's oxygen supply (1). The cessation of cerebral circulation can cause unconsciousness in about 10 seconds. The possibility of vascular origin lesions causing neurological disorders is stronger than any other kind of disease (1). The role of VAs in brain’s blood supply is well known. VA injury is rare but any change in VA haemodynamics may cause permanent neurologic deficit, important disorders in cerebellum, brain stem, inner ear and spinal cord (2-5) The VA is a branch of the subclavian artery. It ascends toward the transverse foramen of C6 vertebrae (V1) and then passes vertically through the transverse foramina of C6 to C2 (V2). After leaving the transverse foramen of C2, it runs over the axis and atlas (V3) and enters the cranial cavity (V4). Eventually, the right and left VAs join to form the basilar artery (6, 7).

VA typically originates (50.6–99.9%) from the supero-posterior aspect of the 1st part of the subclavian artery, 0.5–2 cm medial to the thyrocervical trunk origin (6, 8). The right VA (RVA) may be found displaced more than 2 cm medial to the right thyrocervical trunk (RTCT) in 1.4% (17 out of 1228 cases), while the left VA (LVA) may originate from the left thyrocervical trunk (LTCT) in 0.58 % (6, 8). Several congenital anomalies regarding VA have been described (9). Variations of the VA origin usually occur on the left side. The commonest reported atypical VA origin is from the aortic arch with an incidence rate of 5.5%(10-12). Other VA origins include the common carotid artery (CCA), the carotid bulb, external carotid artery (ECA), internal carotid artery (ICA), occipital artery, thyrocervical and costocervical trunk, inferior thyroid artery and the ascending aorta. VAs may also have a dual origin (13-17). The level of entry into the transverse foramen of the left vertebral artery of aortic arch origin was frequently higher than the sixth cervical vertebra (8, 17, 18).

The prevertebral part of the vertebral artery of aortic arch origin was less protected by bone and thus may be accidentally lacerated during surgery. On the other hand, the endovascular approach for supra-aortic lesions has been successful and is now a widely accepted alternative to surgery. Particularly during stenting of subclavian arteries and aortic arch, it might be important to know the dominant VA in decision of which one of the vertebral or subclavian arteries could be sacrificed in case of proximity to the lesion (19).

The advent of multidetector CT has allowed less invasive acquisition of CT angiography from the aortic arch to the intracranial regions with excellent three-dimensional (3D) spatial resolution.

The aim of present study was to determine the characteristics and variations in the origin of vertebral arteries (VA), its level of entry into transverse foramen, VA diameter, Length of VA, and VA dominance.

MATERIALS AND METHODS

This protocol was approved by the AJUMS Ethics Committee in Human Research (IR.AJUMS.HGOLESTAN.REC.1400.171) and has therefore been performed in accordance with the ethical standards laid down in the 1964 Declaration of Helsinki. Because the retrospective nature of the study, the informed consent form was waived.

CT angiograms of 250 consecutive patients, who underwent CT angiography for reasons other than evaluation of vertebral artery disease between September 2021 and September 2022, were retrospectively reviewed. There were 143 men (52.7%) and 107 women (47.3%). The mean age of patients was 60.92±13.44 years (range from 12 to 89). The cervical spine CTs were ordered by neurosurgeons and neurologists for the evaluation of carotid artery stenosis, source of subarachnoid bleeding, or for the workup in multiple trauma patients. Patients who met the following criteria were excluded: Subjects with bony abnormalities, such as Klippel-Feil syndrome and ankylosing spondylitis, previous history of cervical spine surgery, patients with rheumatic involvement of the cervical spine, and those with VA aplasia.

All patients were scanned on a commercially available CT scanner (Siemens SOMATOM Sensation, Erlangen, München) equipped with a 64-slice multidetector array. The standard protocol consisted of a timed contrast injection, with images obtained from the aortic arch to the clinoid process.

To identify the level of entrance of the VA into the transverse foramen, both the axial cuts and the three-dimensional reconstructions were then reviewed by an attending board certified neuroradiologist.

The right and left subclavian arteries were identified and traced to their origins and entrances into the foramen transverse. The lengths of the prevertebral (V1) and intraforaminal segment (V2) of the vertebral arteries were measured. The outer diameters of the prevertebral parts of the vertebral arteries were then measured at their mid-lengths.

RESULTS

Table 1 exhibits the detected variations in length, origin, and level of entry of VA. The left VA of 248 (99.2%) and right VA of 227 (90.8%) subjects normally originated from the subclavian arteries. The left VAs of aortic arch origin were in 1(0.4%) of cases, and 1 (0.4%) case from distal part of subclavian artery. The RVAs with aortic arch origin were not detected, and 22(8.8%) patients from distal part of subclavian artery (SA) (Table1).

The length of V1 and V2 segments was more in men than in women and showed a significant difference (P-value < 0.05). However, there was no sexual dimorphism in the right and left diameter of VA (Table 2).

The results did not show dual origin of the LVAs arising from the aortic arch and the left subclavian artery, also did not encounter any cases of the RVAs arising from another vessel. Only two male cases, 1(0.7%) patient with LVA and 1(0.7%) patient with RVA originate from aortic arch was detected.

Most of the LVA entered the transverse foramina of the sixth (98.8%), and only 1.2% entered fifth cervical vertebrae. The level of entry of RVA was 96.8% sixth, 2.4% fifth and only 0.4% (1 patient) fourth cervical vertebrae. The LVA with direct aortic origin proximal to the LSA entered the transverse foramen of the sixth vertebra.

The average length of the prevertebral part of the right and left VA was 81.38±14.38 and 82.49±14.16 mm, respectively. The length of the prevertebral part of the LVA of aortic arch origin was 88 mm.

The average outer diameters of the prevertebral part of the left and right VA were 3.676±0.88 and 3.297±0.85, respectively. No significant difference was observed between male and female groups. The outer diameters of the prevertebral part of the LVA of aortic arch origin measured at mid-length was 2.7 cm. The mean width of the corresponding parts of the LVA of aortic arch origin compared with of subclavian origin were not statistically different.

Fisher's exact test was used to compare VA dominance between both gender. No significant difference was observed between men and women (Table 3). Among 250 patients, right side was found wider in 90(36%) patients and left side was found wider in 160 (64%) patients (Table 3). There was no statistically significant relation between gender and VA dominance.

DISCUSSION

The aortic arch and its branches develop in the early weeks of fetal life (20). The primitive third arch forms the bilateral carotid arteries; the right fourth arch forms the brachiocephalic trunk and RSA; and the left fourth arch forms the aortic arch and LSA and joins the descending aorta. The primitive third arch forms the bilateral carotid arteries; the right fourth arch forms the brachiocephalic trunk and RSA; and the left fourth arch forms the aortic arch and LSA and joins the descending aorta. Bilateral VAs are formed by anastomoses of neural axes between each upper segmental artery. Normally, only the seventh segmental artery, which arises from the SA, persists. Persistence or obliteration of these arches may lead to anatomical variations.

Vertebral arteries in the brain's blood supply has an essential place as being the second largest blood supplier. In case of failure of the carotid artery system with occlusive diseases, VA compensate the circulation by collateral pathways (21).

The entrance and origin of the VA is essential to neck tumor resection as vascular damage may occur when VA goes through the abnormal region. Additionally, the entrance of the VA is of significance to the stellate ganglion block, where the VA is vulnerable to be located in the needle path (22).

The incidence of vertebral artery injury during anterior cervical medical procedures ranges from 0.22% to 2.77% (23-25). The VA is protected by the transverse process in the V2 segment, and iatrogenic injury to the VA is low(26-28). However, if the VA is outside the bony structure, the risk of injury is greater such as at the C7 level in normal patients and in the presence of anomalous VA (27, 29). Therefore, a complete preoperative understanding of the patient's anatomy is crucial to prevent arterial injury and its complications. Various types of VA variation have been reported in the literature, including fenestration, anomalous artery entry, and tortuous course of the VA in V2 segment with foraminal erosions (29, 30).

The VA may enter the transverse foramen at other levels than C6 (29). In the literature, the incidence of normal entrance ranges from 90% to 93% (22, 23). The prevalence of VA entry at C4 ranges from 0.5% to 1.3%, at C5 ranges from 5% to 6.6%, and at C7 ranges from 0.8% to 5.4% (22, 29, 31). The results from this research are consistent with the previous studies (31). Abnormal level of entrance was observed in 4.4% of subjects (10 VA course), with the level of entrance into the right C4 (0.4%), right C5 (2.4%), right C7 (0.4%), and left C5 (1.2%) transverse foramen. Previous studies show that there were some differences in the rate of variation of VA (22). The variability of anomalous entry level of VA is reported in different population(12, 17, 31-36), which could be explained by sample sizes and structure differences. The findings of this study fills in the gap in Korean population and sheds lights on further related research with a reliable foundation.

Studies shows the frequency of origin of the left VA from aortic arch in the range of about 1–3%(37). The results of present research indicated that the overall variability of origin of VA was 0.4%. In addition, this study found that the origin variation of VA all occurred on the left side, which is consistent with Yi et al.(22) report.

In this inquiry, VA diameter differences in right and left side had been evaluated and dominant side was explained. There are different criteria for the diagnosis of the dominant VA in literature. In a study by Zwiebel et al.(38), they found that left VA is wider than right VA in 73% of a healthy population and reported this as left VA dominance. Turan-Ozdemir et al. (39), reported similar results of left VA dominance in 64% (55/85 patients) with colour Doppler ultrasound. In contrast to earlier findings, there are also studies reporting no differences in diameter of VA, or indicating RVA is wider than LVA (40). In the present study, the right side was found wider in 36% of the patients and the left side was found wider in 64% of the subjects. In a study by Hong et al. (41), they explained the dominant VA with criterion of side to side diameter difference ≥ 0.3 mm in CTA, and found left VA was dominant with a rate of 69.2% (63/91). Songur et al. (42) measured the widths of the VA in a large series of an anatomic study with 109 cadavers, and difference of 1 mm or greater between the widths of VA was accepted as the dominancy criterion. They observed left dominancy in 21.2% and right dominancy in 17.3%. This study couldn't find the gold standard criterion statistically with just only diameter. In the study ahead, using this criterion (1mm), RVA was dominant in 35.7%% of the patients and left VA was dominant in 64.3% of the patients. It seems that diameter could give an idea in assessment of the dominance but it must be also supported by velocities and blood flow volume.

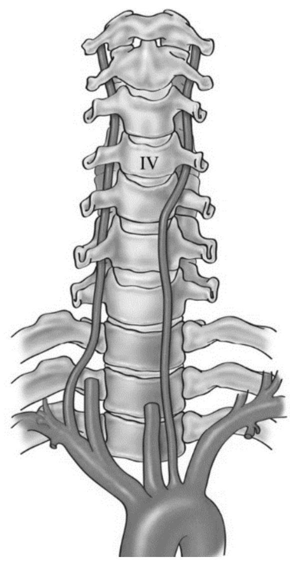

Figure 1. Schematic drawing of the VA anomaly. This picture depicts the aortic arch origin of LVA, its entrance into the transverse foramen of C4, and the entrance of the RVA into the transverse foramen of C6. With courtesy to Edwards et al (10).

Direct aortic origin of the left and right VA between the left common carotid artery and left subclavian artery was found 1.4% of cases. In a similar study by Uchino et al.(17), right VA originating from aberrant right subclavian artery prevalence was 0.4%. The findings of the current study do not support the previous research (4, 43). The study by Ergun et al.(4), showed 13 patients with the variations in the origin of the VA (5.1%). They reported the left VA with direct origin from the aortic arch in 10 (3.9%) patients, and right VA arising from aberrant right subclavian artery in 3 (1.2%) patients with no direct aortic origin.

The present study has some limitations. It is a retrospective single center analysis performed with only the data of VA diameter and without any flow parameters. Also the number of the subjects might be insufficient for such a study about anatomical arterial variations.

Table 1. The results of demographic, origin and vertebral artery level of entrance presented as average ± standard deviation (95% confidence interval). All vertebral artery measurement parameters are in millimeters.

Variable			**Measure**
Age		Mean±SD	60.916±13.44
Sex	Female	Mean±SD	107(42.8)
	Male	Number(Percent)	143(57.2)
Origin of Right vertebral artery	Proximal	Number(Percent)	227(90.8)
	Distal	Number(Percent)	22(8.8)
	Arch	Number(Percent)	0
Origin of Left vertebral artery	Proximal	Number(Percent)	248(99.2)
	Distal	Number(Percent)	1(0.4)
	Arch	Number(Percent)	1(0.4)
Level of entry of Right vertebral artery	C4	Number(Percent)	1(0.4)
	C5	Number(Percent)	6(2.4)
	C6	Number(Percent)	242(96.8)
	C7	Number(Percent)	1(0.4)
Level of entry of Left vertebral artery	C5	Number(Percent)	3(1.2)
	C6	Number(Percent)	247(98.8)

Table 2. The results of length of VA in V1 and V2 part and diameter of VA presented as average ± standard deviation (95% confidence interval). All the parameters are in millimeters. *significant at α=0.05 Level. a= T-test. B= U-Mann Withney.

Variable Name	Total Measure (Mean±SD)	Male Measure (Mean±SD)	Female Measure (Mean±SD)	P-Value
length R (V1+V2)	115.2±17.924	118.66±18.379	110.59±16.267	0.0001*[a]
Right V1 length	33.82±4.592	34.43±4.437	33.02±4.692	0.014*[b]
Right V2 length	81.38±14.375	84.23±14.667	77.57±13.101	0.0001*[a]
length L (V1+V2)	115.27±16.939	118.6±17.71	110.82±14.796	0.0001*[b]
Left V1 length	32.78±4.338	33.48±4.172	31.84±4.396	0.003*[b]
Left V2 length	82.49±14.162	85.12±14.982	78.98±12.195	0.001*[a]
diameter R	3.297±0.8528	3.357±0.9118	3.216±0.7636	0.195[a]
diameter L	3.676±0.8829	3.694±0.8786	3.651±0.8922	0.754[b]

Table 3. The results of VA dominance by digital subtraction angiography among 250 patients in both gender presented. all results are summarized with number of patients and ratio on male and female.

Dominancy		Right Dominance Number(Present)	Left Dominance Number(Present)	P-Value
Gender	Male	54(37.8)	89(62.2)	0.296
	Female	36(33.6)	71(66.4)	
Total		90(35.7)	160(64.3)	

Conclusion

In conclusion, to be aware of which VA is dominant is very important in the interventions in which one of the subclavian arteries must be sacrificed. There are different diameter criteria in the studies for the determination of VA dominance. The present study found that in most cases right VA was dominant in all the groups. Anomalous entrance of the VA into the transverse foramen has been described. This research reports the total prevalence of variations in origin of the LVA as 0.6 % and of the RVA, 8.8 %, as diagnosed by CT angiography. If entering above C6, the pre-entry course of the VA may be at risk for injury during aortic arch or lower neck surgery below the entry level. It is also important to recognize anomalous origin of the VAs before arterial catheterization to the VAs to reduce examination time and catheterization failure.

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References

1. Kiernan JA, Barr ML. Barr's the human nervous system: an anatomical viewpoint: Lippincott Williams & Wilkins; 2009.
2. Kim JS, Lee H, editors. Inner ear dysfunction due to vertebrobasilar ischemic stroke. Seminars in neurology; 2009: © Thieme Medical Publishers.
3. Morović S, Škarić-Jurić T, Demarin V. Morphologic and hemodynamic characteristics of vertebral arteries in men and women. Rad Hrvatske akademije znanosti i umjetnosti Medicinske znanosti. 2007(497= 31):121-7.
4. Ergun O, Tatar IG, Birgi E, Hekimoglu B. Evaluation of vertebral artery dominance, hypoplasia and variations in the origin: angiographic study in 254 patients. Folia morphologica. 2016;75(1):33-7.
5. Garcia Alzamora M, Rosahl SK, Lehmberg J, Klisch J. Life-threatening bleeding from a vertebral artery pseudoaneurysm after anterior cervical spine approach: endovascular repair by a triple stent-in-stent method. Case report. Neuroradiology. 2005;47:282-6.
6. George B, Bruneau M, Spetzler RF, Campero A, Rubino P, Rhoton A. Anatomy of the vertebral artery. Pathology and surgery around the vertebral artery. 2011:29-40.
7. Eskander MS, Drew JM, Aubin ME, Marvin J, Franklin PD, Eck JC, et al. Vertebral artery anatomy: a review of two hundred fifty magnetic resonance imaging scans. Spine. 2010;35(23):2035-40.
8. Yamaki Ki, Saga T, Hirata T, Sakaino M, Nohno M, Kobayashi S, et al. Anatomical study of the vertebral artery in Japanese adults. Anatomical Science International. 2006;81(2):100-6.
9. Einstein EH, Song LH, Villela NL, Fasani-Feldberg GB, Jacobs JL, Kim DO, et al. Anomalous origin of the left vertebral artery from the aortic arch. Aorta. 2016;4(02):64-7.
10. Tardieu GG, Edwards B, Alonso F, Watanabe K, Saga T, Nakamura M, et al. Aortic arch origin of the left vertebral artery: an anatomical and radiological study with significance for avoiding complications with anterior approaches to the cervical spine. Clinical Anatomy. 2017;30(6):811-6.
11. Magklara E-P, Pantelia E-T, Solia E, Panagouli E, Piagkou M, Mazarakis A, et al. Vertebral artery variations revised: origin, course, branches and embryonic development. Folia morphologica. 2021;80(1):1-12.
12. Woraputtaporn W, Ananteerakul T, Iamsaard S, Namking M. Incidence of vertebral artery of aortic arch origin, its level of entry into transverse foramen, length, diameter and clinical significance. Anatomical science international. 2019;94:275-9.
13. Park C, Lee BH. Anomalous origins of the bilateral vertebral arteries arising from the aortic arch: a case report. Journal of the Korean Society of Radiology (Taehan Yŏngsang Ŭihakhoe chi). 2021;82(3):743.
14. Lazaridis N, Piagkou M, Loukas M, Piperaki E-T, Totlis T, Noussios G, et al. A systematic classification of the vertebral artery variable origin: clinical and surgical implications. Surgical and Radiologic Anatomy. 2018;40:779-97.
15. Yuan S-M. Aberrant origin of vertebral artery and its clinical implications. Brazilian journal of cardiovascular surgery. 2016;31:52-9.
16. Thomas AJ, Germanwala AV, Vora N, Prevedello DM, Jovin T, Kassam A, et al. Dual origin extracranial vertebral artery: case report and embryology. Journal of Neuroimaging. 2008;18(2):173-6.
17. Uchino A, Saito N, Takahashi M, Okada Y, Kozawa E, Nishi N, et al. Variations in the origin of the vertebral artery and its level of entry into the transverse foramen diagnosed by CT angiography. Neuroradiology. 2013;55:585-94.
18. Tetiker H, Çimen M, Koşar Mİ. Evaluation of the vertebral artery by 3D digital subtraction angiography. 2014.
19. Lajos PS, Jacobs DL. Endovascular technique for percutaneous stent graft repair of subclavian artery pseudoaneurysm. CTSNet. 2008;11:1-5.
20. DH P. Development of cranial arteries in human embryo. Contrib Embryol. 1948;32:205-62.
21. Katsanos AH, Kosmidou M, Kyritsis AP, Giannopoulos S. Is vertebral artery hypoplasia a predisposing factor for posterior circulation cerebral ischemic events? A comprehensive review. European neurology. 2013;70(1-2):78-83.
22. Yi X, Xie P, Zhang L, Lu F, Chen H, Liu K. Entrance and origin of the extracranial vertebral artery found on computed tomography angiography. Scientific Reports. 2022;12(1):15274.
23. Burke JP, Gerszten PC, Welch WC. Iatrogenic vertebral artery injury during anterior cervical spine surgery. The Spine Journal. 2005;5(5):508-14.
24. Biffl WL, Moore EE, Elliott JP, Ray C, Offner PJ, Franciose RJ, et al. The devastating potential of blunt vertebral arterial injuries. Annals of surgery. 2000;231(5):672.
25. Golfinos JG, Dickman CA, Zabramski JM, Sonntag V, Spetzler RF. Repair of vertebral artery injury during anterior cervical decompression. Spine. 1994;19(22):2552-6.
26. Inamasu J, Guiot B. Vascular injury and complication in neurosurgical spine surgery. Acta neurochirurgica. 2006;148:375-87.
27. Bruneau M, Cornelius JF, George B. Anterolateral approach to the V2 segment of the vertebral artery. Operative Neurosurgery. 2005;57(4):262-7.

28. Knoop M, Kröger J, Schulz K, Ascher P, Schareck W, Witter K, et al. Diagnosis and management of an intraoperative vertebral artery injury. Der Chirurg; Zeitschrift fur Alle Gebiete der Operativen Medizen. 1999;70(7):789-94.
29. Bruneau M, Cornelius JF, Marneffe V, Triffaux M, George B. Anatomical variations of the V2 segment of the vertebral artery. Operative Neurosurgery. 2006;59(1):ONS-20-ONS-4.
30. Sim E, Vaccaro AR, Berzlanovich A, Thaler H, Ullrich CG. Fenestration of the extracranial vertebral artery: review of the literature. Spine. 2001;26(6):E139-E42.
31. Hong JT, Park DK, Lee MJ, Kim SW, An HS. Anatomical variations of the vertebral artery segment in the lower cervical spine: analysis by three-dimensional computed tomography angiography. Spine. 2008;33(22):2422-6.
32. Vujmilović S, Spasojević G, Vujnović S, Malobabić S, Vujković Z. Variability of the vertebral artery origin and transverse foramen entrance level—CT angiographic study. Folia Morphologica. 2018;77(4):687-92.
33. Meila D, Tysiac M, Petersen M, Theisen O, Wetter A, Mangold A, et al. Origin and course of the extracranial vertebral artery: CTA findings and embryologic considerations. Clinical neuroradiology. 2012;22:327-33.
34. Lin C-Y, Liu Y-S, Chen Y-C, Shih Y-H, Chang C-C, Chuang M-T. Variations in the origin and course of the extracranial vertebral artery on multidetector computed tomography angiography. Iranian Journal of Radiology. 2018;15(2).
35. Shin HY, Park JK, Park SK, Jung GS, Choi YS. Variations in entrance of vertebral artery in Korean cervical spine: MDCT-based analysis. The Korean journal of pain. 2014;27(3):266-70.
36. Tasdemir R, Cihan O. Multidetector computed tomography evaluation of origin, V2 segment variations and morphology of vertebral artery. Folia Morphologica. 2023;82(2):274-81.
37. Robb CL, Bhalla S, Raptis CA. Subclavian Artery: Anatomic Review and Imaging Evaluation of Abnormalities. RadioGraphics. 2022;42(7):2149-65.
38. Zwiebel WJ, Pellerito JS. Introduction to vascular ultrasonography: Elsevier Saunders Philadelphia; 2005.
39. Ozdemir S, Yildiz C, Cankur N. Evaluation of vertebral artery system in a healthy population by using colour duplex Doppler ultrasonography. Med School J Uludag. 2002;28:95-9.
40. Scheel P, Ruge C, Schöning M. Flow velocity and flow volume measurements in the extracranial carotid and vertebral arteries in healthy adults: reference data and the effects of age. Ultrasound in medicine & biology. 2000;26(8):1261-6.
41. Hong JM, Chung C-S, Bang OY, Yong SW, Joo IS, Huh K. Vertebral artery dominance contributes to basilar artery curvature and peri-vertebrobasilar junctional infarcts. Journal of Neurology, Neurosurgery & Psychiatry. 2009;80(10):1087-92.
42. Songur A, Gonul Y, Ozen OA, Kucuker H, Uzun I, Bas O, et al. Variations in the intracranial vertebrobasilar system. Surgical and Radiologic Anatomy. 2008;30:257-64.
43. Celikyay ZRY, Koner AE, Celikyay F, Denız C, Acu B, Firat MM. Frequency and imaging findings of variations in human aortic arch anatomy based on multidetector computed tomography data. Clinical imaging. 2013;37(6):1011-9..

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Cerebral hydatid cyst masquerading as multiple cystic metastases. A rare presentation

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ABSTRACT

Hydatid disease is caused by encysted larvae of the dog tapeworm Echinococcus granulosus. Cerebral hydatidosis is a rare central nervous system larval infection affecting approximately 2–3% of patients. CT and MRI scans of the boy, described in our case, showed multiple cystic areas. Total surgical extirpation is the therapeutic approach, emphasizing the importance of early diagnosis for a favourable prognosis. Recurrence and unfavourable outcomes are commonly associated with incomplete excision and surgical rupture, necessitating careful removal to prevent anaphylaxis and widespread infection. Dowling's technique is the preferred surgical approach and postoperatively, patients are administered antiparasitic drugs such as Albendazole or Mebendazole for 6–12 months in most cases, with doses ranging from 10-15mg/kg in divided doses. The results of pharmacological treatment vary across series, with response rates ranging from 43.5 to 80%. Early diagnosis significantly contributes to a favourable prognosis by preventing neurological consequences.

Keywords
cerebral hydatid cyst,
cystic metastases

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INTRODUCTION

Hydatid disease, caused by encysted larvae of the dog tapeworm Echinococcus granulosus, results in the formation of proctoscoleces. The primary definitive host of the adult worm is the dog, while intermediate hosts for the larval stage include sheep and humans. Human infection occurs through the ingestion of food contaminated with ova or direct contact with infected dogs. Cerebral hydatidosis is a rare central nervous system larval infection affecting approximately 2–3% of patients, with the incidence of hydatid cysts among intracranial space-occupying lesions varying between 1.6 and 5.2 percent in different countries (1).

CASE DETAILS

A 16-year-old boy, previously in good health, initially presented to the Emergency Department after a fall following vertigo. Being vitally and clinically stable, he was discharged, from the emergency room. Two days later, he returned with progressive weakness in the right upper and lower limbs. On arrival, his Glasgow Coma Scale (GCS) was 15, but he exhibited reduced strength in various muscle groups on the right side (right hemiparesis). CT and MRI scans of the brain with IV contrast revealed multiple well-defined cystic areas in the bilateral frontal and parietal regions, accompanied by moderate surrounding edema and peripheral ring enhancement on post-contrast images (shown in figure 1 and 2). The largest lesion, measuring 3.8x 3.3x 2.3cm, was seen in the left frontal lobe. Abscess was ruled out due to the absence of restriction on the DWI sequence, leading to an initial impression of cystic metastasis. A subsequent CT of the chest, abdomen, and pelvis failed to identify a primary source, prompting a biopsy. Burr hole craniostomy with neuro navigation was planned. During surgery a grayish cyst-like structure was identified, which was biopsied. Postoperatively, the patient remained stable with mild right hemiparesis, and was discharged. During subsequent follow up in the clinic, his hemiparesis improved with no residual deficit. Histopathology indicated glial tissue with increased cellularity of lymphocytes and histiocytes (CD 68+). The presence of round to oval organisms within histiocytes led to the impression of an infected etiology, prompting referral to an infectious disease specialist. Positive echinococcus titre and other tests confirmed the diagnosis, and the patient commenced albendazole treatment, with ongoing clinic follow-ups.

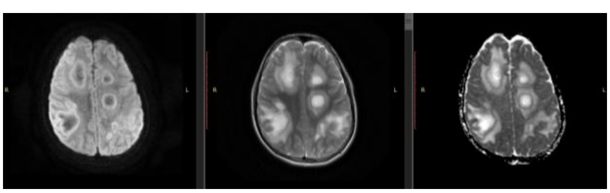

Figure 1 showing DWI, T2 and ADC images.

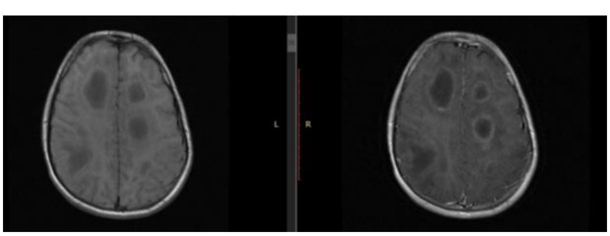

Figure 2 showing T1 pre and post contrast images.

Discussion

Hydatid disease, also known as echinococcosis, is a zoonotic parasitic infection transmitted from animals to humans through the larval stage of tapeworms (cestodes) belonging to the genus Echinococcus. In regions where echinococcosis is endemic, the World Health Organization (WHO) estimates an annual incidence of human infection exceeding 50/100,000 persons (2). Approximately 1-2% of cases involve hydatid cysts affecting the human brain. Children constitute 80% of cases with brain involvement, often associated with dysfunctional valves or patent ductus arteriosus, primarily affecting the middle cerebral artery region(3) . The clinical manifestation of brain hydatid cysts is determined by their size and location, commonly presenting with symptoms such as hemiparesis, convulsions, migraines, vomiting, altered behavior, and even skull deformities. Over half of patients exhibit multiple cysts, predominantly in the cerebral hemispheres but also reported in various other brain regions (4).

Brain hydatid cysts appear as well-circumscribed cystic lesions on CT and MRI scans, rarely displaying daughter cysts. They typically lack wall calcification or surrounding edema, presenting only cerebrospinal fluid (CSF) density on CT or signal intensity on MRIs. Hypo intense rims on T2-weighted images are characteristic, with a low signal intensity rim surrounding the cyst visible on T2-weighted MRIs(5) . Cysts may appear non-complex or complicated, the latter involving per cystic edema due to rupture and leakage(6). Non-complicated cysts on MRI are well-defined and isointense, lacking rim enhancement or pericystic edema. Conversely, complex cysts with superadded infections exhibit hyper intense pericystic edema and a ring of enhancement, either fully or partially, due to cyst rupture, making them prone to recurrence. Brain hydatid cysts should be considered in the differential diagnosis of cystic lesions, alongside conditions like arachnoid cysts, porencephalic cysts, pyogenic abscesses, neurocysticercosis, and brain metastasis(7).

A high degree of suspicion is crucial when encountering cerebral cystic lesions on imaging, especially in regions with a high prevalence of hydatid disease, to ensure early diagnosis(8). Despite limited studies in the region, Nasir et al. reported 33 cases of cerebral hydatid cysts, all appearing as isolated cystic masses on imaging. Clinicians suspected over 67% of these lesions to be hydatid cysts, with histopathological examination revealing transparent, thin-walled, unilocular, or multilocular cysts in 52% of cases. The intact cysts had an average size of 7 cm, displaying standard histology and responding well to medical treatment following surgical excision(9) . Total surgical extirpation is the therapeutic approach, emphasizing the importance of early diagnosis for favorable prognosis. Recurrence and unfavorable outcomes are commonly associated with incomplete excision and surgical rupture, necessitating careful removal to prevent anaphylaxis and widespread infection(10). Dowling's technique is the preferred surgical approach(11), and postoperatively, patients are administered antiparasitic drugs such as Albendazole or Mebendazole for 6–12 months in most cases, with doses ranging from 10-15mg/kg in divided doses(12). The results of pharmacological treatment vary across series, with response rates ranging from 43.5 to 80%. Early diagnosis significantly contributes to a favorable prognosis by preventing neurological consequences.

References

1. Alshoabi SA, Alkalady AH, Almas KM, Magram AO, Algaberi AK, Alareqi AA, et al. Hydatid Disease: A Radiological Pictorial Review of a Great Neoplasms Mimicker. Diagnostics. 2023;13(6):1127.
2. Torgerson PR, Devleesschauwer B, Praet N, Speybroeck N, Willingham AL, Kasuga F, et al. World Health Organization Estimates of the Global and Regional Disease Burden of 11 Foodborne Parasitic Diseases, 2010: A Data Synthesis. PLoS medicine. 2015;12(12):e1001920.
3. Arega G, Merga G, Tafa G, Salah FO, Abebe G, Maru S, et al. Temporoparietal Brain Hydatid Cyst in an Eight-Year-Old Child: A Rare Case Report. Pediatric health, medicine and therapeutics. 2022;13:361-5.
4. Duransoy YK, Mete M, Barutçuoğlu M, Unsal U, Selçuki M. Intracranial hydatid cyst is a rare cause of midbrain herniation: A case report and literature review. Journal of pediatric neurosciences. 2013;8(3):224-7.
5. Abbasi B, Akhavan R, Ghamari Khameneh A, Darban Hosseini Amirkhiz G, Rezaei-Dalouei H, Tayebi S, et al. Computed tomography and magnetic resonance imaging of hydatid disease: A pictorial review of uncommon imaging presentations. Heliyon. 2021;7(5):e07086.
6. Abbassioun K, Rahmat H, Ameli NO, Tafazoli M. Computerized tomography in hydatid cyst of the brain. Journal of neurosurgery. 1978;49(3):408-11.
7. Turgut M. Intracranial hydatidosis in Turkey: its clinical presentation, diagnostic studies, surgical management, and outcome. A review of 276 cases. Neurosurgical review. 2001;24(4):200-8.
8. Padayachy LC, Dattatraya M. Hydatid disease (Echinococcus) of the central nervous system. Child's nervous system : ChNS : official journal of the International Society for Pediatric Neurosurgery. 2018;34(10):1967-71.
9. Din NU, Raza M, Rahim S, Memon W, Ahmad Z. Hydatid disease of central nervous system, a clinicopathological study of 33 cases. Journal of neurosciences in rural practice. 2023;14(2):293-7.
10. Gezen F, Baysefer A, Köksel T, Gönül E, Akay KM, Erdogan E. Hydatid cysts of the brain. Clinical infectious diseases : an official publication of the Infectious Diseases Society of America. 1995;21(4):938-42.
11. Hage P, Salle H, Ibrahim I, Khalil W. Hydatid cyst excision using Dowling's technique of hydrodissection. Acta neurochirurgica. 2022;164(11):2851-4.
12. Dehkordi AB, Sanei B, Yousefi M, Sharafi SM, Safarnezhad F, Jafari R, et al. Albendazole and Treatment of Hydatid Cyst: Review of the Literature. Infectious disorders drug targets. 2019;19(2):101-4.

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Spinal thoracic tuberculoma in neurofibromatosis type-1

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ABSTRACT
The clinical manifestations of neurofibromatosis type-1 have in common the presence of neurofibromas, schwannomas and cafe`-au-lait macules, which can potentially appear within any organ system of the body, involving primarily the skeleton, skin and soft tissues. The spinal thoracic tuberculoma in neurofibromatosis is exceptional.
We report here, the case of a 31-year-old male with neurofibromatosis type-1 who presented a year agoa spinal thoracic pain. The evolution was marked by the appearance of a dorsal para-vertebral mass, progressively increasing in volume for 03 months.
Neurological Examination revealed normal muscle bulk and tone, and power was grade 5/5. Deep tendon reflexes were brisk and the Babinski sign was present. The sensory deficit was present below the D9 level. The remainder of the examination found a voluminous dorsal para vertebral mass ovoid, renitent, and adhering to the superficial and the deep planes. There were also "café-au-lait" spots disseminated on his body. The imagery showed a formation with respect to D11-D12, isointense on T1 and T2, heterogeneously enhanced after contrast with central necrosis, with a foraminal starting point measuring 85x78x66 mm, with external canal extension. Laminectomy D11-D12 was performed with incomplete excision of the lesion. The histological examination showed casein-follicular vertebral tuberculosis, with secondary abdominal changes. Then the patient was put on anti-bacillary drugs. The evolution was marked two weeks later by the reappearance of the back pain and the back mass. On the 42nd day of treatment, the patient had a febrile consciousness disorder with a GCS of 8, right mydriasis and meningeal stiffness. Paraclinic investigations revealed tuberculosis meningoencephalitis, responsible for an active ventricular hydrocephalus associated with a left temporoparietal extrudal hematoma. An external ventricular shunt was performed as well as a left temporo-parietal extrudal hematoma evacuation. The patient died 7 days later in a poly visceral failure chart.

Keywords
extrudal,
hydrocephalus,
neurofibromatosis type-1,
para-vertebral mass,
spinal thoracic pain,
spinal tuberculoma,
tuberculosis
meningoencephalitis

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INTRODUCTION

Neurofibromatosis is the most frequent single-gene disorder affecting mankind [1]. It is a disorder of neural crest cells defined as a spectrum of multifaceted diseases, probably hamartomatous in origin, involving neuroectoderm, mesoderm and endoderm [2]. Its clinical manifestations have in common the presence of neurofibromas, schwannomas and cafe-au-lait macules, which can potentially appear within any organ system of the body, involving primarily the skeleton, skin and soft tissues. The spinal thoracic tuberculoma in neurofibromatosis is exceptional. This case appears to be the first reported case in the literatureof this kind of tumor.The aim of this case is to report the clinical outcomes following resection ofspinal thoracic tuberculoma.

CASE REPORT

A 31-year-old male of low socioeconomic status, with a history of neurofibromatosis type-1, admitted to the neurosurgery department for a para-vertebral mass of progressive installation evolving for 03 months. The history of the disease dates back to a year before his admission by back painreticent to symptomatic treatment. The development was marked by the appearance of a dorsal para-vertebral mass, progressively increasing in volume for 03 months. The whole evolving in an apyretic context and conservation of the general state. The initial clinical examination was aimed at a conscious, generally good, apyretic and hemodynamically and respiratoryly stable patient. Neurological examination revealed normal muscle bulk and tone, and power was grade 5/5. Deep tendon reflexes were brisk and Babinski sign was present. Sensory deficit was present below D9 level. The locoregional examination found a voluminous dorsal paravertebral mass, ovoid, renitent, adhering to both superficial and deep planes. It measured 23x16 cm with long axis. There were also "café-au-lait macules" scattered around his body (Fig.1).

The medullar MRI revealed a formation with respect to D11-D12, in isotense T1 and T2, heterogeneously enhanced after contrast with central necrosis, with a foraminal starting point measuring 85 x 78 x 66 mm, with external canal extension that measured 140 x 45 mm. We conclude that all of the abnormalities described fall within the scope of an NF1 in its plexiform form with degenerate neurofibroma D11-D12 (Fig.2). Viral serology (HIV, syphilis and hepatic) was negative.

Figure. 1: "café-au-lait macules" scattered around his body and voluminous dorsal paravertebral mass.

We performed median cutaneous incision with respect to D10-D11. Cutaneous dissection of the cyst lesion, showed the sero-viscous contents of which have been removed as a whole. More realization of a laminectomy of D10-D11 and complete excision of an epidural and intracellular lesion of the intra-dural one. This lesion is friable infiltrating with necrosis (Fig.3).

The histological examination showed the casein-follicular vertebral tuberculosis, with secondary abdominal changes (Fig.4). Then the patient was put on anti-bacillary drugs. The evolution was marked two weeks later by the reappearance of the back pain and the back mass. Postoperative spinal MRI showed a slight increase of the tumor formation with respect to D11-D12, in isotense T1, T2, heterogeneously enhanced after contrast with central necrosis, with a foraminal starting point measuring 88x95x88 mm, with external canal extension (Fig. 5).

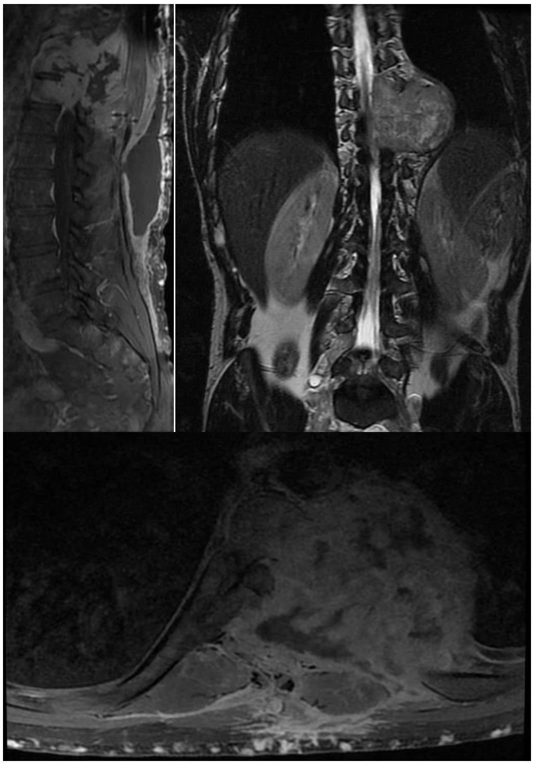

Figure. 2: The medullar MRI revealed a formation with respect to D11-D12, in isotense T1, T2, heterogeneously enhanced after contrast with central necrosis, with a foraminal starting point measuring 85x78x66 mm, with external canal extension that measured 140x45 mm.

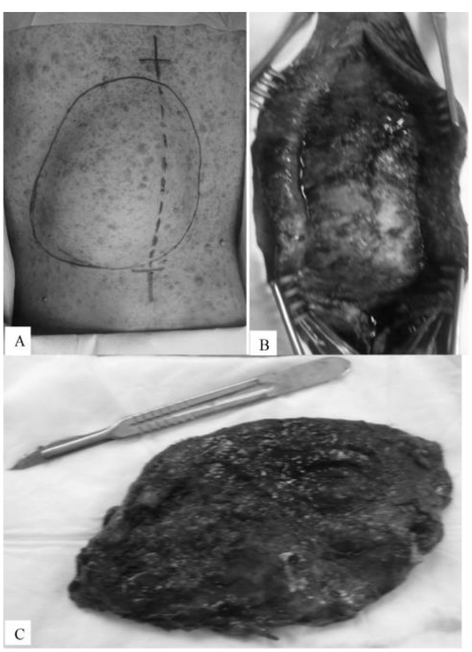

Figure 3: Intraoperative images. A: Anatomical identification with paravertebral swelling, B: the extra-canal and intradural lesion infiltrating the dura mater, C: the operative piece showing caseous necrosis.

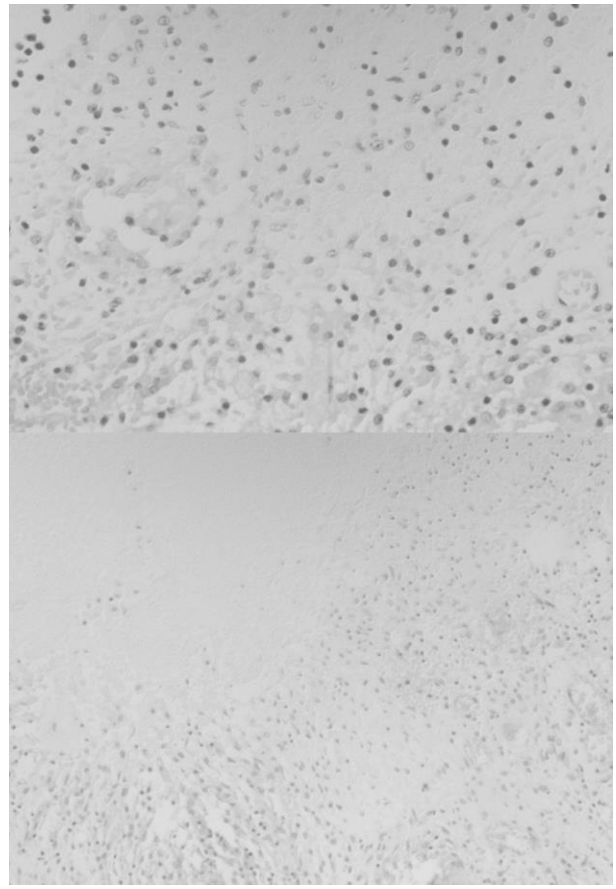

Figure 4: The histological examination showed the casein-follicular vertebral tuberculosis, with secondary abdominal changes.

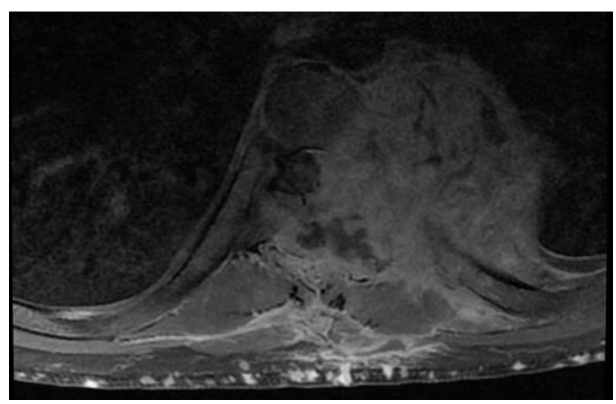

Figure 5: Postoperative spinal MRI showed a slight increase of the tumor formation with respect to D_{11}-D_{12}, in isotense T1, T2, heterogeneously enhanced after contrast with central necrosis, with a foraminal starting point measuring 88 x 95x88 mm, with external canal extension.

At one month of the anti-bacillary treatment, the patient had presented a febrile subicteria with an episode of partial convulsive seizures secondarily generalized. Brain CT-scan showed osteolytic lesions on the right side of the frontal bone (Fig. 6. A).

Biologically, there was an increase in gamma GT at twice the normal. On the 42nd day of treatment, the patient had a febrile consciousness disorder with a GCS of 8, right mydriasis and meningeal stiffness. Brain CT scan had demonstrated ventricular hydrocephalus with a left temporo-parietal extradural hematoma (Fig. 6. B, C). We performed an external ventricular shunt (EVS) in an emergency. The study of ventricular CSF was predominantly lymphocyte-positive at 90%. The brain imagery after EVS showed an increase in the size of the extra-dural hematoma (Fig.6.D) which was evacuated. The patient died 7 days later in a poly visceral failure chart. The autopsy was proposed to find out the exact cause of the death but the family refused because of the usual practices.

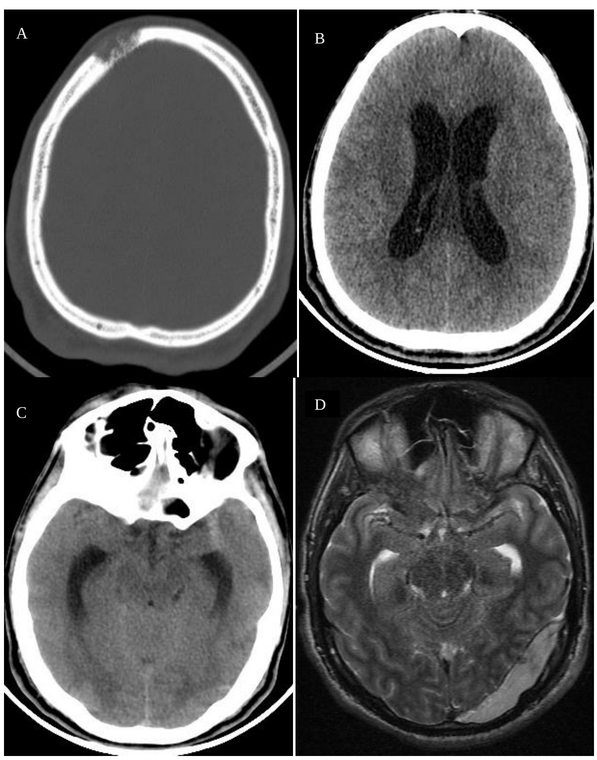

Figure 6: (A) Brain CT scan showed osteolytic lesions on the right side of the frontal bone, (B) Brain imagery had demonstrated ventricular hydrocephalus; (C) left temporo-parietal extradural hematoma; (D) brain imagery after EVS showed an increase in the size of the extra-dural hematoma.

Discussion

Neurofibromatosis type 1 (NF1) is one of the most fascinating and common human mendelian disorders, affecting approximately one in 3000 persons [5]. From the initial artist renderings of patients with NF1 in the 15th century and the earliest medical reports in 18th century, to the complex molecular genetic studies of the late 20th century, physicians and lay persons alike have been fascinated with this disease because of its diverse manifestations and the unusual and bizarre physical appearances associated with the disease. Also known as peripheral neurofibromatosis or von Recklinghausen disease, NF1 is inherited in an autosomal dominant pattern. The disease bears the name of Friedrich von Recklinghausen (1833 - 1910), a German pathologist, who was not the first to report the disease but was the first to recognize that the characteristic peripheral neurofibromas developed from nervous tissue [7]. Patients with NF1 are afflicted with a diverse group of lesions that are predominantly neuroectodermal or mesenchymal in origin. The large and complex NF1 gene, located on chromosome 17, encodes a protein named neurofibromin that works to control cellular proliferation through complex interactions with rasoncogenes [8]. Its clinical manifestations have in common the presence of neurofibromas, schwannomas and cafe-au-lait macules. The spinal tuberculoma is exceptional.

Tuberculoma pathophysiology is complicated to understand.First infected macrophages produce inflammatory mediators which lead to recruitment of peripheral macrophages and monocytes. These infected macrophages migrate to lymph nodes and disseminate to in other part of body. Enzymes in lysosome kill mycobacteria then present their antigens via major histocompatibility complex (MHC) class II to CD4 + T cells; CD4 + T-cells secrete interferon-gamma (IFN-c), which induce macrophage recruitment and enhance lysis of mycobacteria [4]. The patient body react by forming granuloma around the infected and necrosed immune cells to contain it, but viable bacteria has been demonstrated in these granulomas. This granuloma formation is though protective sometime may turn against the patient recovery. This inflammatory process may get exaggerated and produce unwanted effects.

The factors favoring the spinal thoracic tuberculoma being poverty and especially immunosuppressant, would explain its occurrence in NF1. Intradural tuberculous granuloma is the most unusual of all varieties of spinal tuberculous granuloma and can be classified as (a): endural (within two dural layers); (b): subdural; (c):

subarachnoidal or arachnoidal; (d): intramedullary and (e): after transgressing cord and arachnoid sited in subdural spase. According to this classification, our case is of type a.

According to the case of our patient, two kinds of parenchymatous involvement can be described: Type 1: tuberculous meningitis may be present without CNS tuberculoma formation. Rich [6] suggested that tuberculous meningitis is precededby metastatic seeding of Mycobacterium tuberculosis within the parenchyma or meninges, followed by growth andeventual maturation of the caseous tuberculoma into a fluid-filled tuberculous abscess and rupture of this abscess into the subarachnoid space causes tuberculous meningitis. In our case, the contamination of the CNS by the Mycobacterium tuberculosis could be explained by a dissemination of the tuberculoma from the operative focus. Type 2: The development of tuberculous meningitis is a two-step process. Mycobacterium tuberculosis bacilli enter the host by droplet inhalation. The initial point of infection being the alveolar macrophage. Escalating localised infection within the lung with dissemination to the regional lymph nodes produces the primary complex. During this stage there is a short but significant bacteraemia that can seed tubercle bacilli to other organs in the body. In those who develop tuberculous meningitis, bacilli seed to the meninges or brain parenchyma, forming small subpial or subependymal foci. These are called Rich foci. The dissemination to the CNS is more likely, particularly if miliary tuberculosis develops. The second step in the development of tuberculous meningitis is rupture of a Rich focus into the subarachnoid space.

The occurrence of tuberculous meningoencephalitis at the end of the anti-bacillary treatment would come either: The bacillus itself has many ways to protect itself from immune cells and antibiotics. One of the main mechanisms is the inherent resistant nature of mycolic acid present in the cell wall. The paradoxical aggravation under anti-bacillary marked by the reappearance of dorsal pain and back mass two weeks later. The absence of association of corticosteroid therapy with antibacillary therapy could induce this periodontal aggravation.

This complication of tuberculous meningitis may present despite adequate antituberculous treatment [3], as was the case in our patient.

Conclusion

The clinical manifestations of the neurofibromatosis have in common the presence of neurofibromas, schwannomas and "café-au-lait macules". However, an exceptional form of the spinal thoracic tuberculoma can be seen thus mimicking the already described forms of neurofibromatosis. The management of this kind form would perform by an antibacillary therapy associated with corticosteroid therapy and the surgery for good outcome.

References

1. Crawford AH, Bagamery N: Osseous manifestations of neurofibromatosis in childhood. J PediatrOrthop 6:72–88, 1986
2. Crawford AH: Neurofi- bromatosis. In: Weinstein SL (ed) The pediatric spine: principles and practice, 2nd edn. Lippincott Williams & Wilkins, Philadelphia, pp 471–490, 2001
3. Eroles G, Castro MD, Mendivil M, et al: Arachnoiditis and intraspinal lesion. Complications of tuberculous meningitis in 2 patients with human immunodefi-ciency virus infection. Rev Clin Esp 201:575–578, 2001.
4. Hernandez-Pando R, Orozco H, Aguilar D: Factors that deregulate the protective immune response in tuberculosis. Arch Immunol Ther Exp 57:355–67, 2009.
5. Huson SM, Compston DA, Clark P, Harper PS. A: genetic study of von Recklinghausen neurofibro-matosis in south east Wales. I. Prevalence, fitness, mutation rate, and effect of parental transmission on severity. J Med Genet26:704 –711, 1989.
6. Rich AR, Mccordick HA: The pathogenesis of tuberculous meningitis. Bull Johns Hopkins Hosp 52:2–37, 1933.
7. Von Recklinghausen FD. Ueber die multiplenfi-brome der haut und ihrebeiehungzu den multiplenneuromen. Berlin, Germany: Hirschwald,1882.
8. Xu GF, O'connell P, Viskochil D, et al: The neurofibromatosis type 1 gene encodes a protein related to GAP. Cell 62:599 – 608, 1990.

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Characteristics and surgical management of spinal meningiomas in the Himalayan region. A decade-long study at a tertiary care hospital

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ABSTRACT
Background: Spinal meningiomas, originating from arachnoid cap cells, primarily manifest in the intradural extramedullary region, commonly favouring the thoracic area, albeit occurrences in the cervical, lumbar, and exceptionally rare sacral regions have been noted. Among tumours in this location, meningiomas, neurofibromas, and schwannomas prevail. MRI serves as the preferred imaging modality due to its ability to often reveal the distinctive dural origin of meningiomas. Microdissection and resection stand as the established gold standard for treating spinal meningiomas.
Materials and methods: This study, conducted at the Sheri-Kashmir Institute of Medical Sciences Soura Srinagar in Jammu and Kashmir, India, spanned approximately 10 years from August 2009 to July 2017 retrospectively and August 2017 to July 2019 prospectively. It encompassed patients diagnosed with spinal meningiomas, evaluated through comprehensive history-taking, clinical examinations, biochemical assessments, and radiological studies. Surgical interventions predominantly involved laminectomy, aiming for gross total or subtotal tumour resection using a posterior approach. Postoperative complications, such as CSF leaks and wound infections, were monitored, and the duration of hospitalization was recorded from the surgery date to discharge.
Results: The results showed a mean patient age of 44 years, with the youngest being 16 years old and the eldest 70 years old. Most patients (40.90%) fell within the 41-50 age group, with 22.72% in the 51-60 age bracket. Among the 22 patients, females comprised 68.18%, resulting in a female-to-male ratio of 2.1:1. The most prevalent symptoms were pain (77%) and weakness (63%), followed by bladder dysfunction (27%). Tumors were primarily located in the thoracic region (68%), with other occurrences in the cervicothoracic (18%), thoracolumbar (9%), and cervical (4.54%) areas. Posterior surgical approaches were utilized in 91% of cases, with the remaining 9% employing an anterior approach. Tumour sizes varied, with 22.72% smaller than 2 cm and 77.27% larger, having a mean greatest diameter of 2.9 cm. Postoperative

complications were observed in 9.09% of patients, with CSF leaks and wound infections being the major concerns, while 91% experienced no complications.

Conclusions: In conclusion, this study illustrates spinal meningiomas as slow-growing tumors with a subtle onset, typically appearing in the 4th to 5th decade, and exhibiting a female predominance with a 2:1 ratio. Pain emerges as the most prevalent presenting symptom. Surgery stands as the primary treatment, albeit accompanied by potential postoperative complications such as wound infections, CSF leaks, or bowel and bladder dysfunctions. Adjuvant radiotherapy might be considered for recurrent or advanced disease to offer palliative relief.

INTRODUCTION

Spinal meningiomas are tumors that originate from arachnoid cap cells and are commonly situat-ed in the intradural extramedullary region [1, 2]. They predominantly occur in the thoracic region but can also be found in the cervical, lumbar, and rarely, the sacral area [3-5]. The challenges posed by these tumors during surgery vary based on their location along the spinal cord, as well as their orientation—whether anterior or posterior—to the spinal cord and cauda equina. In adults, intradural extramedullary spinal cord tumors constitute approximately two-thirds of all spinal cord tumors, with meningiomas, neurofibromas, and schwannomas being the most common types in this location [7, 8].

Most of the spinal cord meningiomas are situated in the thoracic region, particularly in females, as they occur about 2.5 times more frequently in women than in men, with approximately 75-85% arising in females. Overall, spinal meningiomas represent around 7.5-12.7% of all meningiomas, occurring less frequently than their intracranial counterparts. Most of these tumors are located laterally and typically emerge from arachnoid cap cells within the dural root sleeve [6]. MRI serves as the imaging modality of choice due to its ability to often delineate the characteristic dural origin of meningiomas. These tumors typically appear isointense or hy-pointense to gray matter on T1 and isointense or hyperintense on T2. Radiographically, intraspinal meningiomas display avid homogeneous enhancement with contrast. Additionally, enhancement of the adjacent dura, known as the dural tail, is a characteristic feature of meningiomas [10]. Clin-ically, intraspinal meningiomas may present with varying symptoms depending on their location along the spinal axis. Meningiomas located in the craniovertebral junction and high cervical re-gion often present with myelopathic features and suboccipital pain. They may also cause atrophy of intrinsic hand muscles. Generally, spinal tumors may lead to a dull ache and radicular symp-toms if a nerve root is involved. Bowel and bladder involvement may manifest as a late symptom [13]. Microdissection and resection remain the gold standard for treating spinal meningiomas [9, 14-17].

Cervical meningiomas can pose surgical challenges, especially when they are situated an-terior to the spinal cord, unlike thoracic meningiomas, which tend to favor more posterior and lat-eral locations [18]. Occasionally, a spinal meningioma may present as a dumbbell tumor resem-bling a nerve sheath tumor. Resection of this type of tumor might involve sacrificing the affected nerve root with minimal neurological consequences [6, 19]. The exceedingly rare intramedullary meningioma has been treated using surgical cordectomy as the operative technique [20]. Although uncommon, meningiomas have been described in the lumbosacral spine [21-25]. Multiple spinal meningiomas are relatively rare, especially without an association with NF2 [26, 27]. Treatment options for multiple spinal meningiomas must consider their locations, symptoms, and the pa-tient's premorbid condition.

Symptomatic meningiomas causing significant myelopathic or radiculopathic features should be treated rather than managed conservatively. Post-surgical com-plications such as CSF leak, wound infection, and bladder/bowel dysfunction may occur [4, 9, 12]. Surgery remains the primary treatment for symptomatic multiple spinal meningiomas, though ra-diation therapy may be considered as well [28]. Adjunctive radiation therapy is primarily consid-ered in cases of subtotal resection of recurrent meningiomas or when the risk of surgery is high due to patient comorbidities or tumor location.

The Department of Neurosurgery at Sheri-Kashmir Institute of Medical Sciences (SKIMS) has been managing spinal cord and spinal column tumors since 1982. It is a well-equipped and state-of-the-art center for spinal cord tumor management.

MATERIALS AND METHODS

This study was conducted in our hospital. It encompassed both prospective and retrospective anal-yses, spanning approximately 10 years from

August 2009 to July 2017 retrospectively, and August 2017 to July 2019 prospectively. The study involved patients diagnosed with spinal meningioma. Patients underwent comprehensive evaluations encompassing history-taking, clinical examina-tions, biochemical assessments, and radiological studies.

The patient history collection comprised details such as age, gender, presenting symptoms (pain, numbness, swelling, bowel and urinary dysfunction, leg weakness), symptom duration, any associated comorbidities or prior malignan-cies, and past surgical history. Clinical examinations were conducted, including general physical examinations, systemic assessments (chest, cardiovascular system, abdomen), and detailed neuro-logical examinations, in addition to local assessments. Biochemical and hematological investiga-tions followed these examinations. Subsequently, radiological assessments were performed, in-volving plain X-rays of the spine and CT scans that revealed features such as calcification in cer-tain patients.

MRI scans were then conducted, demonstrating characteristic features indicative of spinal meningiomas. Surgical interventions primarily consisted of laminectomy coupled with total or subtotal tumor resection via a posterior approach. Postoperative complications, including CSF leaks and wound infections, were monitored. The duration of hospitalization was calculated from the surgery date to the discharge date. Patients were regularly followed up as outpatients to moni-tor for recurrence or metastasis. For patients exhibiting recurrence, reoperation or radiation thera-py was employed based on the disease status (locally recurrent or metastatic). The Department of Neurosurgery at SKIMS has been actively involved in surgically managing all types of spinal tu-mors, receiving collaborative support from other affiliated departments.

Results

The mean age of the patients was 44 years, with the youngest patient being 16 years old and the eldest 70 years old. The largest proportion of patients (40.90%) fell within the 41-50 age group, followed by 22.72% in the 51-60 age bracket (Table 1). Among the 22 patients, 15 (68.18%) were females and 7 (31.81%) were males, resulting in a female-to-male ratio of 2.1:1 (Table 2). The most prevalent symptom reported was pain, observed in 17 patients (77%), followed by weakness in 14 patients (63%), and bladder dysfunction in 6 patients (27%) (Table 3). Normal muscle pow-er (grade V) was present in 9 patients (41%), while decreased power (grade III/IV) was noted in 13 patients (59%) (Table 4). Regarding tumor location, 15 patients (68%) had thoracic tumors, 4 (18%) had cervicothoracic tumors, 2 (9%) had thoracolumbar tumors, and 1 (4.54%) had a cervi-cal tumor (Table 5). The posterior approach was employed in the surgical management of 91% of patients, whereas an anterior approach was used in only 2 patients (Table 6). In terms of tumor size, 22.72% of patients had tumors smaller than 2 cm, while 77.27% had tumors larger than 2 cm. The tumor sizes ranged from 1 to 4 cm, with a mean greatest diameter of 2.9 cm (Table 7).

Table 1. Age distribution of study population

Age(years)	**N**	**%**
0-9	0	0
10-18	2	9.09
19-30	1	4.54
31-40	3	13.63
41-50	9	40.90
51-60	5	22.72
61-70	1	4.54
71-80	1	4.54
Total	22	100
Mean	44 Years.	
Range	16-70 Years.	

Table 2. Gender Distribution

Gender	**N**	**%**
Male	7	31.81
Female	15	68.18

Table 3. Clinical Features

Symptoms	**N**	**%**
Pain	17	77.27

Weakness of legs	14	63.63
Swelling	3	13.63
Bowel dysfunction	6	27.27
Bladder symptoms	4	18.18
Mean duration of symptoms	20 months	

Table 4. Neurological Muscle Power (Grade)

Neurological grade	N	%
Grade III/IV	13	59
Grade V	9	41

Table 5. Location of tumors

Site/ Location	N	%
Cervical	01	4.54
Cervicothoracic	04	18.18
Thoracic	15	68.18
Thoraco-lumbar	02	09

Table 6. Surgical approach to tumor

Type of Approach	**N**	**%**
Anterior	2	9
Posterior	20	91

Table 7. Size of tumour (cm)

Tumor size	**N**	**%**
Number of Patients having size of Tumor < 2 cm	5	22.72
Number of Patients having size > 2 cm	17	77.27
Range of tumor size	1-4 cm	
Mean greatest diameter	2.9 cm	

Table 8. Postoperative complications

Complications	**Number of Patients (N)**	**%**
CSF leak	01	4.54
Wound infection	01	4.54
Total patients having complication	02	9
Total patients without complication	20	91

Table 9. Duration of hospital stay

Duration of hospital stay	**No. of patients**	**Percentage**
0-5 days	3	13.63
5-10 days	8	36.36
10-15 days	5	22.72
15-20 days	4	18.18
20-25 days	1	4.54
25-30 days	0	0
30-35 days	0	0
35-40 days	1	4.54
	Total=22	100

Table 10. Local recurrence

	N	**%**
Recurrence	02	9
No Recurrence	20	91

Table 11. Adjuvant therapy

Adjuvant therapy	**N**	**%**
Given	1	5
Not Given	21	95

Post-operatively, 2 out of 22 patients experienced complications, resulting in an overall complication rate of 9.09%. These complications included CSF leak in 4.54% of patients and wound infection in 4.54%. The majority, 91% of patients, did not experience any postoperative complications (Table 8). Regarding hospital stays, 13.63% of patients stayed for 0-5 days, 36.36% stayed for 5-10 days, 22.72% stayed for 10-15 days, 18.18% stayed for 15-20 days, 4.54% stayed for 20-25 days, and 4.54% stayed for 35-40 days.

The range of hospitalization duration varied from 5 to 40 days, with a mean duration of 11 days, as depicted in Table 9. Local recurrence of the disease was observed in 2 patients (9%) among the 22 after a period of 5 years post-surgery within a 7-year follow-up period (Table 10). Adjuvant radiotherapy was administered to 1 patient (4.54%) out of the 22 as part of the treatment regimen (Table 11).

Discussion

Age of presentation

Spinal meningiomas are slow-growing tumors. Most cases are observed in the 4th to 5th decade of life. In our study, the mean age of presentation was 44 years. The youngest patient was 16 years old, while the eldest was 70 years old. Most patients fell within the 40-50 age group. Levy WJ et al. [4], in their study published in 1982, described a mean age of 53 years. Iacob et al. [5], in a study published in 2014, found a mean age of 54 years.

Gender prevalence

In our study of spinal meningiomas, out of 22 patients, 7 were males and 15 were females, resulting in a female-to-male ratio of 2:1. Several investigators have reported a higher prevalence of women in their series [3, 4, 29, 30, 31]. Gezen F et al. [9] found a female-to-male ratio of 3:1 in their study. Namer IJ et al., in their 1987 study, observed 29 patients with 22 females and 7 males, indicating an approximate F:M ratio of 3:1 [29]. Roux FX et al. reported 54 patients, including 43 females and 11 males, with an F:M ratio of 3.9:1. It has been suggested that spinal meningiomas occur more frequently in fertile women due to a possible dependency of these tumors on sex ster-oid hormones [5, 31].

Symptoms

In our study, pain or low back ache was the predominant symptom, present in 17 cases (77.27%). This aligns with other studies that also describe pain or low back ache as the most common symp-tom [3-5, 9, 29, 32]. Other symptoms identified included weakness and/or numbness in the legs (63.63%), swelling (13.63%), bowel dysfunction (27.27%), and bladder symptoms (18.18%). Namer IJ et al., in their 1987 study, reported that pain was the presenting symptom in all patients [29]. Calogero JA, in a study published in 1972, similarly described pain as the most frequent pre-senting symptom [33].

Duration of symptoms

In Spinal meningioma, the mean duration of symptoms from onset to presentation is typically long. In our study, the mean duration between symptom onset and presentation was 20 months. Levy WJ et al. described a mean duration of symptoms of 23 months in their study [4]. Riad et al. reported a clinical symptom formation range between 12 to 24 months, with an average complaint period of 13.7 months [34].

Surgical treatment and approaches

Microdissection and resection of spinal meningiomas remain the gold standard for treatment. The steps involved in the resection of a dorsal meningioma are depicted in Figure 1. The primary and most effective treatment method is laminectomy with complete excision of the tumor. In our study, the predominant surgical procedure utilized was tumor resection via a posterior approach. Among 22 patients, 20 (91%) underwent complete excision of the tumor, while only 2 (9%) had subtotal excision. The rate of total tumor resection reported by various studies differs: Levy et al. [4] reported 82%, Roux et al. [3] reported 92.6%, and Solero et al. [5] reported 97%. Certain tech-nical difficulties in tumor resection, particularly due to ventral location in relation to the cord, were encountered. However, even in these challenging cases, tumor resection can be performed with meticulous microsurgical techniques. Recent advancements in neuroradiological and neuro-surgical techniques have significantly improved the outcomes of surgical treatment for spinal tu-mors. Postoperative results varied based on factors such as preoperative neurological status, tumor nature and location, and the type of surgical resection. Some authors suggested that epidural men-ingiomas [4] and those situated close to a radicomedullary artery posed surgical challenges. There was a belief that spinal meningiomas with epidural extension exhibited a more rapid clinical course and were more invasive [4]. However, others argued that these lesions did not represent a unique subgroup and exhibited an indolent course [3, 5]. Roux et al. [3] cautioned against total re-section of spinal meningiomas near a radicomedullary artery that feeds the anterior spinal artery, citing it as a risky procedure. They advocated for the use of spinal angiography in all such cases.

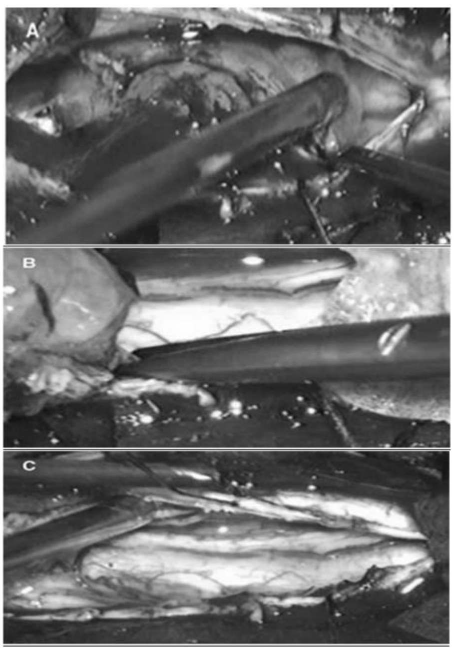

Figure 1. Intraoperative photographs showing the dorsal meningioma (a) after dura opening, (b) following complete resection including the dural attachment and (c) after tumor removal the ven-tral displacement of the spinal cord.

Tumor size and location

Spinal meningiomas are most observed in the thoracic region. In our study, the tumor was in the thoracic region in 15 patients (68.18%), cervicothoracic in 4 (18.18%), thoracolumbar in 2 (9%), and cervical in 1 (4.54%) of the patients. These findings are consistent with studies published in the literature [9, 29, 34, 35]. An example of a contrast MRI sagittal section showing a meningioma (arrow) at the T12-L1 level is presented in Figure 2. Namer IJ et al. reported 29 cases of spinal meningiomas, with 19 lesions in the thoracic regions and 10 in the cervical region [29]. Gezen F et al. reported that 55% of tumors were in the thoracic region [9]. The incidence of thoracic location was reported by Levy et al. as 75% [4], and by Roux et al. as 79.5% [3].

In our study, the size of the tumor ranged from 1 to 4 cm, with a mean greatest diameter of 2.9 cm. The tumor size was greater than 2 cm in 17 patients (77.27%) and less than 2 cm in 5 patients (22.72%). Namer IJ et al. noted that the size of the excised tumors varied between 1 x 1 cm and 4.5 x 1.5 cm [29]. An example of a T1-weighted axial contrast MRI scan displaying the ventro-lateral displacement of the spinal cord (arrow) due to tumor compression is depicted in Figure 3.

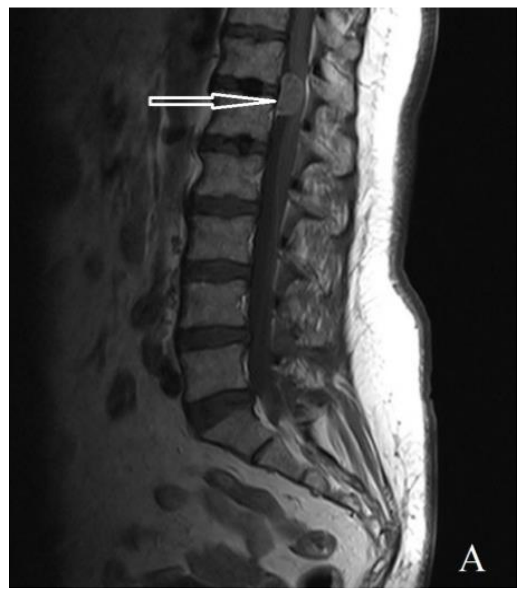

Figure 2. Contrast MRI sagittal section showing meningioma (arrow) at T12-L1 level.

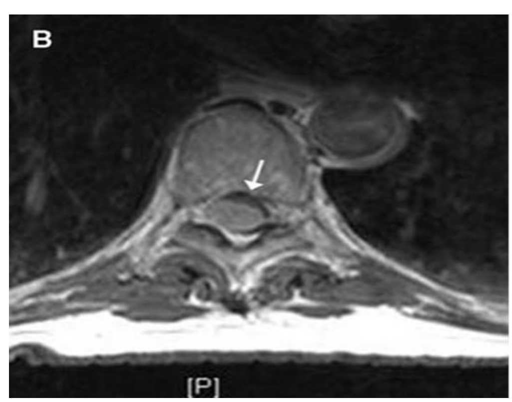

Figure 3. T1-weighted axial contrast MRI scan showing the ventro-lateral displacement of the spinal cord (arrow) due to tumor compression.

Postoperative complications

n our study, among 22 patients, only two (9.09%) experienced postoperative complications, which included one patient with a CSF leak and another with a wound infection. Gezen F et al. [9] ob-served postoperative complications in three patients, including one with cerebrospinal fluid leak-age and two with wound infections. Namer IJ et al. [29] reported postoperative complications in seven patients, with two patients (7%) experiencing wound infections, one patient (4%) with pul-monary infection, one patient (4%) with urinary infection, one patient (4%) with hematemesis, and one patient (4%) with thrombophlebitis. Unfortunately, one patient died on the 11th postoper-ative day. Gottfried ON et al. noted a low incidence of CSF leakage ranging from 0% to 4% [14].

Duration of hospital stay

In our study, the mean duration of postoperative hospital stay was 11 days. This duration was cal-culated from the day of surgery to the day of discharge. Patients who experienced postoperative complications tended to have longer hospital stays. The range of hospital stay duration varied from 5 days to 40 days.

Recurrence

In most series, the recurrence of spinal meningiomas is rare, with rates typically ranging from 1.3 to 6.4% [3-5, 9, 36, 37, 39]. Ketter et al. [37] reported that spinal meningiomas lack the genetic abnormalities found in recurrent intracranial meningiomas, indicating a more indolent nature for these tumors. The slow growth of spinal meningiomas and their occurrence in patients at an ad-vanced age contribute to the low recurrence rates [36]. In our study, only 2 out of 22 patients (9%) were observed to have experienced recurrence. The patient who underwent subtotal resection ex-perienced recurrence after 5 years, while the tumor that was completely resected recurred after 7 years. Long-term studies on spinal meningiomas, especially regarding late recurrences, are lim-ited. Levy et al. reported a late recurrence rate of 4% [4], while Solero et al. reported it as 1.3% [5]. Mirimanoff et al. [30] provided insight into recurrence-free rates after surgery. After total re-section, the rates were reported as 93%, 80%, and 68% at 5, 10, and 15 years, respectively. In con-trast, after subtotal resection, the progression-free rates were significantly lower at 63%, 45%, and 9% during the same periods.

Adjuvant therapy

While the preferred treatment for spinal meningioma is the complete removal of the tumor through microsurgery, Mirimanoff et al. [30] suggested considering radiotherapy as an additional treatment following subtotal excision. Radiotherapy can effectively manage unexcised or recur-rent meningiomas. However, the role of radiotherapy in treating spinal meningioma remains con-troversial due to the disease's slow progression and the potential harm caused by radiation. Gezen et al [9] reported no recurrence in two patients who underwent radiotherapy for recurrent spinal meningioma. Roux et al [3] also conducted radiosurgery in two patients with recurrences, and both patients remained stable during a follow-up examination after 5 years. The authors recommend radiotherapy in specific scenarios: early recurrence post-total or subtotal resection, situations where complete resection isn't feasible due to tumor location or the patient's medical condition, and instances where there's a high surgical risk. If early recurrence occurs, reoperation should pre-cede radiotherapy. In our study, adjuvant therapy in the form of radiotherapy was administered to one patient who experienced lesion recurrence after 5 years.

Conclusions

This study illustrates that spinal meningioma is a slow-growing tumor typically manifesting be-tween the fourth and fifth decades of life, with a female-to-male ratio of 2:1. Pain stands out as the most common symptom during presentation. Radiological investigations such as CT scans and MRI play a crucial role in providing a presumptive diagnosis of spinal meningioma, later con-firmed by histopathological examination. Surgery remains the primary treatment, albeit it may be complicated by postoperative issues like wound infection, CSF leak, or bowel/bladder dysfunc-tion. In cases of recurrence or advanced disease, adjuvant therapy in the form of radiotherapy can be considered for palliative purposes.

Declarations

Ethics approval and consent to participate: The study was assessed by the Institutional ethics committee of SKIMS and was considered exempt from review in accordance with the observa-tional study that was done. A written consent to participate in study was taken form the patient or guardian in case of minor.

Availability of data and material: N/A.
Competing interests: The authors declare that they have no competing interests.
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References

1. Mawrin C, Perry A. Pathological classification and molecular genetics of meningiomas. J Neurooncol. 2010;99:379-91.
2. McLendon RE, Rosenblum MK, Biggner DD. Russell and Rubinstein's Pathology of Tu-mors of the Nervous System. 2006.
3. Roux FX, Nataf F, Pinaudeau M, Borne G, Devaux B, Meder JF. Intraspinal meningiomas: review of 54 cases with discussion of poor prognosis factors and modern therapeutic man-agement. Surg Neurol. 1996; 46: 458-63.
4. Levy WJ Jr, Bay J , Dohn D. Spinal cord meningioma. J Neurosurg. 1982;57:804-812.
5. Iacob G. Spinal Meningiomas: Personal experience and review of literature. Romanian Neurosurgery. 2014;21(2):146–160.
6. Solero CL , Fornari M , Giombini S , Lasio G , Oliveri G, Cimino C . Spinal meningiomas: review of 174 operated cases. . 1989;25:153-160.
7. Winn HR. Youmans Neurological Surgery Elsevier Health Sciences. 2011.
8. Bucci MN, McGillicuddy JE, Taren JA, Hoff JT. Management of anteriorly located C1-C2 neurofibromata. Surg Neurol 1990;33:15-18.
9. Hu HP, Haung QL. Signal intensity correlation of MRI with pathological findings in spinal neurinomas. Neuroradiology 1992;34:98-102.
10. Gezen F, Kahraman S, Canakci Z , Bedük;. A Review of 36 cases of spinal cord meningio-ma.;. Spine (Phila Pa 1976). 2009;25:727-731.
11. Weber DC , Lovblad KO, Rogers L. New pathology classification, imagery techniques and prospective trials for meningiomas: the future looks bright. Curr Opin Neurol 2010;23:563-570.
12. Quekel LG , Versteege CW. The "dural tail sign" in MRI of spinal meningiomas.;. J Com-put Assist Tomogr 1995;19:890-892.
13. Klekamp J , Samii M. Surgical results for spinal meningiomas. Surg Neurol. 1999;52:552-562.
14. Stein BM, Leeds NE, Taveras JM, Pool JL . Meningiomas of the Foramen Magnum. J Neu-rosurg 1963;20:740-751.
15. Gottfried ON, Gulf W, Quinones-Hinojosa A, Kan P, Schmidt MH; Spinal meningiomas: surgical management and outcome. Neurosurg Focus 2003; 14: e2.
16. Dodd RL , Ryu MR, Kamnerdsupaphon P, Gibbs IC, Chang SD Jr, Adler JR Jr. CyberKnife radiosurgery for benign intradural extramedullary spinal tumors. Neurosurgery 2006;58:674-685.
17. Gerszten PC, Ozhasoglu C, Burton SA, Vogel WJ, Atkins BA. Kalnicki S, Welch WC. CyberKnife frameless single-fraction stereotactic radiosurgery for benign tumors of the spine. Neurosurg Focus. 2003;14:e16.
18. Gerszten PC, Burton SA,Ozhasglu C, McCue KJ, Quinn AE. Radiosurgery for benign in-tradural spinal tumors. Neurosurgery. 2008;62:887-895.
19. Payer M. The anterior approach to anterior cervical meningiomas: review illustrated by a case. Acta Neurochir (Wien). 2005;147:555-560.
20. Kim MS, Eun JP, Park JS. A dumbbell-shaped meningioma mimicking a schwannoma in the thoracic spine. J Korean Neurosurg Soc. 2011;50:264-267.
21. Raza SM, Anderson WS, Eberhart CG, Wolinsky JP, Gokaslan ZL. The application of sur-gical cordectomy in the management of an intramedullaryextramedullary atypical menin-gioma: case report and literature review. J Spinal Disord Tech 2005;18: 449-454.
22. Teo M , Zrinzo L , King A , Aspoas AR, David KM. Giant extradural sacral meningio-ma.;Acta Neurochir (Wien). 2010;152:485-488.
23. Rutherford SA, Linton KM, Durnian JM, Cowie RA. Epidural meningioma of the sacral canal. Case report. J Neurosurg Spine. 2006;4:71-74.
24. Lista-Martínez O, Santín-Amo JM, Facal-Varela S, Rossi-Mautone E, Rivas Lopez LA, Amaro-Cendon S. Multifocal clear cell meningioma in the sacral and lumbar spine. Case report and literature review. Neurocir Astur. 2012;23:259-263.
25. Bhadra AK , Casey AT, Saifuddin A, Briggs TW . Primary atypical sacral meningioma--not always benign. Skeletal Radiol. 2007;36:S91-94.
26. Tolias C, Beale DJ, Sakas DE. Giant lumbar meningioma: a common tumor in an unusual location. Neuroradiology 1997;39:276-277.
27. Petit H, Jomin M, Jeulin-Gaillard B, Warot P. Multiple "non-associated" spinal meningi-omas. Lille Med. 1980;25:346-349.
28. Tsuji N, Nishiura I , Koyama T. Extradural multiple spinal meningioma. Literature review a case report. Neurochirurgia (Stuttg). 1986;29:124-127.
29. Lloyd SK, Evans DJ. Neurofibromatosis type 2 (NF2): diagnosis and management. Handb Clin Neurol 2013;115:957-967.
30. Namer IJ, Pamir MN, Benli K, Saglam S, Erbengi A. Spinal meningiomas. Neurochirurgie 1987;30:11–15.

31. Mirimanoff RO, Dosretz DE, Lingood RM, Ojemann RG, Martuza RL. Meningioma: Analysis of recurrence and progression following neurosurgical resection. J Neurosurg. 1985;62:18-24.
32. Nelson JS, Parisi JE, Schochet SS. Principles and practice of neuropathology. Non-GlialTumors StLouis,MO:Mosby-YearBook, Inc. 1993:203–213.
33. Rothman RH, Simeone FA, Weinstein JN, McLain RF. Tumors of the Spine. Philadelphia: WB Saunders Co. 1992;3rd ed:1299–1300.
34. Calogero JA, Moossy J. Extradural spinal meningiomas. J Neurosurg. 1972;37:442-7.
35. Riad H, Knafo S, Segnarbieux F, Lonjon N. Spinal meningioma: Surgical outcome and lit-eratüre review. Neurochirurgie. 2013;59:30-34.
36. Davis RA, Washburn PL. Spinal cord meningiomas. Surg Cv necol Obst. 1970;131:15- 21
37. King AT, Sharr MM, Gullan RW . Spinal meningiomas: a 20-year review Br J Neurosurg. 1998;12:521-526.
38. Ketter R, Henn W, Niedermayer I . Predictive value of progression-associated chromoso-mal aberrations for the prognosis of meningiomas: a retrospective study of 198 cases. J Neurosurg 2001;95:601-607.
39. Umana GE, Scalia G, Vats A, Pompili G, Barone F, Passanisi M, Graziano F, Maugeri R, Tranchina MG, Cosentino S, Ippolito M. Primary extracranial meningiomas of the head and neck. Life. 2021 Sep 9;11(9):942.
40. Umana GE, Passanisi M, Chaurasia B, Scalia G. Incidental craniovertebral junction schwannoma: Surgical or radiosurgical management?. Clinical Case Reports. 2023 Jun;11(6):e7616.

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Gravitational bullet injuries. Unique insights for further investigations

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ABSTRACT
Gravitational bullet injuries, prevalent in the Middle East, particularly in Iraq, are a critical public health concern, often resulting from celebratory gunfire. In our Neurosurgery Teaching Hospital in Baghdad, we've observed that these injuries differ significantly from high-velocity gunshot wounds, characterized by lower velocity and energy due to air resistance and gravity. Unlike high-velocity bullets, gravitational bullets cause less bone fragmentation and radial brain damage. These bullets often end up on the tentorium or within the skull base, rarely transgressing the cerebellar tentorium on a vertical trajectory. We've also noticed that the pediatric population, particularly younger children, are more susceptible to these injuries due to their thinner cranial vertex, leading to more penetrating injuries and aggressive brain bleeding. Our observations underline the need for focused studies, awareness, regulation, and tailored management strategies to combat this overlooked issue.

Keywords
bullet,
injuries

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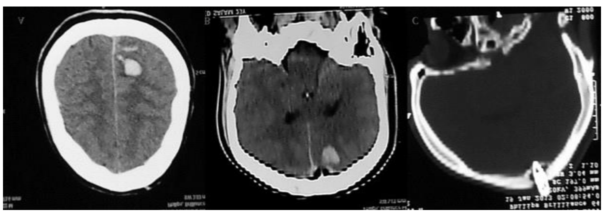
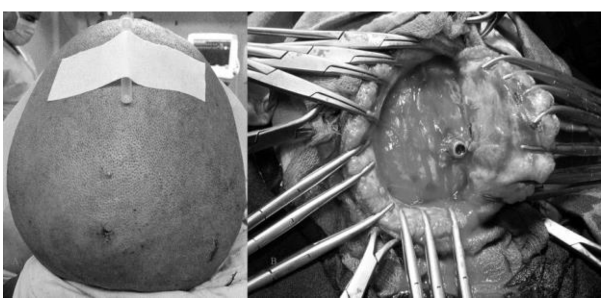
We are writing to share our experience and observations with gravitational bullet injuries, an overlooked yet pressing public health issue, particularly prevalent in the Middle East and notably in Iraq. Over the years, celebratory gunfire, a culturally ingrained phenomenon usually associated with joyous occasions such as weddings and national team football victories or sorrowful events such as the death of a head of a tribe. Nonetheless, it has inadvertently led to a significant number of such injuries [3].

From our extensive experience treating these victims In the Neurosurgery Teaching Hospital in Baghdad; we have gleaned some unique insights. The nature of gravitational bullet injuries differs greatly from that of high-velocity gunshot wounds due to the distinct ballistic characteristics of the projectiles. Gravitational bullets are typically characterized by a lower velocity, attributable to air resistance and the force of gravity, as they descend from their peak altitude. Despite the reduced speed, their mass and shape still have the potential to inflict significant damage upon impact. In contrast to high-velocity bullets, these falling bullets deposit less kinetic energy into the skull, which decreases the likelihood of extensive bone fragmentation and secondary projectiles [2]. This lower energy transfer also leads to a lesser cavitation effect, a phenomenon of temporary cavity formation seen prominently in high-velocity gunshot wounds, which causes extensive radial damage to the surrounding brain tissue [1].



A 23-year-old male presented to our emergency department with an acute onset of scalp bleeding. His initial head computed tomography (CT) scans (Axial and coronal views) show (A, B respectively) intraparenchymal hemorrhage near the superior sagittal sinus. (C) is sagittal bone window CT scan exhibits the metallic object (bullet) penetrating the calvarium near the vertex and reaching the parenchyma of the brain.



Our experience has consistently shown that gravitational bullets, upon entering the cranium, invariably end up either on the tentorium or within the skull base. In the cases that we encountered, gravitational bullets can rarely transgress the cerebellar tentorium if they have a vertical trajectory. This uniform pattern provides us with valuable information about the behavior of these projectiles after cranial entry and may inform surgical approaches, enabling more precise predictions about injury patterns, and improving patient outcomes. Such a phenomenon could be explained by the fact that gravitational bullets are low-velocity projectiles with low kinetic energy.

Furthermore, a particular observation from our clinical experience that warrants further investigation concerns the pediatric population's vulnerability to gravitational bullet injuries. A study conducted by Smith et al. [4] demonstrated that both bone thickness and density increase with age from birth to 18 years, which suggests that the pediatric population, particularly younger children, have a significantly thinner cranial vertex than adults.

The reduced cranial thickness may render this age group more susceptible to severe injury from gravitational bullets. Further, we have noticed that following a gravitational bullet wound, brain injury, and bleeding tend to be more aggressive than adults as the protective vertex bone is thinner resulting in more penetrating injury.

Understanding the reasons behind this more severe presentation in the pediatric population is crucial. Contributing factors could be multifactorial, encompassing the relative vascularity of the pediatric brain, differing responses to trauma, and even elements relating to the gravitational bullet's trajectory or velocity. These observations underscore the importance of tailoring management strategies to this age group, with a focus on prompt surgical intervention and rigorous hemodynamic stabilization.

These observations highlight the urgent need for comprehensive studies on the unique characteristics and outcomes of gravitational bullet injuries. Given the specific cultural context driving the prevalence of these injuries, it is imperative to understand the unique dynamics of gravitational bullet wounds. Greater awareness, stricter regulation of celebratory gunfire, and enhanced understanding of these injuries can collectively contribute to reducing their incidence and improving care for those affected.

References

1. Abdali HA, Hoz SS, Moscote-Salazar LR. Cranial Gravitational (Falling) Bullet Injuries: Point of View. J Neurosci Rural Pract. 2018 Apr-Jun;9(2):278-280.
2. Alvis-Miranda HR, Rubiano AM, Agrawal A, Rojas A, Moscote-Salazar LR, Satyarthee GD, Calderon-Miranda WG, Hernandez NE, Zabaleta-Churio N. Craniocerebral gunshot injuries; a review of the current literature. Bulletin of Emergency & Trauma. 2016 Apr;4(2):65.
3. Shuker ST, Sadda R. Craniomaxillofacial falling bullet injuries and management. J Oral Maxillofac Surg 2010;68:1593-601.
4. Smith K, Politte D, Reiker G, Nolan TS, Hildebolt C, Mattson C, Tucker D, Prior F, Turovets S, Larson-Prior LJ.

Automated measurement of pediatric cranial bone thickness and density from clinical computed tomography. In 2012 Annual International Conference of the IEEE Engineering in Medicine and Biology Society 2012 Aug 28 (pp. 4462-4465). IEEE.

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Posterior auricular artery. Anatomical variations and neurosurgical applications

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ABSTRACT
Introduction: The posterior auricular artery (PAA) is the preterminal branch of the external carotid artery (ECA), arising superiorly to the occipital artery (OA). The PAA has quite a few anatomical variations and established neurosurgical applications. We conducted this study as an overview to illustrate all neurosurgical aspects regarding this artery, its reconstructive uses, and anatomical variation.
Method: We performed a literature review in Google Scholar and PubMed medical databases for studies discussing the PAA, its anatomical variations, and neurosurgical applications.
Results: We identified 30 articles that discuss the anatomical variations and neurosurgical applications of the PAA. While reviewing the available articles and original works regarding PAA.
Conclusion: The PAA has considerable anatomical variations regarding its origin, course, branches, and length. The related neurosurgical applications of PAA include bypass, embolization, aneurysm, AVM, and reconstruction flaps.

INTRODUCTION

The posterior auricular artery (PAA) is the preterminal branch of the external carotid artery (ECA), arising superiorly to the occipital artery (OA), and coursing between the mastoid process anteriorly and the external auditory meatus posteriorly, accompanying the posterior auricular nerve (16). PAA crosses the facial nerve inferior to the stylomastoid foramen and then mainly passes lateral to it. PAA gives off three to five branches supplying part of the external ear, retroauricular area, and part of the facial nerve (15), finally terminating at any point distally between its origin and the vertex (24).

The PAA has limited considerations in standard neurosurgical and neuro-radiographical textbooks (25). Therefore, we conducted this study as an overview to illustrate all neurosurgical aspects regarding this artery, its reconstructive uses, and anatomical variation.

Methods

We searched the databases Google Scholar and PubMed for articles about the PAA, its anatomical variants, and neurosurgical applications. We used the following search terms: "posterior auricular artery vascular anatomy", "posterior auricular artery neurosurgical applications". We included the studies that were written in English and had suitable methodology for the targeted data, while exclusion criteria were, i) non-English papers, ii) questionable results. Results were categorized and selected appropriately. The data extraction includes surgical anatomy and neurosurgical application of the PAA.

Results

We located 30 publications that go into the anatomical differences and neurosurgical uses of the PAA. Considering the inclusion and exclusion criteria, review the original articles and papers on PAA that are currently available. We outline the surgical anatomy of PAA, including its origin, path, branches, diameter, and length. Also covered were the uses of PAA and its significance in neurosurgical bypass and aneurysms.

Discussion

1.PAA anatomy

1.1 PAA Origin

The PAA is a posterior branch of the ECA, arising 25 mm superior to the OA between the parotid gland and stylomastoid foramen (26). PAA originates independently from ECA in most instances: in 10-15% of cases it arises with the OA as an occipito-auricular trunk. PAA could arise with the Ascending Pharyngeal Artery in 1-7% (15,30). However, some authors reported the absence of PAA in two out of ten specimens (23).

1.2 PAA Course

PAA arises lateral to the upper border of the posterior belly of the digastric muscle, ascending backward and upward along or superficial to it. At the level of the stylomastoid foramen, it runs in the auriculo-mastoid sulcus, between the mastoid process anteriorly in at a mean distance of 0.29 cm and the external auditory meatus posteriorly at a mean distance of 1.19 cm parallel to the Frankfort plane. At this point, PAA is superficial, suprafascial, and subcutaneous (16,26).

PAA's position on the anterior surface of the mastoid process is considered to be an important landmark in the surgical identification of the facial nerve in parotidectomy (3). Its location posterior to the external auditory meatus parallel to the Frankfort plane is considered to be ideally located in the posterior border of a standard craniotomy around the Sylvian point (18).

PAA continues to ascend vertically under the cranial surface of the concha, deep into the posterior auricular muscle (15). PAA terminates in the temporoparietal area in 33% of individuals; this variant of PAA is ideally appropriate to establish an extracranial-intracranial bypass when the vessel diameter is large enough. PAA usually terminates in the posterior auricular region in 67% (8,20).

1.3 PAA Branches

PAA divides into auricular and occipital branches; these branches usually arise superior to the mastoid tip to supply the digastric, stylohyoid, sternocleidomastoid muscles, and the parotid gland (6). The mean distance of the auricular branch above the mastoid tip was 0.68 cm, and the mean distance of the occipital branch above the mastoid tip was 0.84 cm (16). The former branches ascend the posterior auricular surface upward and vertically towards the helical rim, passing over the helical margin (20). The later branch can sometimes be palpated as it crosses the mastoid process (1).

The Transverse Nuchal is the third and terminal branch of PAA that anastomoses with the contralateral branch on the midline. And its presence makes the cutaneous territory of the PAA extend to an inferior strip below the OA's territory. Touré et al. reported the constant presence of this branch, although it was mentioned only once in the literature (26).

Some studies reported the presence of parotid and sternocleidomastoid branches separately in some dissections below the level of the mastoid tip (17). The Stylomastoid artery is a small branch that arises from PAA and enters the stylomastoid foramen with the facial nerve to supply the extracranial part of the nerve, the tympanic cavity, the mastoid antrum, and the semicircular canals (6,7). The stylomastoid artery originates from the PAA in 70% of the specimens, from the OA in 20%, and directly from the ECA in 10% in a study by Moreau et al. (17). Whereas, the stylomastoid artery originates from the OA in over than three-quarters of patients, and less commonly from the PAA in less than one-quarter of the patients, in another study by Upile et al. (Figure 1) (27).

PAA is the dominant artery supplying the ear, including retroauricular skin, in 93% of cases, in the other 7%, OA dominates (29). The angiosome of PAA is found to supply an area of 6*10 cm2, extend anteriorly from the tragus to 5 cm far from the external auditory canal posteriorly, and supply 6 cm inferior to the mastoid process (21).

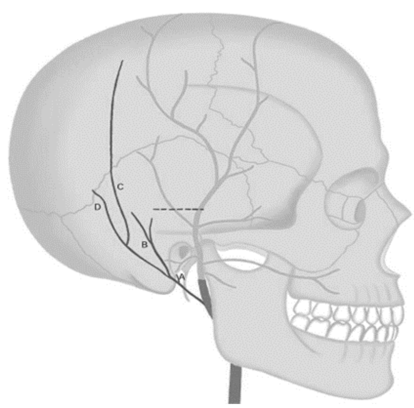

Figure 1. PAA main branches A; stylomastoid artery, B; auricular branch, C; transverse nuchal artery, D; occipital branch. Dotted line represents upper helix margin. Faded artery is superficial temporal artery.

PAA Length

PAA is acknowledged to be one of the ECA's small branches that supplies a small area behind the ear and parts of the external ear relatively (25). However, a recent study by Tokugawa et al. determined a variation in the length of PAA by classifying it into four main types, according to its length on the angiography, as shown in (Table.1). This classification did not include the diameter and the size of the PAA (24).

Table 1. Novel Classification of the Posterior Auricular Artery Based on Angiographical Appearance (24)

Type	Termination	Angiographical characteristics	%
A	between PAA origin and the center of the external auditory meatus	Short, slender, and sometimes so faint that cine angiography was needed for identification	15.1%
B	between the center of the external auditory meatus and the top of the helix	More obvious than Type A but still slender	34.9%
C	between the top of the helix and the vertex	Easy to identify but not as large as the superficial temporal artery or OA	48.8%
D	PAA reaches up to the vertex in	As large as, or sometimes larger, than the or OA	1.2%

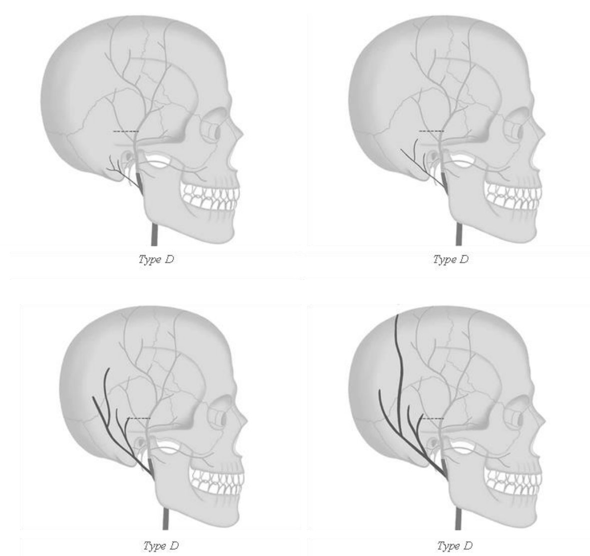

Figure 2. classification of PAA based angiografical appearance, type C,D are possible candidates for extracranial intracranial bypass for cerebral revascularization. Dotted line represents upper helix margin.

2. Neurosurgical applications

2.1 Bypass

PAA is considered as an extra-vessel within the scalp vasculature, which raises its importance as a donor artery (8). PAA variant that reach the temporoparietal area with at least 1 mm of diameter can be used for various extracranial-intracranial bypass surgeries;

this type of PAA has a prevalence of 5.7% (25). Usual arterial candidates for extracranial-intracranial bypass surgeries are the superficial temporal artery and to a lesser extent, OA can be used (9).

PAA can be used as a donor artery for extracranial-intracranial bypass revascularization surgeries for multiple cerebrovascular cases, including initial and refractory cases of moyamoya disease. Initial management by PAA was primarily in cases of an absent parietal superficial temporal artery, which was found in 50 autopsy specimens (13).

PAA-based bypass can also be used in intracranial aneurysm surgery with a decided sacrifice of the parent vessel. It can also be used in symptomatic atherosclerosis of internal carotid artery (ICA).

2.2 Embolization

Embolization of PAA has been reported in the literature in multiple aspects. Embolization of ECA for endovascular treatment of dural arteriovenous fistula or decompression of skull base tumors has some concerns, regarding extracranial-intracranial anastomosis routes to avoid the possible risk of embolic stroke or cranial nerve palsies (7). One of these anastomoses involves PAA extracranially through the stylomastoid artery that supplies cranial nerve VII. Proximal embolization of these arteries with particles can lead to temporary cranial nerve palsy, while distal embolization with either particles or liquid materials will lead to permanent cranial nerve palsy or can open connections with the intracranial contributions (22). Direct embolization of PAA as a feeder for dural arteriovenous malformation (AVM) has been reported to be safe, without significant complications or recurrence. However, Jankowitz BT et al, reported ear necrosis after onyx embolization of PAA for dural AVM (10).

2.3 AVM of PAA

AVM most commonly occurs intracranially, it is rare to occur in the head and neck region. A retrospective review of extracranial AVMs revealed 61% of external AVMs occur in the cheeks, followed by the ear area in 16% of cases, and the PAA is the main feeder artery (11). Traumatic AVMs of the PAA, unlike spontaneous ones, occur commonly in the head and neck area, most likely due to penetrating trauma (5). Both kinds of scalp AVMs present as pulsatile masses, palpable thrills, machine-like bruits, pulsatile tinnitus and cranial nerve compression. S W Cha et al, reported a 2-month-post-trauma PAA- internal jugular vein fistula (4).

Color doppler ultrasound guided by MRI, CT scan, and angiography is used to aid in the diagnosis of scalp AVMs (4). PAA could be a feeder artery for retroauricular AVMs or dural AVMs.

Management of the scalp PAA-originating AVM require total removal by excision or embolization of the feeder artery. Partial removal of such lesions could lead to recurrence (4).

2.4 Aneurysm of PAA

Aneurysms that originate from ECA and its branches are rare; they arise either due to atherosclerosis changes or trauma. Fibromuscular dysplasia is responsible for a small entity of ECA aneurysms. Traumatic pseudoaneurysms of PAA mostly present as auricular or retroauricular pulsating masses, with thrill and audiable bruit. Bleeding, compression symptoms could be other presentations for a PAA pseudoaneurysm. Management of ECA pseudoaneurysms, including PAA aneurysms, involves surgical repair or embolization. Wang D et al, stated that embolization of ECA pseudoaneurysms is a good alternative to open surgical management to avoid post-operative morbidity (28).

2.5 PAA flaps

Several PAA-based flaps have been used since sixties of the past century. PAA flaps are largely used for external ear, mastoid bowel reconstruction, and nose repair. Recent articles described island PAA flaps for face reconstruction. Pedicle PAA flaps for temoroparietal soft tissue grafting. McKinnon BJ confirmed the possibility of harvesting an 8*4 cm scalp pedicled flap based on PAA in the posterior auricular area, depending on the commonest PAA variant. A larger flap could result in arterial insufficiency with further distant skin necrosis and venous congestion (19). However, Lescour et al. (14) reported a case of PAA-dominant scalp vascularization that helped harvesting a 16 cm scalp flap based on PAA to reconstruct an occipital wound defect. Kolhe S P et al. (12) retrieved from dissection of 50 cadavers that a PAA variant with only a small auricular and stylomastoid artery as terminal branches, which resemble a type A variant, have no possibility of harvesting a flap. This type was encountered in 1.4% of his cadaveric studies.

Pericranial flaps

Dural defects and CSF leaks are major complications after skull base surgeries, in most instances, local vascularized pedicle percranial flaps are used. Percranial flaps are periosteal flaps for large dural defects. Stow NW et al. have described a smaller, deep periosteal branch of PAA running over the mastoid process and supplying mastoid cortex. As a result, the reconstructive potential of a PAA-based pericranial flap should be clearly considered (2).

Conclusion

The PAA has considerable variations in its surgical anatomy involving its origin, course, branches and length. This article aims to highlight the significance of PAA for neurosurgery procedures such bypass, embolization, aneurysm, and AVM surgery. These variations establish an important implication of PAA in the neurosurgical field. It is vital for neurosurgeons to have a complete understanding of the PAA's anatomical variances prior to any treatments, as these variations can affect the success and consequences of endovascular procedures.

References

1. Alvernia JE, Fraser K, Lanzino G. The Occipital Artery: Amicroanatomical Study. Operative Neurosurgery. 2006 Feb 1;58(suppl_1):ONS-114.
2. Archer SM, Jones RO. Traumatic pseudoaneurysm of the posterior auricular artery. Southern medical journal. 1992 Jan;85(1):47-8.
3. Beahrs OH, Adson MA. The surgical anatomy and technic of parotidectomy. Plastic and Reconstructive Surgery. 1958 Sep 1;22(3):276-7.
4. Bist SS, Saxena RK. Arteriovenous malformation and Color Doppler: posterior auricular artery. Indian Journal of Otolaryngology and Head and Neck Surgery. 2006 Jul 1;58(3):318-20.
5. Chae SW, Kang HJ, Lee HM, Hwang SJ. Tinnitus caused by traumatic posterior auricular artery–internal jugular vein fistula. The Journal of Laryngology & Otology. 2001 Apr;115(4):313-5.
6. Elvan Ö, Bobuş A, Erdoğan S, Aktekin M, Olgunus ZK. Fetal anatomy of the facial nerve trunk and its relationship with posterior auricular artery. Surgical and Radiologic Anatomy. 2019 Feb;41(2):153-9.
7. Geibprasert S, Pongpech S, Armstrong D, Krings T. Dangerous extracranial–intracranial anastomoses and supply to the cranial nerves: vessels the neurointerventionalist needs to know. American journal of neuroradiology. 2009 Sep 1;30(8):1459-68.
8. Germans MR, Regli L. Posterior auricular artery as an alternative donor vessel for extracranial-intracranial bypass surgery. Acta neurochirurgica. 2014 Nov;156(11):2095-101.
9. Horiuchi T, Kusano Y, Asanuma M, Hongo K. Posterior auricular artery-middle cerebral artery bypass for additional surgery of moyamoya disease. Acta neurochirurgica. 2012 Mar;154(3):455-6.
10. Jankowitz BT, Vora N, Jovin T, Horowitz M. Ear Necrosis Resulting from the Endovascular Onyx-18 Embolization of a Dural Arteriovenous Fistula Fed by the Posterior Auricular Artery. Journal of Neuroimaging. 2009 Jul;19(3):259-62.
11. Kim SH, Han SH, Song Y, Park CS, Song JJ. Arteriovenous malformation of the external ear: a clinical assessment with a scoping review of the literature☆. Brazilian journal of otorhinolaryngology. 2017 Nov;83:683-90.
12. Kolhe PS, Leonard AG. The posterior auricular flap: anatomical studies. British journal of plastic surgery. 1987 Nov 1;40(6):562-9.
13. Kurihara H, Yamaguchi K, Ishikawa T, Funatsu T, Matsuoka G, Omura Y, Okada Y, Kawamata T. Direct double bypass using the posterior auricular artery as initial surgery for moyamoya disease. Journal of neurosurgery. 2019 Aug 23;133(4):1168-71.
14. Lescour V, Perrot P, Ruiz F, Hamel A, Duteille F. Scalp flap pedicled on the posterior auricular artery. Anatomical study and clinical application. InAnnals of Aesthetic Plastic Surgery 2015 Jun 1 (Vol. 60, No. 3, pp. 235-241). Elsevier Masson.
15. Liu M, Wang SJ, Benet A, Meybodi AT, Tabani H, El-Sayed IH. Posterior auricular artery as a novel anatomic landmark for identification of the facial nerve: A cadaveric study. Head & neck. 2018 Jul;40(7):1461-5.
16. McKinnon BJ, Wall MP, Karakla DW. The vascular anatomy and angiosome of the posterior auricular artery: a cadaver study. Archives of facial plastic surgery. 1999 Jun 1;1(2):101-4.
17. Moreau S, Bourdon N, Salame E, Goullet de Rugy M, Babin E, Valdazo A, Delmas P. Facial nerve: vascular-related anatomy at the stylomastoid foramen. Ann Otol Rhinol Laryngol. 2000 Sep;109(9):849-52.
18. Newell DW, Vilela MD. Superficial temporal artery to middle cerebral artery bypass. Neurosurgery. 2004 Jun 1;54(6):1441-9.
19. Oufkir AA, Kajout M, Chadli R, Alami MN. Comments on the article "Scalp flap with pedicle on the posterior auricular artery. Anatomical study and clinical application ". InAnnals of Aesthetic Plastic Surgery 2015 Jun 1 (Vol. 60, No. 3, pp. 252-253). Elsevier Masson.
20. Pinar YA, Ikiz ZA, Bilge OK. Arterial anatomy of the auricle: its importance for reconstructive surgery. Surgical and Radiologic Anatomy. 2003 Aug 1;25(3-4):175.
21. Sharma RK, Pandey SK. Extended posterior auricular artery flap for coverage of a large temporo-parietal

defect. Journal of Plastic, Reconstructive & Aesthetic Surgery. 2010 Nov 1;63(11):e775-8.

22. Siddiqui AH, Chen PR. Intracranial collateral anastomoses: relevance to endovascular procedures. Neurosurgery Clinics of North America. 2009 Jul 1;20(3):279-96.
23. Tilotta F, Lazaroo B, Laujac MH, Gaudy JF. A study of the vascularization of the auricle by dissection and diaphanization. Surgical and radiologic anatomy. 2009 Apr;31(4):259-65.
24. Tokugawa J, Cho N, Suzuki H, Sugiyama N, Akiyama O, Nakao Y, Yamamoto T. Novel classification of the posterior auricular artery based on angiographical appearance. Plos one. 2015 Jun 1;10(6):e0128723.
25. Tokugawa J, Nakao Y, Kudo K, Iimura K, Esaki T, Yamamoto T, Mori K. Posterior Auricular Artery-Middle Cerebral Artery Bypass: A Rare Superficial Temporal Artery Variant with Well-developed Posterior Auricular Artery–Case Report. Neurologia medico-chirurgica. 2014;54(10):841-4.
26. Touré G, Méningaud JP, Vacher C. Arterial vascularization of occipital scalp: mapping of vascular cutaneous territories and surgical applications. Surgical and radiologic anatomy. 2010 Oct 1;32(8):739-43.
27. Upile T, Jerjes W, Nouraei SA, Singh SU, Kafas P, Sandison A, Sudhoff H, Hopper C. The stylomastoid artery as an anatomical landmark to the facial nerve during parotid surgery: a clinico-anatomic study. World Journal of Surgical Oncology. 2009 Dec;7(1):1-5.
28. Wang D, Su L, Han Y, Fan X. Embolization treatment of pseudoaneurysms originating from the external carotid artery. Journal of vascular surgery. 2015 Apr 1;61(4):920-6.
29. Wang Y, Zhuang X, Jiang H, Yang Q, Zhao Y, Han J, Yu D, Zhang Z. The anatomy and application of the postauricular fascia flap in auricular reconstruction for congenital microtia. Journal of Plastic, Reconstructive & Aesthetic Surgery. 2008 Jan 1;61:S70-6.
30. Zümre Ö, Salbacak A, Çiçekcibaşi AE, Tuncer I, Seker M. Investigation of the bifurcation level of the common carotid artery and variations of the branches of the external carotid artery in human fetuses. Annals of Anatomy-Anatomischer Anzeiger. 2005 Sep 1;187(4):361-9.

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Potential psychological responses in patients who underwent MRI scanning

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ABSTRACT

This paper explores the potential impact of magnetic resonance imaging (MRI) on patients' psychological states, focusing on reported mood changes post-procedure. Factors influencing the psychological state during an MRI, including claustrophobia, noise, scan duration, and fear of the unknown, are discussed. We also draw parallels with darkness therapy, a stress and depression management technique, due to the similar environment. Notably, a subset of patients reported transient improvement in depressive symptoms following an MRI, suggesting a need for further research. The paper underscores the necessity for rigorous scientific exploration of these observations to validate them and better inform patients about possible mood alterations post-MRI.

BACKGROUND

Depression, a significant global contributor to disability, often goes undiagnosed due to its subjective diagnostic process, which primarily relies on clinical observations [16]. Recently, magnetic resonance imaging (MRI) has shown promise for enhancing our understanding and management of depression. MRI's potential lies in its ability to detect structural changes in the brain associated with depression. Notably, incidental mood improvement observed following MRI scans requires further examination [16]. This paper aims to investigate the potential psychological effects of undergoing an MRI, specifically the impact on mood disorders, and to explore the possible implications of these effects in a clinical context.

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MRI

MRI, introduced in the 1980s, has revolutionized diagnostic imaging with its diverse applications across neurological, psychiatric, cardiac, abdominal, musculoskeletal, and vascular fields. Despite MRI's general safety, certain contraindications exist, particularly for patients with cardiac implantable electronic devices (CIEDs) or metal/magnetic implants. Additionally, some surgical stents, implants, clips, wires, rods, patches, and tattoos require cautious evaluation before MRI use [5,7,18]. The duration of an MRI scan varies between 20 to 60 minutes [5]. Anecdotally, we've observed mood changes in patients post-MRI, a phenomenon yet to be well-documented in scientific literature.

The direct effects of magnetic fields on a patient's psychological state are poorly understood. However, FDA-approved repetitive transcranial magnetic stimulation (rTMS), which uses magnetic fields to treat medication-resistant depression, shows an average response rate of 29.3% in major depressive disorder cases [4,6,15]. Moreover, according to Wang et al., administering low-frequency pulsed magnetic field stimulation (a type of TMS) at a frequency of 1Hz could potentially alleviate depression symptoms in rats that have undergone prolonged unpredictable stress [17].

Hattapoğlu et al. studied cervical disc herniation patients using pulsed electromagnetic fields (PEMF). Studying different factors, including pain, anxiety, and depression, after the therapy, which lasted for 12th weeks, showed improvement in the pain, anxiety, depression, sleep, and quality of life scores as known pain can cause limitations and affect psychological state; however, no evidence can explain if the enhancement in the anxiety and depression state related solitary to the improvement of the pain, may the magnetic field have an unspecified role in this improvement [9].

Interestingly, studies suggest that fetuses develop memories six weeks before birth, possibly through exposure to low-level light passing through the human skin into the uterus [6]. The resemblance between the confined space and low light level of the uterus and an MRI machine may possibly induce a soothing effect, explaining post-scan mood changes. Given the similar magnetic principles underlying MRI and rTMS, the potential mood-altering effects of MRI warrant further investigation, particularly for patients with depressive disorders.

Several factors associated with the MRI procedure could potentially influence a patient's psychological state:

1. Claustrophobia: The confining nature of MRI machines can induce claustrophobia, a fear of enclosed spaces, which may provoke anxiety or panic in some individuals [10].
2. Noise: MRI machines' loud, recurring sounds during the scan can be distressing, leading to increased discomfort or anxiety for some patients [3].
3. Duration: The length of an MRI scan, which varies from a few minutes to over an hour, can exacerbate feelings of restlessness, impatience, or anxiety [2]. However, The duration and the frequency of the exposure play a significant role in the psychological state; according to a study by Ghotbi et al., workers at a copper electrolysis unit who were exposed chronically to static magnetic fields experienced a notable increase in depression, anxiety, and sleep disorders [8]. Furthermore, being subjected frequently to extremely low-frequency electromagnetic fields (ELF-EMF) has led to memory impairment, anxiety, stress-related behaviors, and behavior resembling depression in rats [1].
4. Uncertainty: Patients unfamiliar with the MRI procedure may experience fear or anxiety from the unknown, including potential health risks or apprehension about scan results.
5. Darkness therapy: This prevalent treatment technique, entailing a restful, solitary period in a dimly lit space for 24-48 hours, has demonstrated efficacy in managing stress and depression, providing self-recognition, and facilitating potential spiritual experiences [12]. Flotation rest, a form of darkness therapy, has been associated with mental and physical benefits like improved mood, reduced stress, enhanced athletic performance, and increased creativity. Some patients have reported contrasting experiences during MRI procedures, akin to aspects of darkness therapy [14].

In conclusion, while the majority of patients reported minimal mood changes post-MRI, a subset observed a temporary upliftment in depressive symptoms in the days following the procedure. These findings highlight a potential direction for future research: exploring the possible therapeutic effects of MRI on mood disorders. As a part of ethical patient care, future considerations could involve informing patients about this potential "side effect." Despite the controversy surrounding this issue and the current lack of substantial scientific evidence, further studies are warranted to investigate this phenomenon.

References

1. Bagheri Hosseinabadi M, Khanjani N, Ebrahimi MH, Haji B, Abdolahfard M. Chronic exposure to extremely low-frequency electromagnetic fields affects sleep quality, stress, depression, and anxiety. Electromagn Biol Med. 2019;38(1):96-101.
2. Beker K, Garces-Descovich A, Mangosing J, Cabral-Goncalves I, Hallett D, Mortele KJ. Optimizing MRI Logistics: Prospective Analysis of Performance, Efficiency, and Patient Throughput. AJR Am J Roentgenol. 2017 Oct;209(4):836-844.
3. Bongers S, Slottje P, Kromhout H. Hearing loss associated with repeated MRI acquisition procedure-related acoustic noise exposure: an occupational cohort study. Occup Environ Med. 2017 Nov;74(11):776-784.
4. Cheng CM, Li CT, Tsai SJ. Current Updates on Newer Forms of Transcranial Magnetic Stimulation in Major Depression. Adv Exp Med Biol. 2021; 1305:333-349.
5. Edelstein WA, Mahesh M, Carrino JA. MRI: time is dose--and money and versatility. J Am Coll Radiol. 2010 Aug;7(8):650-2.
6. Ford H, Hahn L, Clarke P, Gill S, Carnell B, Galletly C. A comparison of 15-minute vs. 30-minute repetitive transcranial magnetic stimulation sessions for treatment-resistant depression - are longer treatment sessions more effective? J Affect Disord. 2021 Mar 1; 282:974-978.
7. Ghadimi M, Sapra A. Magnetic Resonance Imaging Contraindications. [Updated 2023 May 1]. In: StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing; 2023 Jan.
8. Ghotbi, M. R., Mardi, H., Khanjani, N., et al. (2015). Occupational exposure to steady magnetic fields and workers' mental health at the copper electrolysis unit. J. Saf. Stud. 1:1–10.
9. Hattapoğlu E, Batmaz İ, Dilek B, Karakoç M, Em S, Çevik R. Efficiency of pulsed electromagnetic fields on pain, disability, anxiety, depression, and quality of life in patients with cervical disc herniation: a randomized controlled study. Turk J Med Sci. 2019 Aug 8;49(4):1095-1101.
10. Iwan E, Yang J, Enders J, Napp AE, Rief M, Dewey M. Patient preferences for development in MRI scanner design: a survey of claustrophobic patients in a randomized study. Eur Radiol. 2021 Mar;31(3):1325-1335.
11. Lang A, Ott P, Del Giudice R, Schabus M. Memory Traces Formed in Utero-Newborns' Autonomic and Neuronal Responses to Prenatal Stimuli and the Maternal Voice. Brain Sci. 2020 Nov 11;10(11):837.
12. Malůš, Marek & Kavková, Veronika & Kupka, M.. (2014). The Darkness therapy is a tool for reducing anxiety, depression and increasing well-being (2014).
13. Reid et al., 2017 V.M. Reid, K. Dunn, R.J. Young, J. Amu, T. Donovan, N. Reissland The human fetus preferentially engages with face-like visual stimuli Current Biology: CB, 27 (12) (2017), pp. 1825-1828 e1823.
14. Reiter RJ, Tamura H, Tan DX, Xu XY. Melatonin and the circadian system: contributions to successful female reproduction. Fertil Steril. 2014 Aug;102(2):321-8.
15. Taylor R, Galvez V, Loo C. Transcranial magnetic stimulation (TMS) safety: a practical guide for psychiatrists. Australas Psychiatry. 2018 Apr;26(2):189-192. Epub 2018 Jan 17.
16. Vaziri-Bozorg SM, Ghasemi-Esfe AR, Khalilzadeh O, Sotoudeh H, Rokni-Yazdi Antidepressant effects of magnetic resonance imaging-based stimulation on major depressive disorder: a double-blind, randomized clinical trial. Brain Imaging Behav. 2012 Mar;6(1):70-6.
17. Wang L, Yang J, Wang F, Zhou P, Wang K, Ming D. Modulation of Low-Frequency Pulsed Magnetic Field on Hippocampal Neural Oscillation in Depression Rats. Annu Int Conf IEEE Eng Med Biol Soc. 2018 Jul; 2018:259-262.
18. Yousaf T, Dervenoulas G, Politis M. Advances in MRI Methodology. Int Rev Neurobiol. 2018; 141:31-76.

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Supratrochlear artery. Anatomy, variations and neurosurgical applications

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ABSTRACT

Introduction. The supratrochlear artery (STA) is a small vessel with a relatively tiny and quite constant course. The literature describing the STA fails to provide a collective description of the anatomy and neurosurgical applications of the STA. Therefore, we are here to present an overview of anatomy, anatomical variability, and the clinical application of STA.

Method. We conducted a literature review in Google Scholar and PubMed medical databases to review the existing studies on STA regarding its anatomy and neurosurgical applications.

Results. We identified 18 articles that discuss the anatomical variations and neurosurgical applications of the STA. Certain parameters are used to describe the surgical anatomy of STA, including origin, course, diameter, branches, depth, and distance in relation to the midline and vertical glabellar line. We also discussed certain applications of STA and its importance in neurosurgical reconstruction flaps and the diagnosis of carotid artery disease.

Conclusion. Comparable to the supraorbital artery (SOA), the STA is less variable in its anatomical course, and exhibits a more superficial course. The STA has certain important neurosurgical applications through its involvement in reconstruction flaps for the skull base and plays an important role in the diagnosis of carotid artery disease.

INTRODUCTION

The supratrochlear artery (STA) is a terminal branch of the ophthalmic artery. It is a small vessel with a relatively tiny and quite constant course (2). Although its anatomical path is predictable, several anatomical variations in its origin and branches have been reported, even within the two hemi-faces of the same individual (10). Notwithstanding its relatively pitiful size, the STA has an essential role in the blood supply of the glabellar region and the neighboring medial aspect of the forehead (3). Furthermore, a rich anastomotic vascular network was formed that connected the following vessels: STA, Supraorbital artery (SOA) and angular artery (AA) in the nasoglabellar region. It is crucial to mention that STA communication with internal and external carotid arteries is feasible, amplifying the STA's role. (7)

Understanding the anatomy of the forehead and its vascularity plays an important role in skin flap and gives the best chance to of graft survival. The STA has certain important neurosurgical applications through its involvement in reconstruction flaps for the skull base and plays an important role in the diagnosis of carotid artery disease.

The literature describing the STA fails to provide a collective description of the anatomy and neurosurgical applications of the STA. Therefore, we are here presenting an overview of anatomy, anatomical variability, and the clinical application of STA.

Methods

In order to assess the existing research on STA with regard to its anatomy and neurosurgical applications, we did a literature review in the medical databases Google Scholar and PubMed. The following search terms were used: “supratrochlear artery anatomy”, “supratrochlear artery vascular anatomy variations”. We include the studies with the following criteria: i) English language, ii) suitable methodology for targeted data. We exclude the studies which are i) non-English, ii) questionable results. Results were categorized and selected appropriately. The data extraction includes surgical anatomy and neurosurgical application of STA.

Results

While reading the available articles and original works regarding SOA, taking into consideration the inclusion and exclusion criteria, 18 papers that cover the anatomical variants and neurosurgical uses of the STA were found. The origin, course, diameter, branches, depth, and distance from the midline and vertical glabellar line are some of the characteristics used to characterize the surgical anatomy of STA. We also covered other STA uses, including its significance in carotid artery disease diagnostics and neurosurgical repair flaps.

Discussion

1. STA anatomy

STA exhibits a more superficial course than SOA and has less variability in its anatomical path. Moreover, the branching pattern of the STA and the vessel’s relationship to bony and soft tissue landmarks were remarkably consistent. (15)

1.1 STA origin

The STA originated as a terminal branch of the ophthalmic artery, which represents the first branch of the internal carotid artery inside the cranial cavity (2). This was found in 85% of cases, while in the remaining one, the STA and the SOA originated as a single vessel from the ophthalmic artery that bifurcates later on, forming the STA and SOA (2,7). Klenjet reported unusual incidents cases in which STA was absent. In the first case, the paracentral artery, a branch of the AA, contributed to maintaining the blood supply as a lateral branch in the paramedian position of the forehead. While in the second one, a lateral branch from the paracentral artery arises. Later, it connects with the transverse frontal artery, the frontal branch of the superficial temporal artery, following a transverse course (10). There's a rare case when STA originates directly from the AA as described by Cong et al. (5).

1.2 STA course

The STA traverses the trochlea, accompanying the supratrochlear nerve. Subsequently, it crosses the supraorbital margin to penetrate the orbital septum and reach the forehead (16). Later, it passes between the forehead's muscles; corrugator supercilii, orbicularis oculi, and the frontalis muscle just above mid-forehead; it penetrates the frontalis muscle to be subcutaneous (17).

Moreover, STA participates in a rich anastomotic network in the nasoglabellar region with the AA, the SOA, and their contralateral vessels to create vascular arcades, allowing in this way the communication of the internal carotid artery (ICA) with the external carotid artery (ECA) (3). In addition, this network of anastomoses includes, apart from the infraorbital, the lateral nasal, the bilateral dorsal nasal, and tiny periosteal perforating arteries that are responsible for supplying the paranasal region

(4,9). Furthermore, there is another anastomosis formed between the lateral branches of STA, SOA, and the frontal branch of the superficial temporal artery. Last but not least, several horizontal arteries cross the midline to connect the pair of STAs (12).

1.3 STA branches

An overabundance of STA branches exists in the literature. Kleintjes describes Nine side branches of the STA (10). These branches supply the periosteum of the supraorbital rim and glabella, the muscle of the upper eyelid, corrugator supercilii, the frontalis, and the procerus muscle. Furthermore, cutaneous branches supply the skin of the glabella and the medial aspect of the forehead (3). In most cases, STA divides into superficial and deep branches, although in some cases, the deep branch was absent (figure 1) (7).

Figure 1 shows the branches of supratrochlear artery

1.4 STA depth

The average distance between the skin surface and STA at the horizontal mid-eyebrow level was 3.34 mm and it varies with differences in facial expression. Furthermore, no statistically significant difference was reported between genders and sides. Cotofana et al. study on generalized linear models for age, BMI, and forehead width revealed no statistical influence on the depth for the STA (6).

1.5 STA diameter

The mean diameter of the STA was 0.90 ± 0.02 mm (range, 0.5-1.3 mm) when measured at the horizontal mid-eyebrow level (6).

1.6 Distance of STA from the Midline

The mean distance between the STA and the midline at rest was 16.13 mm and 14.80 mm for males and females, respectively. Furthermore, zero percent of STA were located within 5 mm from the midline (6).

1.7 Relationship between STA and Vertical Glabellar Line

In addition, the mean distance between the STA and the ipsilateral vertical glabellar line at rest was in 10.59 mm and 8.21 mm in males and females, respectively (6).

2. Neurosurgical application of STA

In contrast to SOA, STA applications in the field of neurosurgery are quite limited; although both arteries have almost the same course and run parallel and near each other, the usage of SOA is greater than that of STA. The reason behind this is unknown.

2.1 Pericranial flap

Anteriorly based pericranial flaps are one of the pedicled flaps that are widely in anterior cranial base reconstruction because of their simplicity, reliability, and low morbidity. STA has an important contribution to the arterial supply of the pericranial flap through the deep branches that divided from the main trunk at, below, or above the level of the supraorbital rim (18,14,11).

2.2 Diagnosis of carotid artery diseases

STA has been implicated in the diagnosis of disease in the common and internal carotid arteries. The technique involves non-invasive directional continuous wave doppler ultrasound to assess the direction of flow in the STA and waveform analysis of the common carotid and STA signals. This technique provides a safe, atraumatic method of assessing patients with symptoms of extracranial arterial disease (13,8).

Conclusion

STA has less variability in its anatomical structure and limited neurosurgical applications comparable to SOA. However, STA is still a valuable option for certain neurosurgical procedures, such as bypass surgeries. It provides a reliable source of blood flow and can be easily accessed and manipulated during surgery. In order to clarify both the benefits and drawbacks of STA in neurosurgical procedures, more study needs to be conducted.

References

1. Abdelhady A, Patel BC, Aslam S, Al Aboud DM. Anatomy, Head and Neck, Eye Superior Oblique Muscle. 2021 Aug 11. In: STtPearls [Internet]. Treasure Island (FL): STtPearls Publishing; 2021 Jan–. PMID: 30725837.

2. Agorgianitis L,Panagouli E,Tsakotos G,Tsoucalas G,Filippou D, The STRevisited: An Anatomic Review in Favor of Modern Cosmetic Applications in the Area. Cureus. 2020 Feb 29; [PubMed PMID: 32257686]
3. Cai XY,Li ZM,Xu YB,Cheng G,Luo P, [The anatomic features of supratrochlear artery]. Zhonghua zheng xing wai ke za zhi = Zhonghua zhengxing waike zazhi = Chinese journal of plastic surgery. 2009 Nov; [PubMed PMID: 20209940]
4. Cho KH, Dalla Pozza E, Toth G, Bassiri Gharb B, Zins JE: Pathophysiology study of fillerinduced blindness. Aesthet Surg J. 2019, 39:96-106. 10.1093/asj/sjy141
5. Cong LY, Lee SH, Tansatit T, Hu KS, Kim HJ: Topographic anatomy of the inferior medial palpebral artery and its relevance to the pretarsal roll augmentation. Plast Reconstr Surg. 2016, 138:430-436. 10.1097/PRS.0000000000002434
6. Cotofana S, Alfertshofer M, Frank K, Bertucci V, Beleznay K, Nikolis A, Sykes J, Swift A, Lachman N, Schenck TL. Relationship between vertical glabellar lines and the supratrochlear and supraorbital arteries. Aesthetic surgery journal. 2020 Dec;40(12):1341-8.
7. Erdogmus S, Govsa F: Anatomy of the supraorbital region and the evaluation of it for the reconstruction of facial defects. J Craniofac Surg. 2007, 18:104-112.
8. Keller H, Meier W, Yonekawa Y, Kumpe D. Noninavasive angiography for the diagnosis of carotid artery disease using Doppler ultrasound (carotid artery Doppler). Stroke. 1976 Jul;7(4):354-63.
9. Kelly CP, Yavuzer R, Keskin M, Bradford M, Govila L, Jackson IT: Functional anastomotic relationship between the supratrochlear and facial arteries: an anatomical study. Plast Reconstr Surg. 2008, 121:458-465. 10.1097/01.prs.0000297651.52729.ec
10. Kleintjes WG, Forehead anatomy: arterial variations and venous link of the midline forehead flap. Journal of plastic, reconstructive [PubMed PMID: 17485046]
11. Potpari Z, Fukuta K, Colen LB, Jackson IT, Carraway JH. Galeo-pericranial flaps in the forehead: a study of blood supply and volumes. British journal of plastic surgery. 1996 Jan 1;49(8):519-28.
12. Potparić Z, Fukuta K, Colen LB, Jackson IT, Carraway JH: Galeo-pericranial flaps in the forehead: a study of blood supply and volumes. Br J Plast Surg. 1996, 49:519-528.
13. Prichard DR, Martin TR, Sherriff SB. Assessment of directional Doppler ultrasound techniques in the diagnosis of carotid artery diseases. Journal of Neurology, Neurosurgery & Psychiatry. 1979 Jun 1;42(6):563-8.
14. Safavi-Abbasi S, Komune N, Archer JB, Sun H, Theodore N, James J, Little AS, Nakaji P, Sughrue ME, Rhoton AL, Spetzler RF. Surgical anatomy and utility of pedicled vascularized tissue flaps for multilayered repair of skull base defects. Journal of neurosurgery. 2016 Aug 1;125(2):419-30.
15. Schwenn OK, Wüstenberg EG, Konerding MA, Hattenbach LO. Experimental percutaneous cannulation of the supraorbital arteries: implication for future therapy. Investigative ophthalmology & visual science. 2005 May 1;46(5):1557-60.
16. Shum rick KA,Smith TL, The anatomic basis for the design of forehead flaps in nasal reconstruction. Archives of otolaryngology--head [PubMed PMID: 1554465]
17. Walker HM,Chauhan PR, Anatomy, Head and Neck, Glabella 2020 Jan; [PubMed PMID: 32310453]
18. Yoshioka N, Rhoton Jr AL. Vascular anatomy of the anteriorly based pericranial flap. Neurosurgery. 2005 Jul 1;57(1 Suppl):11-6.

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The impact of rehabilitation programs on patients postoperative recovery after spine surgery

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ABSTRACT

Spine surgery is a common intervention aimed at improving the lives of individuals with various spinal conditions, and the success of this procedure extends beyond the operating room to the postoperative recovery phase. This research paper explores the impact of rehabilitation programs on postoperative recovery in spine surgery patients. By delving into the multidisciplinary approach of rehabilitation, including physical therapy, occupational therapy, pain management, and patient education, the study aims to provide a comprehensive understanding of how these programs optimize outcomes and restore functional abilities.

Rehabilitation programs play a vital role in managing postoperative pain, restoring mobility, promoting muscle strength, and enhancing overall functional abilities. The paper investigates the specific interventions involved, such as physical therapy exercises, manual therapy, pain management strategies, and patient education, highlighting their collective contribution to a holistic recovery process. The benefits of rehabilitation programs extend beyond physical aspects to address the psychological and emotional well-being of patients, providing a supportive environment through counselling and stress management techniques.

Factors influencing the effectiveness of rehabilitation programs, including patient-specific factors, surgical complexity, timing, and patient compliance, are examined. The study draws upon a comprehensive literature review, presenting evidence from research studies, randomized controlled trials, and prospective cohort studies that consistently demonstrate the positive impact of rehabilitation programs on pain management, functional outcomes, and quality of life.

Challenges in implementing rehabilitation programs, such as resource constraints and patient education, are acknowledged, and potential strategies for improvement are proposed. These include the integration of technology, collaboration among healthcare professionals, and a focus on patient education and engagement to enhance accessibility and effectiveness.

In conclusion, this research underscores the critical role of rehabilitation programs in optimizing postoperative recovery for spine surgery patients. The findings have implications for clinical practice, emphasizing the need for comprehensive, tailored rehabilitation approaches, collaboration among healthcare professionals, and the integration of technology to further improve patient outcomes. Future research should explore the optimal timing and duration of rehabilitation interventions, comparative studies of different approaches, and long-term outcomes to inform clinical decision-making in the field of spine surgery recovery.

Keywords
rehabilitation,
postoperative recovery,
spine surgery

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INTRODUCTION

Spine surgery is a commonly performed procedure aimed at alleviating pain, improving functionality, and enhancing the quality of life for individuals with various spinal conditions. While surgical intervention can be effective in addressing specific pathologies, such as herniated discs, spinal stenosis, or degenerative disc disease, the success of the procedure relies not only on the surgical technique but also on the subsequent postoperative recovery process. The recovery phase plays a critical role in achieving optimal outcomes and restoring patients' functional abilities. (1,2)

The postoperative period following spine surgery represents a critical phase for patients to regain functionality and return to their daily activities. Rehabilitation programs specifically designed for spine surgery patients play a pivotal role in optimising the recovery process. These programs encompass a comprehensive and multidisciplinary approach, involving physical therapy, occupational therapy, pain management, and patient education. By addressing pain, restoring mobility, promoting muscle strength, and enhancing overall functional abilities, rehabilitation programs aim to maximise the long-term benefits of spine surgery. (3,4)

The purpose of this research paper is to explore and evaluate the impact of rehabilitation programs on postoperative recovery in spine surgery patients. By examining the benefits, factors influencing effectiveness, research studies supporting the efficacy of rehabilitation programs, and challenges in implementation, we aim to provide a comprehensive understanding of the role of rehabilitation in optimising outcomes and enhancing functional recovery for individuals undergoing spine surgery.

THE ROLE OF REHABILITATION PROGRAMS IN SPINE SURGERY RECOVERY

Rehabilitation programs play a crucial role in facilitating the recovery process for individuals undergoing spine surgery. These programs are designed to address the specific needs of patients and aim to achieve several key goals. Firstly, they focus on managing postoperative pain through a combination of pharmacological interventions, physical modalities, and pain education techniques. Secondly, rehabilitation programs aim to restore mobility and improve range of motion through targeted exercises, stretching, and manual therapy. Additionally, these programs promote muscle strength, stability, and endurance to enhance functional abilities. Lastly, rehabilitation programs provide patient education and guidance to promote self-management skills, independence, and a smooth transition back to daily activities. (5, 6)

Postoperative rehabilitation programs for spine surgery patients typically adopt a multidisciplinary approach. This approach involves collaboration among various healthcare professionals, including physical therapists, occupational therapists, pain specialists, and psychologists. Each discipline brings unique expertise and contributes to different aspects of the patient's recovery. Physical therapists focus on improving physical function, mobility, and strength through tailored exercise programs. Occupational therapists address activities of daily living, work-related tasks, and ergonomic adjustments to facilitate a safe return to regular routines. Pain specialists provide pain management strategies, including medication management and interventions such as nerve blocks. Psychologists offer support, counselling, and coping strategies to address emotional well-being and mental health during the recovery process. (7, 8)

Rehabilitation programs for spine surgery recovery incorporate a variety of interventions to address the unique needs of each patient. These interventions may include:

Physical therapy exercises: Specific exercises are prescribed to improve muscle strength, flexibility, and overall mobility. These may include stretching, aerobic conditioning, core stabilisation exercises, and functional training. (9)

Manual therapy: Techniques such as joint mobilisation, soft tissue mobilisation, and spinal manipulation are employed by physical therapists to enhance joint mobility, alleviate pain, and restore proper movement patterns. (10)

Pain management strategies: Pharmacological interventions, such as non-steroidal anti-inflammatory drugs (NSAIDs), opioids, and adjuvant medications, may be utilised in combination with other modalities to manage postoperative pain effectively. (11,12)

Patient education and self-management: Rehabilitation programs emphasise educating patients about their condition, postoperative precautions, proper body mechanics, and strategies for self-management of symptoms. This empowers patients to actively participate in their recovery process and make informed decisions about their health. (13)

BENEFITS OF REHABILITATION PROGRAMS IN POSTOPERATIVE SPINE SURGERY

Rehabilitation programs in postoperative spine surgery play a vital role in effectively managing pain and reducing the reliance on medication. Through a combination of therapeutic exercises, manual therapy techniques, and pain education, these programs aim to address the underlying causes of pain and promote effective pain management strategies. By improving muscular strength, enhancing flexibility, and optimising movement patterns, rehabilitation helps alleviate pain and discomfort. As a result, patients may experience reduced dependence on pain medications, such as opioids, leading to improved overall pain control and minimising the potential risks associated with long-term medication use. (14, 15)

Rehabilitation programs are designed to restore and enhance mobility, range of motion, and functional abilities in patients undergoing spine surgery. Through specific exercises and therapeutic interventions, such as stretching, strengthening, and functional training, these programs aim to improve physical capabilities. Rehabilitation helps regain lost mobility, restore normal joint function, and enhance overall functional performance. By targeting specific impairments and limitations, patients can achieve improved movement patterns, increased flexibility, and enhanced functional abilities required for daily activities, work, and recreational pursuits. (16, 17)

Rehabilitation programs in postoperative spine surgery not only address the physical aspects but also prioritise the psychological and emotional well-being of patients. Surgery and the subsequent recovery process can be emotionally challenging, leading to anxiety, depression, and a reduced quality of life. Rehabilitation programs provide a supportive environment and incorporate psychological interventions to help patients cope with the emotional aspects of their recovery. Through education, counselling, and techniques such as relaxation exercises and stress management, rehabilitation programs aim to improve psychological well-being, promote positive coping strategies, and enhance overall emotional resilience. (18, 19)

Rehabilitation programs in postoperative spine surgery also play a crucial role in preventing postoperative complications and rehospitalization. These programs focus on early mobilization, optimizing respiratory function, and educating patients on proper wound care and postoperative precautions. By addressing potential complications such as deep vein thrombosis, pneumonia, and surgical site infections, rehabilitation programs help minimize the risk of complications and reduce the likelihood of rehospitalization. Furthermore, early intervention and close monitoring during the recovery process enable healthcare professionals to detect and address any potential issues promptly, leading to improved overall outcomes. (20,21)

FACTORS INFLUENCING THE EFFECTIVENESS OF REHABILITATION PROGRAMS

The effectiveness of rehabilitation programs in postoperative spine surgery can be influenced by patient-specific factors. Age, comorbidities, and overall health play a significant role in determining the outcomes of rehabilitation interventions. Older patients may have reduced physiological reserves and slower healing processes, which can affect the pace and extent of recovery. The presence of comorbid conditions, such as diabetes or cardiovascular disease, can impact the response to rehabilitation and the ability to engage in certain exercises. Additionally, the overall health status and functional capacity of the patient prior to surgery can influence the potential for improvement and the ability to achieve rehabilitation goals. (22,23)

The type and complexity of the surgical procedure performed on the spine can impact the effectiveness of rehabilitation programs. Different surgical techniques, such as spinal fusion, discectomy, or laminectomy, require specific considerations in the rehabilitation process. The extent of tissue trauma, surgical site stability, and postoperative restrictions influence the rehabilitation approach and progression. Complex spine surgeries involving extensive fusion or instrumentation may necessitate a more gradual and cautious rehabilitation program to ensure proper healing and optimal outcomes. Therefore, tailoring the rehabilitation interventions to the specific surgical procedure is essential for achieving successful recovery. (24, 25)

The timing and duration of rehabilitation interventions can significantly impact their effectiveness in postoperative spine surgery. Early initiation of rehabilitation, when deemed appropriate by the healthcare team, allows for the optimization of wound healing, prevention of complications, and early mobilization. The duration of rehabilitation varies depending on the individual's progress and the complexity of the surgery. It is essential to strike a balance between providing sufficient time for tissue healing and allowing for progressive rehabilitation. Tailoring the timing and duration of rehabilitation interventions to individual patient needs and surgical considerations is crucial for achieving optimal outcomes. (26, 27)

Patient compliance and adherence to the prescribed rehabilitation program play a crucial role in determining its effectiveness. Patients need to actively engage in their rehabilitation, consistently performing exercises, following postoperative precautions, and attending scheduled sessions. Compliance with activity modifications, lifestyle changes, and home exercise programs contributes to successful outcomes. Patient education, clear communication, and ongoing support from the healthcare team can help promote adherence to the rehabilitation program. Identifying and addressing barriers to compliance, such as pain, fatigue, or psychosocial factors, are essential for maximizing the benefits of rehabilitation. (28 ,29)

LITERATURE REVIEW AND EVIDENCE SUPPORTING THE EFFICACY OF REHABILITATION PROGRAMS

Numerous research studies and clinical trials have investigated the efficacy of rehabilitation programs in postoperative spine surgery. These studies have examined various aspects, including pain management, functional outcomes, patient satisfaction, and quality of life. The research has utilized both quantitative and qualitative methods to evaluate the effectiveness of rehabilitation interventions. Randomized controlled trials, prospective cohort studies, and systematic reviews form the foundation of the evidence base. These studies have involved diverse patient populations, different surgical procedures, and various rehabilitation approaches to provide a comprehensive understanding of the benefits of rehabilitation in spine surgery recovery.

One meta-analysis evaluated the effectiveness of physical therapy in patients undergoing lumbar spinal fusion surgery. The study concluded that physical therapy interventions, including exercise programs, mobilization, and education, resulted in improved functional outcomes and reduced disability in postoperative patients.(5)

In one prospective cohort study, the authors investigated the association between physical therapy utilization and subsequent healthcare costs in patients with acute low back pain. The study found that early physical therapy intervention led to decreased healthcare costs and utilization of healthcare resources, highlighting the cost-effectiveness of rehabilitation programs. (30)

Analysis of outcomes and results demonstrating the positive impact of rehabilitation programs

Multiple research studies and clinical trials have consistently demonstrated the positive impact of rehabilitation programs in postoperative spine surgery. These interventions have shown significant improvements in pain management, functional outcomes, and overall quality of life. Patients participating in rehabilitation programs have reported reduced pain intensity, decreased reliance on pain medications, and improved physical functioning, including mobility, range of motion, and functional abilities. Furthermore, rehabilitation interventions have been associated with enhanced psychological well-being, reduced postoperative complications, and decreased rates of rehospitalization. The cumulative evidence strongly supports the efficacy of rehabilitation programs in optimizing recovery and improving patient outcomes following spine surgery.

One randomized controlled trial compared surgical and nonsurgical treatment approaches for lumbar degenerative spondylolisthesis. The study demonstrated that both surgical and nonsurgical treatment led to significant improvements in pain and function. However, the surgical group had greater improvements in the short term, emphasizing the potential benefits of rehabilitation following surgery. (31)

In one retrospective analysis examined the longitudinal association between incident lumbar spine MRI findings and chronic low back pain or radicular symptoms. The study found that specific

MRI findings were not strongly associated with the development of chronic low back pain or radicular symptoms, highlighting the importance of a comprehensive approach to rehabilitation that considers individual patient characteristics and symptoms. (32)

Challenges and limitations in implementing rehabilitation programs

One of the significant challenges in implementing rehabilitation programs in postoperative spine surgery is resource constraints and limited access to rehabilitation services. Availability of specialized rehabilitation centers, trained healthcare professionals, and necessary equipment can vary across different healthcare settings. In some regions or communities, there may be a shortage of rehabilitation facilities or a lack of financial resources to support comprehensive rehabilitation programs. This can result in limited access to appropriate rehabilitation interventions, delayed initiation of therapy, and suboptimal outcomes for patients undergoing spine surgery. (33)

Variations in healthcare settings and availability of specialized rehabilitation centers

The availability and accessibility of specialized rehabilitation centers can vary across different healthcare settings. While some regions may have well-established rehabilitation centers with experienced multidisciplinary teams, others may have limited options or rely on general healthcare facilities for postoperative rehabilitation. Variations in the availability of specialized rehabilitation centers can impact the quality and continuity of care for patients undergoing spine surgery. Patients in remote areas or underserved communities may face challenges in accessing appropriate rehabilitation services, leading to potential disparities in outcomes. (34)

Patient education and awareness about the importance of rehabilitation in postoperative spine surgery can present a significant challenge. Some patients may have limited knowledge or misconceptions about the role and benefits of rehabilitation. This can result in hesitancy to participate in rehabilitation programs, lack of compliance with prescribed exercises, or premature discontinuation of therapy. It is crucial to educate patients about the goals, rationale, and expected outcomes of rehabilitation, empowering them to actively engage in the recovery process and adhere to the rehabilitation program. (30,35)

Strategies for improving rehabilitation programs in spine surgery recovery

The integration of technology and digital solutions in rehabilitation can enhance the effectiveness and accessibility of postoperative spine surgery recovery programs. Telemedicine, mobile applications, wearable devices, and virtual reality platforms offer opportunities for remote monitoring, real-time feedback, and home-based rehabilitation. These technologies can facilitate personalized exercise programs, provide educational resources, and track patient progress. By leveraging technology, rehabilitation programs can reach a broader patient population, improve adherence to therapy, and enable more frequent communication between healthcare providers and patients. (36, 37)

Collaboration between healthcare professionals, including surgeons, physiatrists, physical therapists, and occupational therapists, along with rehabilitation specialists, is crucial for optimizing postoperative spine surgery recovery. Multidisciplinary team-based care allows for comprehensive assessment, personalized treatment planning, and coordinated rehabilitation interventions. Regular communication and coordination among team members ensure that rehabilitation programs are tailored to individual patient needs and goals. Collaboration also promotes seamless transitions of care from the acute surgical setting to outpatient rehabilitation, ensuring continuity and effectiveness of the rehabilitation process. (38)

Patient education and engagement play a vital role in the success of rehabilitation programs in spine surgery recovery. Educating patients about their condition, surgical procedure, and the importance of rehabilitation fosters active participation and promotes adherence to therapy. Providing clear instructions, written materials, and multimedia resources empowers patients to take ownership of their recovery journey. Involving patients in goal setting, shared decision-making, and self-monitoring of progress enhances motivation and encourages long-term engagement in the rehabilitation process. (39,40)

Conclusion

In summary, rehabilitation programs play a crucial role in the postoperative recovery of spine surgery patients. The benefits of these programs include improved pain management, enhanced mobility and functional abilities, and better psychological and emotional well-being. Rehabilitation programs also contribute to the prevention of postoperative complications and rehospitalization. Research studies and clinical trials have provided evidence supporting the efficacy of rehabilitation interventions in improving outcomes in postoperative spine surgery patients. Factors influencing the effectiveness of these programs include patient-specific factors, the surgical procedure complexity, timing and duration of interventions, and patient compliance.

The findings discussed in this paper have several implications for clinical practice. Healthcare professionals should consider incorporating comprehensive rehabilitation programs into the standard care pathway for spine surgery patients. Collaboration between healthcare professionals and rehabilitation specialists is crucial to ensure coordinated and individualized care. Patient education and engagement should be prioritized to optimize adherence to the rehabilitation program. Furthermore, the integration of technology and digital solutions can enhance the accessibility and effectiveness of rehabilitation interventions.

Future research should focus on further investigating the optimal timing and duration of rehabilitation interventions in different spine surgery populations. Comparative studies evaluating different rehabilitation approaches and strategies would provide valuable insights into the most effective interventions. Additionally, research exploring the long-term outcomes and cost-effectiveness of rehabilitation programs in postoperative spine surgery patients would further inform clinical decision-making.

References

1. Deyo RA, Mirza SK, Martin BI, Kreuter W, Goodman DC, Jarvik JG. Trends, major medical complications, and charges associated with surgery for lumbar spinal stenosis in older adults. JAMA. 2010;303(13):1259-1265. doi:10.1001/jama.2010.338
2. Bono CM, Ghiselli G, Gilbert TJ, et al. An evidence-based clinical guideline for the diagnosis and treatment of cervical radiculopathy from degenerative disorders. Spine J. 2011;11(1):64-72. doi:10.1016/j.spinee.2010.10.023
3. Manchikanti L, Singh V, Falco FJ, Cash KA, Fellows B. Comparative outcomes of a 2-year follow-up of cervical medial branch blocks in management of chronic neck pain: a randomized, double-blind controlled trial. Pain Physician. 2010;13(5):437-450.
4. Manchikanti L, Singh V, Falco FJ, Cash KA, Fellows B. Comparative outcomes of a 2-year follow-up of cervical medial branch blocks in management of chronic neck pain: a randomized, double-blind controlled trial. Pain Physician. 2010;13(5):437-450.
5. Madera M, Brady J, Deily S, et al. The role of physical therapy and rehabilitation after lumbar fusion surgery for degenerative disease: a systematic review. J Neurosurg Spine. 2017;26(6):694-704. doi:10.3171/2016.10.SPINE16627
6. Urits I, Burshtein A, Sharma M, et al. Low Back Pain, a Comprehensive Review: Pathophysiology, Diagnosis, and Treatment. Curr Pain Headache Rep. 2019;23(3):23. Published 2019 Mar 11. doi:10.1007/s11916-019-0757-1
7. Gatchel RJ, McGeary DD, McGeary CA, Lippe B. Interdisciplinary chronic pain management: past, present, and future. Am Psychol. 2014;69(2):119-130. doi:10.1037/a0035514
8. Kamper SJ, Apeldoorn AT, Chiarotto A, et al. Multidisciplinary biopsychosocial rehabilitation for chronic low back pain: Cochrane systematic review and meta-analysis. BMJ. 2015;350:h444. Published 2015 Feb 18. doi:10.1136/bmj.h444
9. Greenwood J, McGregor A, Jones F, Mullane J, Hurley M. Rehabilitation Following Lumbar Fusion Surgery: A Systematic Review and Meta-Analysis. Spine (Phila Pa 1976). 2016;41(1):E28-E36. doi:10.1097/BRS.0000000000001132
10. Synnott A, O'Keeffe M, Bunzli S, Dankaerts W, O'Sullivan P, O'Sullivan K. Physiotherapists may stigmatise or feel unprepared to treat people with low back pain and psychosocial factors that influence recovery: a systematic review. Journal of physiotherapy. 2015 Apr 1;61(2):68-76.
11. Sutbeyaz ST, Sezer N, Koseoglu BF. The effect of pulsed electromagnetic fields in the treatment of cervical osteoarthritis: a randomized, double-blind, sham-controlled trial. Rheumatol Int. 2006;26(4):320-324. doi:10.1007/s00296-005-0600-3
12. Van Backer JT, Jordan MR, Leahy DT, Moore JS, Callas P, Dominick T, Cataldo PA. Preemptive analgesia decreases pain following anorectal surgery: a prospective, randomized, double-blinded, placebo-controlled trial. Diseases of the Colon & Rectum. 2018 Jul 1;61(7):824-9.
13. Skolasky RL, Mackenzie EJ, Wegener ST, Riley III LH. Patient activation and adherence to physical therapy in persons undergoing spine surgery. Spine. 2008 Oct 10;33(21):E784.
14. Chou R, Qaseem A, Snow V, et al. Diagnosis and treatment of low back pain: a joint clinical practice

guideline from the American College of Physicians and the American Pain Society [published correction appears in Ann Intern Med. 2008 Feb 5;148(3):247-8]. Ann Intern Med. 2007;147(7):478-491. doi:10.7326/0003-4819-147-7-200710020-00006

15. Jirarattanaphochai K, Jung S. Nonsteroidal antiinflammatory drugs for postoperative pain management after lumbar spine surgery: a meta-analysis of randomized controlled trials. J Neurosurg Spine. 2008;9(1):22-31. doi:10.3171/SPI/2008/9/7/022
16. Mombell K, Perry N, Wade SM, Fredericks D, Glassman D, Morrissey P. Physical therapy after lumbar spinal fusion is necessary to optimize patient outcomes. Clinical Spine Surgery. 2019 Jul 1;32(6):223-5.
17. Iversen MD, Fossel AH, Katz JN. Enhancing function in older adults with chronic low back pain: a pilot study of endurance training. Arch Phys Med Rehabil. 2003;84(9):1324-1331. doi:10.1016/s0003-9993(03)00198-9
18. Vowles KE, Witkiewitz K, Sowden G, Ashworth J. Acceptance and commitment therapy for chronic pain: evidence of mediation and clinically significant change following an abbreviated interdisciplinary program of rehabilitation. J Pain. 2014;15(1):101-113. doi:10.1016/j.jpain.2013.10.002
19. Ho EK, Chen L, Simic M, et al. Psychological interventions for chronic, non-specific low back pain: systematic review with network meta-analysis. BMJ. 2022;376:e067718. Published 2022 Mar 30. doi:10.1136/bmj-2021-067718
20. Wai EK, Roffey DM, Bishop P, Kwon BK, Dagenais S. Causal assessment of occupational lifting and low back pain: results of a systematic review. Spine J. 2010;10(6):554-566. doi:10.1016/j.spinee.2010.03.033
21. Andersen LL, Mortensen OS, Hansen JV, Burr H. A prospective cohort study on severe pain as a risk factor for long-term sickness absence in blue- and white-collar workers. Occup Environ Med. 2011;68(8):590-592. doi:10.1136/oem.2010.056259
22. Latham NK, Bennett DA, Stretton CM, Anderson CS. Systematic review of progressive resistance strength training in older adults. J Gerontol A Biol Sci Med Sci. 2004;59(1):48-61. doi:10.1093/gerona/59.1.m48
23. Zhao L, Manchikanti L, Kaye AD, Abd-Elsayed A. Treatment of Discogenic Low Back Pain: Current Treatment Strategies and Future Options-a Literature Review. Curr Pain Headache Rep. 2019;23(11):86. Published 2019 Nov 9. doi:10.1007/s11916-019-0821-x
24. Fritzell P, Hägg O, Wessberg P, Nordwall A; Swedish Lumbar Spine Study Group. Chronic low back pain and fusion: a comparison of three surgical techniques: a prospective multicenter randomized study from the Swedish lumbar spine study group. Spine (Phila Pa 1976). 2002;27(11):1131-1141. doi:10.1097/00007632-200206010-00002
25. Schoenfeld AJ, Carey PA, Cleveland AW 3rd, Bader JO, Bono CM. Patient factors, comorbidities, and surgical characteristics that increase mortality and complication risk after spinal arthrodesis: a prognostic study based on 5,887 patients. Spine J. 2013;13(10):1171-1179. doi:10.1016/j.spinee.2013.02.071
26. Wong JJ, Côté P, Shearer HM, et al. Clinical practice guidelines for the management of conditions related to traffic collisions: a systematic review by the OPTIMa Collaboration. Disabil Rehabil. 2015;37(6):471-489. doi:10.3109/09638288.2014.932448
27. Carlesso LC, Gross AR, Santaguida PL, Burnie S, Voth S, Sadi J. Adverse events associated with the use of cervical manipulation and mobilization for the treatment of neck pain in adults: a systematic review. Man Ther. 2010;15(5):434-444. doi:10.1016/j.math.2010.02.006
28. Slade SC, Keating JL. Trunk-strengthening exercises for chronic low back pain: a systematic review. J Manipulative Physiol Ther. 2006;29(2):163-173. doi:10.1016/j.jmpt.2005.12.011
29. MacDermid JC, Walton DM, Avery S, et al. Measurement properties of the neck disability index: a systematic review. J Orthop Sports Phys Ther. 2009;39(5):400-417. doi:10.2519/jospt.2009.2930
30. Fritz JM, Cleland JA, Speckman M, Brennan GP, Hunter SJ. Physical therapy for acute low back pain: associations with subsequent healthcare costs. Spine (Phila Pa 1976). 2008;33(16):1800-1805. doi:10.1097/BRS.0b013e31817bd853
31. Weinstein JN, Lurie JD, Tosteson TD, et al. Surgical versus nonsurgical treatment for lumbar degenerative spondylolisthesis. N Engl J Med. 2007;356(22):2257-2270. doi:10.1056/NEJMoa070302
32. Suri P, Boyko EJ, Goldberg J, Forsberg CW, Jarvik JG. Longitudinal associations between incident lumbar spine MRI findings and chronic low back pain or radicular symptoms: retrospective analysis of data from the longitudinal assessment of imaging and disability of the back (LAIDBACK). BMC Musculoskelet Disord. 2014;15:152. Published 2014 May 13. doi:10.1186/1471-2474-15-152
33. Stampas A, Tansey KE. Spinal cord injury medicine and rehabilitation. InSeminars in neurology 2014 Nov (Vol. 34, No. 05, pp. 524-533). Thieme Medical Publishers.
34. Hwang R, Morris NR, Mandrusiak A, Bruning J, Peters R, Korczyk D, Russell T. Cost-utility analysis of home-based telerehabilitation compared with centre-based rehabilitation in patients with heart failure. Heart, Lung and Circulation. 2019 Dec 1;28(12):1795-803.
35. Jordan K, Dunn KM, Lewis M, Croft P. A minimal clinically important difference was derived for the Roland-Morris Disability Questionnaire for low back pain. J Clin Epidemiol. 2006;59(1):45-52. doi:10.1016/j.jclinepi.2005.03.018
36. Rendon AA, Lohman EB, Thorpe D, Johnson EG, Medina E, Bradley B. The effect of virtual reality gaming on dynamic balance in older adults. Age and ageing. 2012 Jul 1;41(4):549-52.

37. Kim GJ. A SWOT analysis of the field of virtual reality rehabilitation and therapy. Presence. 2005 Apr;14(2):119-46.
38. Pastora-Bernal JM, Martín-Valero R, Barón-López FJ, Estebanez-Pérez MJ. Evidence of benefit of telerehabilitation after orthopedic surgery: a systematic review. Journal of medical Internet research. 2017 Apr 28;19(4):e142.
39. Darlow B, Fullen BM, Dean S, Hurley DA, Baxter GD, Dowell A. The association between health care professional attitudes and beliefs and the attitudes and beliefs, clinical management, and outcomes of patients with low back pain: a systematic review. Eur J Pain. 2012;16(1):3-17. doi:10.1016/j.ejpain.2011.06.006
40. Sluijs EM, Kok GJ, van der Zee J. Correlates of exercise compliance in physical therapy. Phys Ther. 1993;73(11):771-786. doi:10.1093/ptj/73.11.771.

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The future of spine surgery: technological innovations and advancements. A comprehensive review

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ABSTRACT

Spine surgery has witnessed remarkable advancements in technology, techniques, and patient outcomes. The future of spine surgery holds even greater promise as technological innovations continue to shape the field. This comprehensive review explores the role of various technological advancements in the future of spine surgery, focusing on robotic-assisted surgery, augmented reality and virtual reality, 3D printing and custom implants, artificial intelligence and predictive analytics, biomaterials and tissue engineering, nanotechnology, and telemedicine.

Robotic-assisted surgery offers enhanced precision and improved outcomes through real-time guidance and surgical manoeuvre assistance. Augmented reality and virtual reality technologies provide valuable tools for preoperative planning, intra-operative navigation, and surgeon training. 3D printing and custom implants enable personalised treatment approaches with improved fit and alignment. Artificial intelligence and predictive analytics offer decision support, precise diagnostics, and real-time monitoring. Biomaterials and tissue engineering approaches facilitate tissue regeneration and targeted drug delivery. Nanotechnology holds promise for precise diagnostics, real-time monitoring, and targeted therapies. Telemedicine and remote monitoring enhance postoperative care and improve accessibility to specialised care.

These technological advancements have the potential to revolutionise spine surgery by improving surgical outcomes, enhancing patient experiences, increasing accessibility to specialised care, and optimising healthcare delivery. However, challenges such as cost, training, regulatory approvals, privacy, and ethical considerations must be addressed for successful implementation.

Future research directions include further exploration of robotic-assisted surgery, advancement of augmented reality and virtual reality technologies, development of advanced biomaterials and tissue engineering strategies, exploration of nano-materials, and ongoing evaluation of telemedicine and remote monitoring. Collaboration among surgeons, engineers, and scientists is crucial to advancing these technologies and optimising their clinical applications.

In conclusion, the future of spine surgery is shaped by technological advancements that offer improved precision, personalised treatment approaches, and enhanced patient outcomes. While challenges exist, ongoing research and innovation will drive the field forward, improving patient care and advancing the field of spine surgery as a whole.

Keywords
spine surgery,
innovation,
new technology,
robotic surgery,
artificial intelligence,
augment reality,
nano technology,
telemedicine

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INTRODUCTION

Spine surgery has undergone a remarkable evolution over the years, driven by advancements in technology, surgical techniques, and patient outcomes. The field has witnessed significant improvements in surgical precision, patient safety, and functional outcomes, leading to enhanced quality of life for individuals suffering from various spinal conditions (1). However, the future of spine surgery holds even more promise, as ongoing technological innovations continue to shape the landscape of this specialized field.

The significance of technological advancements in spine surgery cannot be overstated (1). These advancements have the potential to revolutionize surgical techniques, improve patient outcomes, and enhance the overall patient experience. The integration of cutting-edge technologies into spine surgery offers the prospect of greater accuracy, efficiency, and personalized treatment approaches. By exploring the latest innovations and their potential impact, this review aims to provide a comprehensive understanding of the future of spine surgery. (2)

The purpose of this review is to critically analyze the current state of technological advancements in spine surgery and their potential implications. The review will focus on key areas of innovation, including robotic-assisted surgery, augmented reality and virtual reality, 3D printing and custom implants, artificial intelligence and predictive analytics, biomaterials and tissue engineering, nanotechnology, and telemedicine. By examining the existing literature from reputable sources, such as Google Scholar and PubMed, we will evaluate the benefits, challenges, and future prospects associated with these technological advancements in the context of spine surgery.

ROBOTIC-ASSISTED SPINE SURGERY

Robotic systems designed for spine surgery have gained significant attention and adoption in recent years. These systems typically consist of robotic arms or platforms, navigation systems, and specialized instruments. Examples of robotic systems used in spine surgery include the Mazor X, Medtronic's StealthStation, and the Globus ExcelsiusGPS (3).

Benefits of robotic assistance, including enhanced precision and improved outcomes

Robotic-assisted spine surgery offers several potential benefits compared to traditional techniques. The use of robotics allows for enhanced precision and accuracy in surgical maneuvers, enabling surgeons to perform complex procedures with increased control (4). Robotic systems provide real-time feedback, which aids in optimal implant placement and alignment. This improved precision can potentially lead to better surgical outcomes, reduced complication rates, and improved patient satisfaction (3,4,5).

Robotic-assisted spine surgery has been utilized in various procedures, including pedicle screw placement, tumor resection, and spinal deformity correction (3). Robotic systems assist surgeons in preoperative planning, intraoperative navigation, and guidance during procedures. The ability to preoperatively plan trajectories and simulate surgeries allows for optimized surgical strategies and implant placement. Future possibilities for robotic-assisted spine surgery include expanding the scope of procedures, incorporating artificial intelligence for automated planning, and integrating robotics with other advanced technologies such as augmented reality (4,5).

Despite the potential benefits, widespread adoption of robotic-assisted spine surgery faces certain challenges. One significant challenge is the cost associated with implementing and maintaining robotic systems. The initial investment and ongoing expenses can limit the accessibility of these technologies in many healthcare settings (3). Surgeon training and learning curve are also important considerations for successful adoption. Training programs are necessary to ensure surgeons become proficient in utilizing the robotic systems effectively (5). Additionally, concerns regarding surgical workflow disruption, potential technical failures, and patient safety require careful consideration (5).

AUGMENTED REALITY AND VIRTUAL REALITY

Augmented reality (AR) and virtual reality (VR) technologies have shown potential in various aspects of spine surgery. AR can overlay digital information onto the surgeon's view, providing real-time guidance, anatomical visualization, and trajectory planning. VR creates immersive virtual environments that enable surgeons to interact with three-dimensional models of the spine for surgical planning and simulation (6).

AR and VR can enhance preoperative planning by allowing surgeons to visualize and interact with patient-specific anatomy in a virtual environment. Surgeons can accurately assess the patient's anatomy, simulate surgical maneuvers, and plan optimal trajectories for instrumentation placement (7). These technologies enable a comprehensive understanding of the patient's pathology, facilitating precise surgical strategies.

AR-based navigation systems can provide real-time guidance during spine surgeries. Surgeons can view patient-specific anatomy overlaid with virtual information, such as preoperative plans, instrument positions, and critical structures, improving accuracy and reducing reliance on fluoroscopy (6,7). The integration of intraoperative imaging with AR technology allows for precise localization and instrument tracking, enhancing surgical precision.

AR and VR technologies offer valuable tools for surgeon training and education. Virtual simulations can replicate complex surgical scenarios, allowing surgeons to practice procedures in a risk-free environment (8). Surgeons-in-training can gain hands-on experience, refine their skills, and develop proficiency before performing surgeries on actual patients. Additionally, these technologies can be utilized for remote surgical mentoring and collaboration, enabling experts to provide guidance and feedback to surgeons in real-time (8).

The use of AR and VR technologies in spine surgery has the potential to improve surgical outcomes and enhance the patient experience. Precise preoperative planning and intraoperative guidance can lead to more accurate instrument placement, reduced complications, and improved surgical outcomes (9). Moreover, the visualization and interactive nature of AR and VR technologies can enhance patient education, enabling patients to better understand their condition and the planned surgical intervention, ultimately leading to increased patient satisfaction.

3D PRINTING AND CUSTOM IMPLANTS

3D printing, also known as additive manufacturing, is a technology that allows the creation of three-dimensional objects from digital designs by layering materials. In the context of spine surgery, 3D printing has gained attention due to its ability to produce patient-specific implants and surgical tools with high precision and accuracy (10). The technology enables the fabrication of complex geometries that are challenging to achieve using traditional manufacturing methods.

One of the significant advantages of 3D printing in spine surgery is the ability to create patient-specific implants tailored to individual anatomies. Based on patient-specific imaging data, such as CT or MRI scans, custom implants can be designed and manufactured to fit the patient's anatomy precisely (11). Additionally, surgical tools, such as patient-specific guides or templates, can be 3D printed to assist surgeons in accurately placing implants or performing precise osteotomies.

Custom implants offer several advantages over standard off-the-shelf implants. The personalized design ensures a precise fit to the patient's anatomy, resulting in improved implant alignment and stability (12). This improved fit can potentially lead to better surgical outcomes, reduced risk of complications, and enhanced long-term implant performance. Furthermore, custom implants can address complex anatomical variations or defects that cannot be adequately addressed with standard implants.

Currently, 3D printing is utilized in spine surgery for various applications, including patient-specific cages for spinal fusion, intervertebral disc replacements, and osteotomy guides (11,12). The technology has the potential to expand to other areas, such as patient-specific pedicle screw guides, anatomical models for surgical planning and education, and bioresorbable implants for spinal fusion. As the technology continues to advance, the possibilities for customized implants in spine surgery are likely to expand further.

While 3D printing offers tremendous potential, there are challenges and regulatory considerations that need to be addressed. The quality control and standardization of 3D-printed implants need careful consideration, ensuring their safety and effectiveness (13). Regulatory agencies, such as the U.S. Food and Drug Administration (FDA), have provided guidelines for the use of 3D-printed medical devices, and adherence to these regulations is crucial. Additionally, cost-effectiveness, scalability, and the integration of 3D printing into existing healthcare systems are factors that need to be considered for widespread adoption.

Artificial intelligence and predictive analytics

Artificial intelligence (AI) has the potential to revolutionize spine surgery by enabling the analysis of vast amounts of data and extracting valuable insights. AI algorithms can assist in various aspects, including surgical planning, intraoperative guidance, and postoperative monitoring. By leveraging machine learning and deep learning techniques, AI can process complex data sets and provide valuable decision support to surgeons (14). AI systems can learn from previous surgical cases and continuously improve their performance, enhancing surgical outcomes.

Predictive analytics utilizes AI algorithms to analyze patient-specific data, such as demographics, medical history, and imaging studies, to predict surgical outcomes and assess risks. By integrating patient data with AI models, surgeons can make informed decisions about surgical approaches, anticipated complications, and expected outcomes. Predictive analytics can help optimize surgical planning, improve patient selection, and enhance patient counseling regarding potential risks and benefits (15).

AI algorithms have demonstrated significant potential in image recognition and diagnostic support for spine conditions. By analyzing medical images, such as X-rays, CT scans, and MRI scans, AI systems can aid in the detection and classification of spinal pathologies. AI algorithms can assist radiologists and surgeons in identifying abnormalities, measuring parameters, and providing diagnostic support, potentially reducing interpretation errors and improving efficiency (16).

AI-powered real-time monitoring and decision support systems can enhance patient safety and surgical outcomes. By integrating data from various sources, such as intraoperative sensors, patient vital signs, and surgical parameters, AI algorithms can analyze the data in real-time and provide feedback and alerts to the surgical team. These systems can aid in identifying potential complications, guiding decision-making during surgery, and improving overall situational awareness (14).

The adoption of AI in spine surgery raises important ethical considerations. Privacy and security of patient data, transparency of AI algorithms, and the potential for biases in AI models are significant concerns (17). Ensuring patient consent, maintaining data integrity, and addressing the potential impact of AI on the surgeon-patient relationship are critical aspects to consider. Additionally, challenges related to regulatory approvals, integration of AI into clinical workflows, and liability in AI-driven decision-making need to be carefully addressed.

Biomaterials and tissue engineering

Utilization of biomaterials in regenerative spine surgery

Biomaterials play a crucial role in regenerative spine surgery by providing scaffolds, carriers, and therapeutic agents that facilitate tissue repair and regeneration. These materials are designed to mimic the natural properties of the extracellular matrix and create a favorable environment for tissue healing and integration (18). The utilization of biomaterials offers the potential to enhance the outcomes of spine surgeries by promoting tissue regeneration, reducing inflammation, and improving implant stability.

Bioactive scaffolds are designed to provide mechanical support to damaged or degenerated spinal tissues while promoting cellular infiltration, adhesion, and proliferation. These scaffolds often incorporate bioactive molecules, such as growth factors or extracellular matrix components, to enhance tissue regeneration and repair (19). They can facilitate cell attachment, migration, and differentiation, providing a conducive microenvironment for tissue healing.

Growth factors are potent signaling molecules that regulate various cellular processes involved in spinal fusion, such as osteogenesis and angiogenesis. In regenerative spine surgery, growth factors are often incorporated into biomaterials or delivered locally to stimulate bone formation and fusion (20). Growth factors, such as bone morphogenetic proteins (BMPs), can promote osteogenic differentiation of stem cells and enhance the formation of new bone tissue, leading to successful spinal fusion.

Stem cell therapies hold significant promise for functional recovery in spine surgery. Mesenchymal stem cells (MSCs) derived from various sources, such as bone marrow or adipose tissue, can differentiate into bone-forming cells, promote tissue regeneration, and modulate the inflammatory response (21). Stem cells can be delivered alone or in combination with biomaterials to promote spinal tissue regeneration, reduce scar formation, and potentially restore function.

Biomaterials and tissue engineering approaches have found clinical applications in various aspects of spine surgery, including intervertebral disc regeneration, spinal fusion, and spinal cord injury repair (19,20,21). Future prospects in this field include the development of advanced biomaterials with enhanced properties, the incorporation of bioactive molecules with controlled release kinetics, and the use of tissue engineering strategies to regenerate complex spinal tissues, such as the intervertebral disc or spinal cord.

NANOTECHNOLOGY IN SPINE SURGERY

Nanotechnology offers the potential to improve diagnostic capabilities in spine surgery through the development of nanoscale imaging tools. These tools can provide high-resolution imaging, enabling the detection of subtle structural abnormalities and pathological changes at the cellular or molecular level (22). Nanoparticles and nanosensors can be engineered to interact with specific targets, enhancing contrast and sensitivity in imaging modalities such as magnetic resonance imaging (MRI) or computed tomography (CT) scans.

Nanosensors hold promise for real-time monitoring of spinal conditions during surgery or postoperative recovery. These miniature devices can be designed to detect and measure various parameters, such as temperature, pH, pressure, or the presence of specific biomarkers (23). Nanosensors can provide valuable data on tissue status, implant integration, or infection, enabling timely intervention and personalized treatment approaches.

Nanotechnology enables the development of targeted drug delivery systems for spine surgery. Nanoparticles can be engineered to encapsulate drugs or therapeutic agents and deliver them directly to the desired site of action (24). This targeted approach improves drug efficacy, reduces systemic side effects, and enhances patient outcomes. Nanoparticles can be designed to release drugs in a controlled manner, ensuring sustained therapeutic effects and reducing the need for frequent dosing.

Nanotechnology has potential applications across various aspects of spine surgery. In addition to precise diagnostics and targeted drug delivery, nanomaterials can be utilized for tissue regeneration, spinal fusion enhancement, or prevention of implant-associated infections (25). However, several challenges need to be addressed for successful clinical translation. These challenges include safety concerns, biocompatibility of nanomaterials, regulatory approvals, scalability of production, and cost-effectiveness (25). Additionally, the long-term effects of nanomaterials on the human body and the potential for unintended consequences require thorough investigation.

TELEMEDICINE AND REMOTE MONITORING

Telemedicine has emerged as a valuable tool for postoperative care in spine surgery. Telemedicine platforms enable remote communication between patients and healthcare providers, allowing for virtual consultations, monitoring, and follow-up visits (26). Through telemedicine, patients can receive postoperative instructions, discuss their recovery progress, and address any concerns without the need for in-person visits. This enhances convenience, reduces travel requirements, and improves access to care, particularly for patients in remote or underserved areas.

Remote monitoring technologies have the potential to revolutionize real-time patient assessment in spine surgery. These technologies can include wearable devices, mobile health applications, or connected sensors that capture and transmit patient data, such as vital signs, physical activity, or medication adherence (26, 27). Remote monitoring enables healthcare providers to track patient progress, identify potential complications, and intervene promptly when necessary. It promotes early detection of issues and facilitates timely interventions, leading to improved patient outcomes.

Virtual follow-up visits through telemedicine platforms eliminate the need for patients to travel for in-person appointments, particularly for routine postoperative visits. This improves accessibility to specialized care, especially for patients who may face geographical or mobility challenges (26). Virtual visits allow patients to connect with their healthcare providers conveniently, discuss their recovery, review imaging results, and receive guidance on rehabilitation protocols. It also reduces the burden on healthcare facilities and allows for more efficient use of resources.

Telemedicine and remote monitoring can have a positive impact on patient outcomes and healthcare delivery in spine surgery. Studies have shown that telemedicine can lead to comparable patient satisfaction, reduced healthcare costs, and decreased readmission rates. Remote monitoring facilitates early identification of complications, enables timely intervention, and supports personalized care management, potentially leading to better clinical outcomes and improved patient experiences (28). Furthermore, the integration of telemedicine can optimize healthcare delivery, improve workflow efficiency, and enhance resource allocation.

Conclusion

The technological advancements discussed in this paper have the potential to shape the future of spine surgery in significant ways. Robotic-assisted surgery offers enhanced precision and improved outcomes through real-time guidance and surgical maneuver assistance. Augmented reality and virtual reality technologies provide valuable tools for preoperative planning, intraoperative navigation, and surgeon training. 3D printing and custom implants enable personalized treatment approaches, improved fit, and alignment. Artificial intelligence and predictive analytics offer decision support, precise diagnostics, and real-time monitoring. Biomaterials and tissue engineering approaches facilitate tissue regeneration and targeted drug delivery. Nanotechnology holds promise for precise diagnostics, real-time monitoring, and targeted therapies. Telemedicine and remote monitoring enhance postoperative care and improve accessibility to specialized care.

The potential impact of these advancements includes improved surgical outcomes, enhanced patient experiences, increased accessibility to specialized care, and optimized healthcare delivery. They have the potential to revolutionize surgical techniques, increase surgical precision, and promote personalized treatment approaches. These advancements can lead to better patient outcomes, reduced complications, and improved patient satisfaction.

However, challenges, limitations, and considerations must be addressed for successful implementation. These include the cost of adopting and maintaining new technologies, surgeon training and proficiency, regulatory approvals, privacy and security of patient data, standardization and quality control of new techniques, and addressing ethical considerations and potential biases. Additionally, scalability, integration into existing healthcare systems, and long-term effects on patients need to be carefully evaluated.

Future directions for research in spine surgery include further exploration of the potential of robotic-assisted surgery, refinement and advancement of augmented reality and virtual reality technologies, development of advanced biomaterials and tissue engineering strategies, exploration of new applications and nanomaterials, and ongoing evaluation of the impact of telemedicine and remote monitoring. Continued research and collaboration among surgeons, engineers, and scientists are crucial to advancing these technologies, addressing challenges, and optimizing their clinical applications.

In conclusion, the future of spine surgery is being shaped by technological advancements that offer improved precision, personalized treatment approaches, and enhanced patient outcomes. While challenges and considerations exist, the potential benefits are substantial. By continuing to innovate, collaborate, and address limitations, spine surgery can further evolve, providing better care for patients and advancing the field as a whole.

List of abbreviations

AR: Augmented Reality
VR: Virtual Reality
3D: Three Demential
CT: Computed Tomography
MRI: Magnetic Resonance Imaging
MSCs: Mesenchymal stem cells

References

1. Sielatycki JA, Mitchell K, Leung E, Lehman RA. State of the art review of new technologies in spine deformity surgery-robotics and navigation. Spine Deform. 2022;10(1):5-17. doi:10.1007/s43390-021-00403-6
2. Truumees E. The (rocky) road to innovation in spine care. Spine J. 2022;22(1):1-7. doi:10.1016/j.spinee.2021.11.001
3. Mattei TA, Rodriguez AH, Sambhara D, Mendel E. Current state-of-the-art and future perspectives of robotic technology in neurosurgery. Neurosurg Rev. 2014;37(3):357-366. doi:10.1007/s10143-014-0540-z
4. Ahern DP, Gibbons D, Schroeder GD, Vaccaro AR, Butler JS. Image-guidance, Robotics, and the Future of Spine

Surgery. Clin Spine Surg. 2020;33(5):179-184. doi:10.1097/BSD.0000000000000809
5. Judy BF, Pennington Z, Botros D, et al. Spine Image Guidance and Robotics: Exposure, Education, Training, and the Learning Curve. Int J Spine Surg. 2021;15(s2):S28-S37. doi:10.14444/8138
6. Ghaednia H, Fourman MS, Lans A, et al. Augmented and virtual reality in spine surgery, current applications and future potentials. Spine J. 2021;21(10):1617-1625. doi:10.1016/j.spinee.2021.03.018
7. Berton A, Longo UG, Candela V, et al. Virtual Reality, Augmented Reality, Gamification, and Telerehabilitation: Psychological Impact on Orthopedic Patients' Rehabilitation. J Clin Med. 2020;9(8):2567. Published 2020 Aug 7. doi:10.3390/jcm9082567
8. Godzik J, Farber SH, Urakov T, et al. "Disruptive Technology" in Spine Surgery and Education: Virtual and Augmented Reality. Oper Neurosurg (Hagerstown). 2021;21(Suppl 1):S85-S93. doi:10.1093/ons/opab114
9. Yuk FJ, Maragkos GA, Sato K, Steinberger J. Current innovation in virtual and augmented reality in spine surgery. Ann Transl Med. 2021;9(1):94. doi:10.21037/atm-20-1132
10. Gadia A, Shah K, Nene A. Emergence of Three-Dimensional Printing Technology and Its Utility in Spine Surgery. Asian Spine J. 2018;12(2):365-371. doi:10.4184/asj.2018.12.2.365
11. Cho W, Job AV, Chen J, Baek JH. A Review of Current Clinical Applications of Three-Dimensional Printing in Spine Surgery. Asian Spine J. 2018;12(1):171-177. doi:10.4184/asj.2018.12.1.171
12. Costanzo R, Ferini G, Brunasso L, et al. The Role of 3D-Printed Custom-Made Vertebral Body Implants in the Treatment of Spinal Tumors: A Systematic Review. Life (Basel). 2022;12(4):489. Published 2022 Mar 28. doi:10.3390/life12040489
13. Willemsen K, Nizak R, Noordmans HJ, Castelein RM, Weinans H, Kruyt MC. Challenges in the design and regulatory approval of 3D-printed surgical implants: a two-case series. Lancet Digit Health. 2019;1(4):e163-e171. doi:10.1016/S2589-7500(19)30067-6
14. Hornung AL, Hornung CM, Mallow GM, et al. Artificial intelligence in spine care: current applications and future utility. Eur Spine J. 2022;31(8):2057-2081. doi:10.1007/s00586-022-07176-0
15. Tariciotti L, Palmisciano P, Giordano M, et al. Artificial intelligence-enhanced intraoperative neurosurgical workflow: current knowledge and future perspectives. J Neurosurg Sci. 2022;66(2):139-150. doi:10.23736/S0390-5616.21.05483-7
16. Martín-Noguerol T, Oñate Miranda M, Amrhein TJ, et al. The role of Artificial intelligence in the assessment of the spine and spinal cord. Eur J Radiol. 2023;161:110726. doi:10.1016/j.ejrad.2023.110726
17. Amann J, Blasimme A, Vayena E, Frey D, Madai VI; Precise4Q consortium. Explainability for artificial intelligence in healthcare: a multidisciplinary perspective. BMC Med Inform Decis Mak. 2020;20(1):310. Published 2020 Nov 30. doi:10.1186/s12911-020-01332-6
18. DiStefano TJ, Shmukler JO, Danias G, Iatridis JC. The Functional Role of Interface Tissue Engineering in Annulus Fibrosus Repair: Bridging Mechanisms of Hydrogel Integration with Regenerative Outcomes. ACS Biomater Sci Eng. 2020;6(12):6556-6586. doi:10.1021/acsbiomaterials.0c01320
19. Iaquinta MR, Mazzoni E, Manfrini M, et al. Innovative Biomaterials for Bone Regrowth. Int J Mol Sci. 2019;20(3):618. Published 2019 Jan 31. doi:10.3390/ijms20030618
20. Li G, Li P, Chen Q, Thu HE, Hussain Z. Current Updates on Bone Grafting Biomaterials and Recombinant Human Growth Factors Implanted Biotherapy for Spinal Fusion: A Review of Human Clinical Studies. Curr Drug Deliv. 2019;16(2):94-110. doi:10.2174/1567201815666181024142354
21. Widjaja G, Jalil AT, Budi HS, et al. Mesenchymal stromal/stem cells and their exosomes application in the treatment of intervertebral disc disease: A promising frontier. Int Immunopharmacol. 2022;105:108537. doi:10.1016/j.intimp.2022.108537
22. Levet F, Tønnesen J, Nägerl UV, Sibarita JB. SpineJ: A software tool for quantitative analysis of nanoscale spine morphology. Methods. 2020;174:49-55. doi:10.1016/j.ymeth.2020.01.020
23. Shakhbazau A, Mishra M, Chu TH, et al. Fluorescent Phosphorus Dendrimer as a Spectral Nanosensor for Macrophage Polarization and Fate Tracking in Spinal Cord Injury. Macromol Biosci. 2015;15(11):1523-1534. doi:10.1002/mabi.201500150
24. Saeedi M, Eslamifar M, Khezri K, Dizaj SM. Applications of nanotechnology in drug delivery to the central nervous system. Biomed Pharmacother. 2019;111:666-675. doi:10.1016/j.biopha.2018.12.133
25. Viswanathan VK, Rajaram Manoharan SR, Subramanian S, Moon A. Nanotechnology in Spine Surgery: A Current Update and Critical Review of the Literature. World Neurosurg. 2019;123:142-155. doi:10.1016/j.wneu.2018.11.035
26. Riew GJ, Lovecchio F, Samartzis D, et al. Telemedicine in Spine Surgery: Global Perspectives and Practices. Global Spine J. 2023;13(5):1200-1211. doi:10.1177/21925682211022311
27. Maurer RK, Hallan D, Maurer TC, Lee C, Kelleher JP. Telemedicine in a spine clinic setting: a large survey of patient preferences and experiences. J Neurosurg Sci. 2023;67(3):351-354. doi:10.23736/S0390-5616.20.05220-0
28. Lightsey HM 4th, Yeung CM, Samartzis D, Makhni MC. The past, present, and future of remote patient monitoring in spine care: an overview. Eur Spine J. 2021;30(8):2102-2108. doi:10.1007/s00586-021-06921-1.

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The extended post spinal surgery syndrome (EPSS). A narrative review

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ABSTRACT

Pain can occur after any spinal surgery. Despite this, there are other many signs and symptoms of neurological deficits that can occur in patients with varying severity. Our aim is to find some of the main neurological deficits that can occur after any spinal surgery. We searched the literature based on some of the important keywords like neurological deficits after spine surgery, foot drops, cauda equina syndrome, epidural hematoma, and nerve and dural injury. Based on this we analyzed the most important and widely read articles. The problems associated with spine surgery have been published in the literature but are much more than the failed back surgery syndrome and cause more discomfort to patients with varying degrees of neurological deficits. We have coined a new term "Extended Post-spinal Surgery Syndrome (EPSS)" for these conditions. We propose this to include the other complications after lumbar surgery including nerve injury, dural injury, cauda equina syndrome and epidural haematoma.

Keywords
post spinal surgery,
neurological complications,
management,
foot drop,
cauda equine syndrome

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INTRODUCTION

Complications following spine surgery do occur very often. These include persistence or recurrence of the pain, dural and nerve root injuries; cauda equina syndrome; and formation of extradural scar tissue. [1] The recurrence of pain also called the post-laminectomy syndrome has been studied very well probably because of the higher incidence. But others like nerve root injury or cauda equine syndromes have not been that much looked into. An attempt is made in this article to review these possible complications. A new term "Extended Post Spinal Surgery Syndrome" is being coined for these complications.

Marquez-Lara [2] looked at a national database to find out the incidence and outcomes of sentinel events in lumbar spine surgery retrospectively. A total of 414 patients had sentinel events out of 53146 patients. Of this vascular and nerve injuries occurred in 2/10000 cases. This caused longer hospitalization, greater costs, and a greater incidence of in-hospital complications, and mortality. Shah et al, [3] looked at wrong level surgery in lumbar spine surgery. This causes friction between the patient and the surgeon and has a lot of medical and legal consequences. The commonest reason for wrong-level surgery even with such advanced imaging and other techniques include anatomical variations of the lumbosacral spine including transitional vertebrae, lumbar ribs, butterfly vertebrae, hemivertebra, block/fused vertebrae, and spinal dysraphism. Other causes include tumours, infection, previous lumbosacral surgery, obesity, and osteoporosis.

Nerve injury

Neurological complications of spinal surgery were classified as peroperative and postoperative aetiology by de Loubresse. [4] The author described that neurological structures may be damaged by direct or indirect mechanisms. Direct compression, traction, laceration and avulsion from the direct causes. Indirect causes include Ischemic phenomena produced by elongation or compression of medullary or radicular blood vessels. The main peropertive complications noted were ocular injury causing visual disturbances, elongation of the brachial plexus causing pain and mild weakness of the upper limb and compression of the peroneal nerve causing unilateral foot drop. All these injuries can happen due to defective patient positioning. Following defective patient positioning, the rate of neurological lesions is 0.14% for all procedures taken together.

For lumbar surgery procedures especially high-grade lumbar spondylolisthesis, reducing the slippage and local kyphosis entails neurologic risk, especially to the L5 root. It was found that serious neurological impairment after fusion on a well-aligned spine (0.14%) or after lumbar disc surgery was about 0.03%. The other peroperative complication that can happen especially in implantation is malpositioning of the screws. The incidence of malpositioning is quoted as 4.2%, but is around 15.7% on postoperative imaging. Severe lumbar canal stenosis or large disc prolapse can cause neural injury. The incidence of peroperative root injury is 0.4%.

Shin and coworkers [5] retrospectively analysed 627 patients who underwent surgery for lumbar degenerative pathology. Eight patients (1.3%) had intraoperative spinal root injury. Of this 5 patients had undergone laminotomies for discectomy and 3, for instrumentation and fusion. The causative instrument was the Kerrison punch in 4 cases, pituitary forceps in 2 and rongeur in 1. Four patients had L5 injury, 1 had S1 and another had S2 injury. Two patients had sacral rootlet injuries. Six patients had symptoms including sensory loss in 4, pain in 2, and one patient had both sensory loss and EHL weakness. The prognosis was poor in almost 50 % of patients. In fact, Epstein [6] recorded that minimally invasive procedures have a much higher incidence of nerve injuries compared to conventional open procedures. The rate of injury was 2% for transforaminal lumbar interbody fusion (TLIF) versus 7.8% for posterior lumbar interbody fusion (PLIF) and during anterior lumbar interbody fusions (ALIF: 15.8%) versus extreme lumbar interbody fusions (XLIF: 23.8%), addressing disc disease, failed back surgery, and spondylolisthesis. In comparison Desai et al [7] in a large multicentre trial of 792 patients reported that nerve root injury with open discectomy occurred in 0.13–0.25% of cases, in 0% of laminectomy with or without fusion, and just 2% for open laminectomy with or without fusion.

Ghobrial et al[8] had also described iatrogenic neurologic deficits after lumbar spine surgery. These include complications like radiculopathy, spinal cord compression, motor deficits and new onset radiculitis. Neuromonitoring has been successful in reducing these complications but they still occur. Degenerative spondylolisthesis, spondylosis, scoliosis, and lumbar stenosis were the most common indications for surgery. Fifty six patients out of 2783 reported postoperative neurologic deficit (5.7%). Among this, 4.1% had a new neurological deficit after anterior lumbar and 1.9% after posterior surgery.

Dural injury

Espiritu et al[9] felt that dural tears are among the most commonly seen complications in spine surgery. If the tears are diagnosed early and managed appropriately, long-term outcomes are not negatively affected. Direct suture repair is the best method for durotomy caused during surgery. Cammisa et al[10] retrospectively reviewed patients who underwent spine surgery over a ten-year period for the frequency of incidental durotomy. Seventy-four patients had dural tears during or before surgery out of a total of 2144 patients. Of these 74, 66 happened during surgery. Primary repair was done in 60 out of 66 patients; the rest had pseudomeningocoels repaired surgically later. Long-term follow-up showed good results for all patients. McMohan et al[11] looked at incidental durotomies and analysed the long-term patient outcomes as well as the major risk factors prospectively. The frequency of incidental durotomy in elective spinal surgery cases was 3.5%, in minimally invasive procedures it was 3.3% and 6.5% in revision surgery. Incidental durotomy was less in cervical surgery compared to lumbar, less when involving instrumentation and less when senior surgeons were operating. In patients with an incidental durotomy, 7.7% had neurological deficits compared with 1.5% of those without.

The overall failure rate of dural repair was 6.9%, and failure was almost 3 times higher in revision surgery. Guerin et al [12] retrospectively reviewed 1326 spinal surgery patients and identified 51 dural tears were identified. This was more with posterior thoracolumbar approach (48/51). Postoperatively, seven patients had CSF leak and two each of wound infection, pseudomemnigocoel and postoperative haematomas. Kamenova et al[13] looked at the management of incidental dural tears during lumbar spine surgery in 64 patients who had a dural tear out of 1173 patients who underwent lumbar spine surgery. The dural closure technique was direct closure or using a patch only or suture with a patch. They realised that the dural closure technique does not affect long-term results. Jankowitz et al [14] looked at the use of fibrin glue to reduce the frequency of CSF leak in dural tear during spinal surgery. This retrospective study had an incidence of 11% of dural tear of which about 50% had fibrin glue used in the dural repair. They concluded that prior surgery significantly increases the incidence of durotomy during elective lumbar spine surgery but the use of fibrin glue for dural repair did not significantly decrease the incidence of a persistent CSF leak.

Foot drop

Foot drop is defined as weakness in dorsiflexion of the foot[15]. The two top most common aetiologies for foot drop include lumbar degenerative disease and common peroneal nerve injury. Foot drop can be unilateral or bilateral. When the foot can no longer be actively lifted against gravity, an abnormal gait pattern arises. This causes the patient to fall down forwards causing injuries, thus reducing the quality of life [16]. But foot drop in lumbar degenerative disease is alike a chicken and egg story. Whether foot drop was present before surgery or is as a result of surgery is always a point of confusion. Bhargava and colleagues [17] reported a retrospective observational study of 26 patients with foot drop who underwent surgery. Of the 26 patients, 88% improved, with complete recovery observed in 61%. It was concluded that preoperative duration of weakness was a significant predictor of extent of recovery. There have been many reports of both unilateral and bilateral foot drop caused by lumbar degenerative pathology [18].

Ma et al[19] analysed the risk factors for foot drop in patients with lumbar disc herniation retrospectively in 236 patients. Fifty-two patients had foot drop. They concluded that diabetes mellitus, disc calcification, patients with acute episodes, and far lateral disc prolapse had a bigger risk of foot drop. Also, a canal occupancy rate of more than 50% was at greater risk. For every 1 mm change in canal diameter the risk of developing foot drop changed by around 50%. Liu et al [20] reviewed 135 patients with foot drop due to lumbar degenerative disease. Foot drop was observed in 8.1% of all inpatients of lumbar degenerative disease. L5 nerve root compression was observed in 126 of all 135 patients. The muscle strength of TA was improved in 113 (83.7%) patients after surgery. They concluded that patients with shorter duration of palsy, better preoperative muscle strength of TA and younger age showed a better surgical outcome. Aono et al [21] also showed that palsy duration and preoperative strength were factors that most affected drop foot recovery following surgical intervention for spinal degeneration. Investigating a patient of foot drop after lumbar surgery usually involves repeat MRI imaging and electrophysiology. This usually localises the site of lesion. Daniels et al [22] introduced MR neurography to verify the site of the lesion site. MRN also helps in accurately characterizing the cause of the neuropathy and helps guide treatment. MR neurography can help overcome potential pitfalls in clinical and electrodiagnostic evaluation when tailored and focused.

The biggest problem with foot drop is it affects gait and causes patients to trip and fall on uneven surfaces. So this problem needs proper attention. Macki et al [23] looked at the predictors of improvement in foot drop due to lumbar degenerative disease. They retrospectively reviewed 71 patients undergoing posterior lumbar decompression for foot drop due to degenerative spinal disease. Fifty-two patients had postoperative improvement. They concluded that the power of the tibialis anterior muscle and the duration of the foot drop were statistically significant predictors of improvement. The average time to improvement was 6 weeks. Takenaka and Aono [24] also tried to predict postoperative improvement through a Bayesian Network. They studied 102 out of 141 patients who underwent decompressive surgery for foot drop. The models showed that weaker muscle power before surgery (≤ 1) and longer duration of neurologic injury before treatment (> 30 days) were associated with a decreased likelihood of return of function by 2 years. Age, herniated soft disc, and leg pain were identified as indirect predictors. The probability estimates of posttibialis anterior muscle strength of 3 or greater and posttibialis anterior muscle strength of 4 or greater were 94% and 85%, respectively, in the most favourable conditions (pretibialis anterior ≥ 2; duration ≤ 30 days) and 18% and 14%, respectively, were the least-favourable conditions.

There are presently many treatment options for foot drop. Repeat surgery offers a realistic chance of restoring nerve function if a compressive element can be demonstrated. In the current DGN guideline on lumbar radiculopathy, a relative and absolute indication for surgery is described for muscle strengths of more than 3/5. Recovery is correlated with the severity of the paresis. There is no clear consensus to what extent the preoperative duration of the paresis correlates with recovery.[16] However, there is a trend for better recovery if the patient undergoes surgery within 48 hours of the onset of the paresis.

Treatment of foot drop is usually a multidisciplinary exercise. In mild cases braces, shoe inserts and other orthotic appliances may be useful. Physical exercises to strengthen the muscles also help. As already mentioned decompressive surgery does have a role. [16, 17] In selected cases, neurolysis of the peripheral nerve help. Repair processes are possible in the peripheral nervous system. As long as the nerve-cell nucleus is intact, axonal sprouting occurs for up to six months after the injury. However, the capacity for regeneration already starts to decline after three months because of a variety of changes in the distal stump [25]. Tendon transfers which help to restore specific movements are another technique used in some patients. The posterior tibial tendon is pulled through the interosseous membrane to the instep where it is anchored or redirected to the front, with the tibialis anterior and the peroneal tendons to create a stirrup. The measured increase in foot lifting strength resulting from a tendon transfer is only about 30% of the full strength, but it produces a significant functional increase and the quality of life is satisfactorily improved [26]. Functional electrical stimulation is another technique used to prevent muscle atrophy but how much it is useful to improve foot drop remains a question. Botulinum toxin (Botox) can be useful if the foot drop is associated with spasticity but in lumbar surgery patients, this is very rare.

Recent studies have shown that direct peroneal nerve stimulation with an implantable 4-channel peroneal nerve stimulator (ActiGait) allows independent electrode adjustment and leads to better functional results and improved quality of life. The application of this therapeutic option is restricted to patients with a drop foot attributable to a lesion of the first motor neuron caused by stroke, multiple sclerosis, or tumours [27]. Yao et al [28] studied 21 patients with chronic foot drop due to a central lesion who had implantation of this implant. They showed that patients had significant improvement in walking speed, gait endurance and gait performance. Patient satisfaction and improvement in mobility were achieved in 95% and quality of life improved in 90% of patients.

CAUDA EQUINA SYNDROME

Cauda equina is the horsetail-like root of the lumbosacral nerves. So any compression of these roots especially at L1 to L5 vertebral levels can cause neurological deficits like incontinence/ retention of urine, foot drop, pain, weakness and wasting of legs and sensory deficits. Usually, lumbar aetiology includes both lumbar disc prolapses especially L4 L5 and L5S1 levels and lumbar canal stenosis. The cauda equina involvement usually occurs preoperatively but does occur after surgery also. As there is a high possibility of litigation, in both cauda equina syndrome and foot drop a detailed history and clinical examination and recording findings is very important.

Todd and Dickson[29] brought out their recommendations for treatment of this condition.

They recommended next-day surgery for patients with bilateral radiculopathy and large central disc prolapse. For patients presenting with acute cauda equine syndrome (CES), emergency surgery is a must. Again, emergency surgery is indicated if large disc prolapse with uncertain cauda equine syndrome with residual nerve function, If there is prolonged cauda equine syndrome or no residual sacral nerve root function, surgery should be planned on the next day's list. Uckun et al [30] retrospectively studied the effect of surgical timing on improvement of motor function and sphincter function in patients with CES due to lumbar disc herniation. In this series muscle strength improved in 13 and returned to normal in nine patients and sphincter control resolved in five patients. Sensory loss resolved in two patients. So they suggested that patients with CES should be operated within 24 hours. Foruria and coworkers [31] retrospectively studied 18 patients to see whether surgical treatment delayed for more than 48 hours influenced the clinical outcome in patients with cauda equina syndrome. All patients operated within 48 hours had good continence and motor recovery. Three out of five with delayed surgery had residual incontinence. But this result was not statistically significant.

Kaiser et al.[32] prospectively investigated the relationship between postoperative urinary function, preoperative duration of neurogenic lower urinary tract dysfunction and the level of canal compromise in 71 patients. After studying this large series of patients they concluded that there is no correlation between the preoperative duration of urinary dysfunction, the size of disc herniation relative to the size of spinal canal, and postoperative urinary function. Srikandarajah and colleagues [33] categorised CES involvement as CES with retention (CESR) and CES incomplete (CESI). CESI operated within 24 hours had a normal function in 89% but only 48% benefitted when operated after 24 hours. If operated within 48 hours 85% of CESI improved but after 48 hours 56% benefitted. For those with CESR the timing of the surgery did not make any difference to the final outcome.

In contrast, there have been some studies which conclude that the timing of surgery is not that important. Aly and Aboramadan [34] studied 14 patients who underwent surgery one to three months after urinary involvement. All patients were relieved of back and leg pain, 12 regained control of the sphincters and nine improved in motor power. So they concluded that even if surgery is delayed improvement can be seen. Qureshi and Sell [35] tried to determine the factors influencing spine and urinary outcomes in CES due to disc herniation in 33 patients prospectively and assessed at 3 months and one year postoperatively. Seven patients underwent surgery within 2 hours and another 5 within 48 hours. No statistically significant difference in outcome between the patients with respect to the length of time from symptom onset to surgery was made out. Patients who were continent of urine at presentation had a much better outcome. So they concluded that the duration of symptoms prior to surgery had no bearing on the outcome. McCarthy et al[36] studied the factors that influence outcomes after surgery for CES. Acute onset of sphincteric symptoms and the time to operation did not influence the outcomes; also more females were affected. They found that the symptom duration before operation and the speed of onset do not affect the outcome more than two years after surgery.

Olivero et al [37] reported 28 patients with CES due to herniated discs and followed up for an average of up to 5 years. Twenty-seven of these patients regained continence not requiring catheterization. There was no correlation between the time to surgery and recovery of bladder function. The majority of the patients were adequately treated without the need for a complete laminectomy. Dhatt and others [38] studied patients who were admitted and operated up to 35 days after CES. There was no statistically significant difference in time of delay in surgery between the recovered and non-recovered groups as tested by Student's t-test. But there was a statistically significant positive correlation between duration taken for total recovery and delay in surgery. Anal wink as a predictor of bladder and bowel recovery also showed statistical significance. The result of surgery in CES is not as dramatic and fast as seen after routine disc surgery. Some improvement can be expected with decompression even in those patients presenting late and results are not universally poor as previously thought. The treating physicians of such patients should be aware that the recovery in this group of patients can take an exceptionally long time and hence should be involved in constant reassurance and rehabilitation of the patient.

A study by Korse and others[39] evaluated the association of MRI features with clinical presentation and outcome of CES. They also compared the lumbar spinal canal diameters of lumbar herniated disc patients with CES and those without CES. They found no association between MRI features and clinical features and outcome. They also found that patients with CES had a significant smaller AP diameter of the lumbar spinal canal in CES patients compared with those without CES. So they warned that patients with lumbar herniated disc patients with a relatively small lumbar spinal canal should be approached differently. Chang, Nakagawa and Mizuno [40] reported 4 patients of 144 consecutive surgical series of lumbar disc herniation, whose presenting symptom was classic cauda equina syndrome. The patients were on follow-up for up to 6.4 years. They reported that in all these patients the voiding function improved to normal even though it took many years.

There are some studies which describe that CES can occur postoperatively. McLaren and Bailey [41] reported six cases that developed CES after lumbar discectomy. Of these five had associated lumbar canal stenosis which was not tackled at time of surgery. They opined that motor recovery was poor if a severe deficit had developed before decompression and bladder and sensory deficits recovered well if decompressed early. Similar reports were made by Jensen [42] and Henriques [43]. The possible mechanism for this could be relative spinal stenosis causing postoperative oedema and triggering venous congestion causing nerve root ischaemia. Extended decompression within 48 hours seems to help patients to improve. We also have an example of a lady who had foot drop and retention of urine for more than 8 years and improved by open L4L5 laminectomy discectomy.

There have been some reports of CES following decompression for lumbar canal stenosis. Duncan and Bailey [44] reported an incidence of 2.8% of CES in patients with lumbar canal stenosis. All patients who developed cauda equina syndrome improved over 3 to 9 months, but none completely resolved. Three cases underwent further decompression with no apparent improvement. Comer and coworkers [45] reported on older adults with lumbar canal stenosis and said the diagnosis could be challenging. The degenerative changes in the elderly can lead to lumbar canal stenosis and gradual compromise of the cauda equina. The very slow onset of symptoms may be overlooked. So careful assessment and vigilance are needed to manage this potentially vulnerable patient group.

Sacral nerve stimulation is an excellent method of treating all types of neurogenic bladder and also pelvic pain [46]. It is effective in urinary and bowel involvement in CES causing bowel and bladder involvement and in severe pelvic pain[47,50-54].

Epidural haematoma

Postoperative lumbar spinal epidural haematoma is another complication of lumbar surgery but it is very rare. Aono et al [48] studied 26 patients who had spinal epidural haematoma (SEH) evacuation and looked at frequency of evacuation, symptoms, time to SEH evacuation, comorbidities, and neurological recovery. The frequency of SEH evacuation was 0.41% which included 0% lumbar discectomy, 0.50% in lumbar laminectomy and 0.67% in posterior lumbar interbody fusion. About 50% of the patients had symptoms like leg pain or bladder dysfunction after the suction drain was removed. The study concluded that neurological recovery was better when the evacuation was earlier. Yi and others [49] looked at the risk factors and clinical outcomes in postoperative spinal epidural haematoma. They observed that patients with coagulopathy and highly vascularized tumour were more vulnerable to spinal epidural hematoma. The postoperative outcome was related to the preoperative neurological deficit and the time interval to the decompression; the earlier and complete the evacuation the better the results. There are also a few other case reports of epidural haematoma causing neurological deficits[55-59].

Conclusion

Extended Post-spinal surgery Syndrome (EPSS)" is the proper term to describe complications after lumbar surgery including nerve injury, dural injury, cauda equina syndrome and epidural haematoma.

References

1. Carroll S E, Wiesel S W. Neurologic complications and lumbar laminectomy. A standardized approach to the multiply-operated lumbar spine. Clin Orthop Relat Res 1992; 284:14-23.
2. Marquez-Lara A, Nandyala S V, Hassanzadeh H, Sundberg E, Jorgensen A, Singh K. Sentinel Events in

Lumbar Spine Surgery. Spine (Phila Pa 1976) 2014; 39: 900-905.
3. Shah M, Halalmeh D R, Sandio A, Tubbs R S, Moisi M D. Anatomical Variations that Can Lead to Spine Surgery at the Wrong Level: Part III Lumbosacral Spine. Cureus. 2020; 12: e9433.
4. Garreau de Loubresse C. Neurological risks in scheduled spinal surgery. .Orthop Traumatol Surg Res. 2014; 100: S85-S90.
5. Shin B J, Lee J C, Ryu K Jung H, Kim K, Kim Y. Intraoperative Spinal Nerve Root Injuries during Surgery for Degenerative Low Back Disease. J Korean Soc Spine Surg 2002; 9:142.
6. Epstein N E. More nerve root injuries occur with minimally invasive lumbar surgery: Let's tell someone. Surg Neurol Int. 2016; 7: S96–S101.
7. Desai A, Bekelis K, Ball P A, Lurie J, Mirza S K, Tosteson T D, Zhao W, Weinstein J N. Spine patient outcomes research trial: do outcomes vary across centers for surgery for lumbar disc herniation? Neurosurgery. 2012; 71: 833-842.
8. Ghobrial G M, Williams K A, Arnold P, Fehings M, Harrop J S. Iatrogenic neurologic deficit after lumbar spine surgery: A review. Clin Neurol and Neurosurg 2015; 139: 76–80.
9. Espiritu M T, Rhyne A, Darden B V. Dural tears in spine surgery. J Am Acad Orthop Surg. 2010; 18: 537-545.
10. Cammisa Jr F P, Girardi F P, Sangani P K, Parvataneni H K, Cadag S, Sandhu H S.
Incidental durotomy in spine surgery. Spine (Phila Pa 1976). 2000; 25: 2663-2667.
11. McMahon P, Dididze M, Levi A D. Incidental durotomy after spinal surgery: a prospective study in an academic institution. J Neurosurg Spine. 2012; 17: 30-36.
12. Guerin P, El Fegoun A B, Obeid I, Gille O, Lelong L, Luc S, Bourghli A, Cursolle J C, Pointillart V, Vital J. Incidental durotomy during spine surgery: incidence, management and complications. A retrospective review. Injury 2012; 43: 397-401.
13. Kamenova M, Leu S, Mariani L, Schaeren S, Soleman J. Management of Incidental Dural Tear During Lumbar Spine Surgery. To Suture or Not to Suture? World Neurosurg 2016; 87: 455-462.
14. Jankowitz B T, Atteberry D S, Gerszten P C, Karausky P, Cheng B C, Faught R, Welch W C Effect of fibrin glue on the prevention of persistent cerebral spinal fluid leakage after incidental durotomy during lumbar spinal surgery. Eur Spine J 2009 Aug;18(8):1169-1174.
15. Macki M, Lim S, Elmenini J, Fakih M, Chang V. Clinching the cause: A review of foot drop secondary to lumbar degenerative diseases. J Neurol Sci 2018; 395: 126-130.
16. Carolus A E, Becker M, Cuny J, Smektala R, Schmieder K, Brenke C. The Interdisciplinary Management of Foot Drop. Dtsch Arztebl Int 2019; 116: 347-354.
17. Bhargava D, Sinha P, Odak S, Tyagi A,Towns G, Pal D. Surgical Outcome for Foot Drop in Lumbar Degenerative Disease. Global Spine J. 2012 Sep; 2(3): 125–128.
18. Ramnarayan R, Pazhanikumar C. Bilateral foot drop without cauda equinae syndrome due to L4-L5 disc prolapse: a case report. Internet Journal of Neurosurgery. 2008, Vol 5, No 1.
19. Ma J, He Y, Wang A, Wang W, Xi Y, Yu J, Ye X. Risk Factors Analysis for Foot Drop Associated with Lumbar Disc Herniation: An Analysis of 236 Patients. World Neurosurg 2018; 110: e1017- e1024.
20. Liu K, Zhu W,, Shi J, Jia L, Shi G, Wang Y, Liu N. Foot drop caused by lumbar degenerative disease: clinical features, prognostic factors of surgical outcome and clinical stage. PLoS One. 2013 Nov 5;8(11):e80375.
21. Aono H, Iwasaki M, Ohwada T, Okuda S, Hosono N, Fuji T, Yoshikawa H. Surgical outcome of drop foot caused by degenerative lumbar diseases. Spine 2007 (Phila); 32: E262-266.
22. Daniels S P, Feinberg J H, Carrino J A, Behzadi A H, Sneag D B. MRI of Foot Drop: How We Do It. Radiology 2018 Oct;289(1):9-24.
23. Macki M, Syeda S, Kerezoudis P, Gokaslan Z L, Bydon A, Bydon M. Preoperative motor strength and time to surgery are the most important predictors of improvement in foot drop due to degenerative lumbar disease. J Neurol Sci. 2016; 361: 133-136.
24. Takenaka S, Aono H. Prediction of Postoperative Clinical Recovery of Drop Foot Attributable to Lumbar Degenerative Diseases, via a Bayesian Network. Clin Orthop Relat Res. 2017; 475: 872-880.
25. Jonsson S, Wiberg R, McGrath AM, et al.: Effect of delayed peripheral nerve repair on nerve regeneration, Schwann cell function and target muscle recovery. PLoS One 2013; 8: e56484.
26. Cho BK, Park KJ, Choi SM, Im SH, SooHoo NF: Functional outcomes following anterior transfer of the tibialis posterior tendon for foot drop secondary to peroneal nerve palsy. Foot Ankle Int 2017; 8: 627–633.
27. Martin K D, Polanski W, Schackert G, Sobottka S B. New Therapeutic Option for Drop Foot with the ActiGait Peroneal Nerve Stimulator--a Technical Note. World Neurosurg 2015; 84:2037-2042.
28. Yao D, Jakubowitz E, Ettinger S, Plaass C, Stukenborg-Colsman C, Daniilidis K. Foot drop treatment by implantation of a neuroprosthesis (ActiGait®). Oper Orthop Traumatol 2017; 29: 266-278.
29. Todd N V, Dickson R A. Standards of care in cauda equina syndrome. Br J Neurosurg 2016; 30: 518-522.
30. Uçkun ÖM, Alagöz F, Polat Ö, Divanlıoğlu D, Dağlıoğlu E, Belen AD, Dalgıç A. Urgent operation improves weakness in cauda equina syndrome due to lumbar disc herniation. Turk J Phys Med Rehab 2019; 65: 222-227.
31. Foruria X , Ruiz de Gopegui K, García-Sánchez I, Moreta J, Aguirre U, Martínez-de Los Mozos J L. Cauda equina syndrome secondary to lumbar disc herniation: Surgical delay and its relationship with prognosis. Rev Esp Cir Ortop Traumatol 2016; 60: 153-159.
32. Kaiser R, Nasto L A, Venkatesan M, Waldauf P, Perez B, Stokes O M, Haddad S, Mehdian H, Tsegaye M. Time

Factor and Disc Herniation Size: Are They Really Predictive for Outcome of Urinary Dysfunction in Patients With Cauda Equina Syndrome? Neurosurgery 2018; 83: 1193-1200.
33. Srikandarajah N, Boissaud-Cooke A M, Clark S, Wilby M J. Does early surgical decompression in Cauda Equina syndrome improve bladder outcome? Spine (Phila Pa 1976) 2015; 40: 580 – 583.
34. Aly T A, Aboramadan MO. Efficacy of delayed decompression of lumbar disk herniation causing cauda equina syndrome. Orthopedics 2014; 37: e153-156.
35. Quershi A, Sell P. Cauda Equina Syndrome Treated by Surgical Decompression: The Influence of Timing on Surgical Outcome. Eur Spine J. 2007; 16: 2143-2151.
36. McCarthy M J H, Aylott C E W, Grevitt M P, Hegarty J. Cauda Equina Syndrome: Factors Affecting Long-Term Functional and Sphincteric Outcome. Spine (Phila Pa 1976). 2007; 32: 207-216.
37. Olivero W C, Wang H, Hanigan W C, Henderson J P, Tracy P T, Elwood P W, Lister J R, Lyle L. Cauda Equina Syndrome (CES) From Lumbar Disc Herniations. J Spinal Disord Tech. 2009; 22: 202-206.
38. Dhatt S, Tahasildar N, Tripathy S K, Bahadur R, Dhillon M. Outcome of Spinal Decompression in Cauda Equina Syndrome Presenting Late in Developing Countries: Case Series of 50 Cases. Eur Spine J. 2011; 20: 2235-2239.
39. Korse N S Kruit M C, Peul W C, Vleggeert-Lankamp C L A. Lumbar spinal canal MRI diameter is smaller in herniated disc cauda equina syndrome patients. PLoS One 2017; 12: e0186148.
40. Chang H S, Nakagawa H, Mizuno J.Lumbar herniated disc presenting with cauda equina syndrome. Long-term follow-up of four cases. Surg Neurol 2000; 53: 100-105.
41. McLaren A C, Bailey S I. Cauda equina syndrome: a complication of lumbar discectomy. Clin Orthop Relat Res. 1986; 204: 143-149.
42. Jensen R L. Cauda equina syndrome as a postoperative complication of lumbar spine surgery Neurosurg Focus 2004; 16: e7.
43. Henriques T, Olerud C, Petrén-Mallmin M, Ahl T. Cauda equina syndrome as a postoperative complication in five patients operated for lumbar disc herniation. Spine (Phila Pa 1976) 2001; 26: 293-297.
44. Duncan J W, Bailey R A. Cauda equina syndrome following decompression for spinal stenosis. Global Spine J 2011; 1: 15-18.
45. Comer C, Finucane L, Mercer C, Greenhalgh S. SHADES of grey - The challenge of 'grumbling' cauda equina symptoms in older adults with lumbar spinal stenosis. Musculoskelet Sci Pract. 2020; 45: 102049.
46. Ramnarayan R, Krishna Moorthy H. Sacral Nerve Stimulation for Neurogenic Bladder: Our Experience". Acta Scientific Neurology 2020; 3: 112-116
47. Kim J, Hong J, Kim M, Kim S. Sacral nerve stimulation for treatment of intractable pain associated with cauda equina syndrome. J Korean Neurosurg Soc 2010; 47: 473-476.
48. Aono H, Ohwada T, Hosono N, Tobimatsu H, Ariga K, Fuji T, Iwasaki M. Incidence of postoperative symptomatic epidural hematoma in spinal decompression surgery. J Neurosurg Spine. 2011; 15: 202-205.
49. Yi S, Yoon D H, Kim K N, Kim S H, Shin H C. Postoperative spinal epidural hematoma: risk factor and clinical outcome. Yonsei Med J. 2006; 47: 326-332.
50. Nicoletti GF, Umana GE, Chaurasia B, Ponzo G, Giuffrida M, Vasta G, Tomasi SO, Graziano F, Cicero S, Scalia G. Navigation-assisted extraforaminal lumbar disc microdiscectomy. Journal of Craniovertebral Junction & Spine. 2020 Oct;11(4):316.
51. Ahsan K, Khan SI, Zaman N, Ahmed N, Montemurro N, Chaurasia B. Fusion versus nonfusion treatment for recurrent lumbar disc herniation. Journal of Craniovertebral Junction & Spine. 2021 Jan;12(1):44.
52. Ahsan K, Hasan S, Khan SI, Zaman N, Almasri SS, Ahmed N, Chaurasia B. Conservative versus operative management of postoperative lumbar discitis. Journal of Craniovertebral Junction & Spine. 2020 Jul;11(3):198.
53. Palmisciano P, Balasubramanian K, Scalia G, Sagoo NS, Haider AS, Alamer OB, Chavda V, Chaurasia B, Deora H, Passanisi M, Da Ros V. Posterior epidural intervertebral disc migration and sequestration: A systematic review. Journal of Clinical Neuroscience. 2022 Apr 1;98:115-26.
54. Khan MS, Ahmed N, Barua KK, Chaurasia B, Vats A, Goel A. Pathogenesis, management strategies, and outcome of non-communicating extradural spinal arachnoid cyst (NEAC): a systematic review. British Journal of Neurosurgery. 2022 Jun 28:1-7.
55. Rashid MH, Hossain MN, Ahmed N, Kazi R, Ferini G, Palmisciano P, Scalia G, Umana GE, Hoz SS, Chaurasia B. Aspergillus spinal epidural abscess: A case report and review of the literature. Journal of Craniovertebral Junction & Spine. 2022 Apr;13(2):204.
56. Ahsan MK, Hossain MR, Khan MS, Zaman N, Ahmed N, Montemurro N, Chaurasia B. Lumbar revision microdiscectomy in patients with recurrent lumbar disc herniation: A single-center prospective series. Surgical Neurology International. 2020;11.
57. Ahmed N, Khan SI, Islam KM, Dey A, Chavda VK, Tomasi O, Scalia G, Umana GE, Chaurasia B. Adult spinal hamartoma involving conus medullaris: Brief review about associated congenital abnormalities and surgical outcome. International Journal of Medical Arts. 2021 Jul 1;3(3):1556-61.
58. Raut VK, Khan AH, Ahmad M. Spinal Epidural varicosity resembling prolapsed intervertebral disc on MRI: A diagnostic dilemma for lumbar canal stenosis. J Neurol Stroke. 2021;11(1):23-5.
59. Ramnarayan R, Chaurasia B. The post spinal surgery syndrome: A review. Journal of Craniovertebral Junction and Spine. 2023 Jan 1;14(1):4.

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The status of nanoneusurgery investigated

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ABSTRACT
Nanoneurosurgery, introduced in 2003, aims to revolutionize neurosurgery using nanotechnology. Despite early excitement, its development has been slower than expected. The field encompasses various neurosurgical domains, utilizing advanced technologies like femtosecond laser and nanoparticle-enhanced stem cell therapies. However, challenges such as diagnostic limitations, nanoparticle toxicity, and ethical issues have impeded progress. Recent trends show a decline in research activity, suggesting a need for more interdisciplinary approaches and practical applications. The field remains distant from fully integrating nanotechnology, indicating that its future impact might be indirect and gradual. Continued research and collaboration are essential for realizing its potential.

Keywords
nanoneurosurgery, nanotechnology, neurosurgical innovations, clinical translation, interdisciplinary approach

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BACKGROUND
The concept of "nanoneurosurgery" was first introduced by Dunn and Black in 2003 to highlight the potential of molecular therapies in neuro-oncology [5]. Since then, interest in nanoneurosurgery has grown substantially, offering the possibility to transform the field. This paper was motivated by an effort to review current practical applications of nanotechnology in neurosurgery, which quickly exposed a pattern: the excitement surrounding nanotechnology's potential to revolutionize neurosurgery in the past decades has not only remained unfulfilled but also seems to have waned. Consequently, we aimed to examine the practical application of nanotechnology in neurosurgery, specifically evaluating nanotechnology's progress in the field and exploring the apparent decline in advancement, investigating the reasons behind it and possibly proposing solutions to accelerate the bench-to-bedside transition in nanoneurosurgery. We hope to answer the question "how far are we from the dawn of the nano age" or, at the very least, analyze existing obstacles and anticipated milestones.

TERMINOLOGY

Generally, the terms nanotechnology and nanomedicine carry different meanings. For example, if "nano" denotes any technology involving particles with at least one dimension of 10-9 (one billionth of a meter), then many devices currently utilized in operating rooms, from monitor electro circuits to the most sophisticated robots, rely on nanoparticle incorporation [1]. However, nanomedicine and, consequently, nanoneurosurgery are used in a more contemporary sense to describe the innovative and sometimes unconventional advancements in preventing, diagnosing, and treating diseases of the central and peripheral nervous systems.

Furthermore, the term nanoneurosurgery is incredibly wide-ranging, covering various neurosurgical domains such as neuroregeneration, targeted neuromodulation, non-surgical repair, prognostic medicine, and molecular imaging, as well as numerous neurosurgical subspecialties like traumatic brain and spine injuries, neurovascular, neurooncology, functional and stereotactic radiosurgery, and peripheral nerve, all while incorporating an array of nano fields. Moreover, the potential is extensive within neurosurgical practice, from hemostasis and wound closure in the operating room to enhanced operating room ergonomics, targeted drug delivery to metastatic tumor cells and stroke therapy, and aneurysm formation prevention [1,3].

NANOMEDICINE APPLICATIONS

Nanomedicine is an interdisciplinary field in which nanotechnology is involved in diagnosing, treating, and monitoring medical diseases. However, applying nanotechnology to the cellular and subcellular levels of engineering and surgery might be challenging. Specific progress has occurred in this direction. Femtosecond (fs) laser multiphoton technology has been used in high-precision surgery, which can be performed on tissues, cells, intracellular organelles, and molecules. Tängenomo et al. examined the biochemical synthesis of the Golgi complex by using the fs laser technique. The Golgi apparatus was also being dissected and manipulated by the similar technique. Such manipulations occur without destabilization of the cell membranes. It is usually performed by focusing fs laser using an objective microscope lens on the Golgi complex. Therefore, forming a cell-depleted Golgi apparatus result in a status where its biosynthesis can be thoroughly studied. Nevertheless, future expansion of this technique is highly probable to be included in the various nanosurgery applications [2]. Choi et al. utilized the same method to stimulate the cell membrane, resulting in the generation of calcium waves. They used an fs laser to enhance astrocytes' function in the mouse brain. As the laser is directed on the cell membrane, the flow of Calcium ions occurs, resulting in astrocyte-mediated vasodilation. This application has potential usage as astrocytes are the most abundant cell in the brain [6]. Furthermore, nanotechnology has extended applications to the molecular level, i.e., DNA.

Stem cell therapy is another field which Nanotechnology has the potential of revolutionizing. Mesenchymal stem cells can accelerate the recovery, axon regeneration, and remyelination in the case of peripheral nerve injury due to their anti-inflammatory and anti-apoptotic effects, autophagy reduction, and optimization of Schwann cell function. A limitation of stem cell therapy, however, is the migration of stem cells after transplantation which reduces their therapeutic effects. nanoparticles such as that superparamagnetic iron oxide nanoparticles can potentially facilitate the homing of mesenchymal stem cells at the injury site [4,7].

Nanotechnology in diagnostics has not advanced significantly. Nevertheless, progress in radiology has been noticed. 7 Tesla (7T) field's strength Magnetic resonance imaging which can process imaging reaching 10 microns details, has been applied in managing certain brain diseases, including Multiple sclerosis, brain tumors, and cerebrovascular diseases. However, besides high cost and limited availability, the disadvantages of this technology include imaging artifacts and the recognition of the details of anatomy and disease characteristics in imaging under such high field strength. An accurate test using nanotechnology to aid in the management of patients is still in its infancy.

The current concept of surgery as a therapeutic option probably will fade with the end of the 21st century. High precision surgery, as an example in precision medicine, may occupy the vacuum of traditional surgery. The precision that comes with the nano-level manipulations may give us the sense that it is the surgery's future. However, doubts still exist in the clinical field about such advances.

CURRENT TREND

In this context, an analysis of the most recent systematic review on nanoneurosurgery reveals that publications on the subject have steadily increased since around 2003, peaked in 2015, then rapidly declined, and have gradually continued to decline since then, possibly reflecting an early period of unmatched enthusiasm followed by conceptual and practical stagnation [3]. Additionally, the relative scarcity of human research in comparison to a promising collection of bench-top and in-vitro applications indicates that nanoscience discoveries will take time to convert into clinical nanoneurosurgery, at least in the direct sense originally anticipated.

There are various reasons for the sluggish progress of nanomedicine toward nanoneurosurgery, and roadblocks will almost certainly continue to follow each discovery in nanoscience or nanomaterials. These difficulties may be categorized as follows, from specific to general: (1) those associated with each potential advancement in nanotechnology or nanomaterials, (2) those related to the intricate complexity of the nervous system and our current limited understanding of neuroanatomy and neuropathophysiology, (3) those linked to neurosurgical practice, given the unmatched diversity and complexity of neurosurgical diseases, as well as their frequently uncertain prognosis. (4) difficulties posed by the inherent physical, chemical, and biological properties of nanoparticles, with concerns about short- and long-term toxicity impeding their entry into clinical studies, and (5) a slew of ethical, economic, and cultural complexities, some inherent to neurosurgery and others well documented and described in nanomedicine across a variety of medical and surgical specialties [3,8].

TRANSITION PHASE

To accelerate the bench-to-bedside transition in nanoneurosurgery, focused efforts should be made at multiple levels, emphasizing a more comprehensive interdisciplinary approach. Additionally, considering the complexity of nanoneurosurgery interactions, the term "nanoneurosurgery" might be an overly broad designation. In this context, the specific steps needed and their anticipated timeline should be assessed concerning the precise situation under examination and customized to the particular complexities of the given interaction.

Therefore, the response to the posed question is that neurosurgery still has a considerable distance to cover before fully leveraging the advantages of nanotechnology, and the reason for this promise-delivery discrepancy is not simple. Moreover, given the immense complexity of the science-to-practice interface, it is too early to dismiss the transformative potential of this emerging field or compare its progress rate to other rapidly developing advancements in neurosurgery, such as robotics or stereotactic radiosurgery. However, it may be reasonable to conclude that, based on the analysis of the predicted future versus current metrics mismatch, nanotechnology may eventually be integrated into daily neurosurgical practice. Still, this integration is more likely to follow indirect pathways rather than the direct translation initially suggested.

FUTURE DIRECTIONS

Finally, until neurosurgery is graced with the "nano era," we should maintain a critical eye on the practicalities and venues for translation of nanoneuroscientific advances, striking the balance between what is scientifically appealing and what is more likely to make its way to our patients.

REFERENCES

1. Choi M, Ku T, Choi K, Choi C, Yoon J. Label-free optical activation of astrocyte in vivo. Journal of biomedical optics. 2011 Jul;16(7):075003.
2. Dunn IF, Black PM. The neurosurgeon as local oncologist: cellular and molecular neurosurgery in malignant glioma therapy. Neurosurgery. 2003 Jun 1;52(6):1411-24.
3. Giakoumettis D, Sgouros S. Nanotechnology in neurosurgery: A systematic review. Child's Nervous System. 2021 Apr;37(4):1045-54.
4. Lam FC, Salehi F, Kasper EM. Integrating Nanotechnology in Neurosurgery, Neuroradiology, and Neuro-Oncology Practice-The Clinicians' Perspective. Frontiers in Bioengineering and Biotechnology. 2022;10.
5. Nasiry D, Khalatbary AR. Stem cell-derived extracellular vesicle-based therapy for nerve injury: A review of the molecular mechanisms. World Neurosurgery: X. 2023 Apr 25:100201.
6. Nejati-Koshki K, Mortazavi Y, Pilehvar-Soltanahmadi Y, Sheoran S, Zarghami N. An update on application of nanotechnology and stem cells in spinal cord injury

regeneration. Biomedicine & pharmacotherapy. 2017 Jun 1;90:85-92.

7. T√§ngemo C, Ronchi P, Colombelli J, Haselmann U, Simpson JC, Antony C, Stelzer EH, Pepperkok R, Reynaud EG. A novel laser nanosurgery approach supports de novo Golgi biogenesis in mammalian cells. Journal of cell science. 2011 Mar 15;124(6):978-87.

8. Tan A, Jeyaraj R, Ashkan K. Nanotechnology in neurosurgery: thinking small, dreaming big. British Journal of Neurosurgery. 2017 Sep 3;31(5):538-50.

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Decompressive craniectomy for dural venous sinus thrombosis. A neurosurgical approach

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ABSTRACT
A rare event, dural sinus thrombosis occurs more frequently in young adults and children. Generally, medical treatment is the preferred option for this condition; however, if no improvement is observed with medical treatment, decompressive craniectomy is suggested as the preferred surgical intervention. A non-systematic literature search was conducted in PubMed and SCOPUS databases until June 2023, using keywords such as "Decompressive craniectomy," "Dural venous sinus thrombosis," and "Traumatic Brain Injury," along with their synonyms in both English and Spanish. The search revealed that genetic or acquired thrombophilia and the use of oral contraceptives were the most common risk factors, explaining the female predominance of this condition. Patients with dural sinus thrombosis commonly experience headaches, the intensity of which is not yet considered pathognomonic for the condition, ranging from mild to severe. Other nonspecific symptoms include nausea, vomiting, and papilledema. Thrombolytic agents are utilized to rapidly dissolve the clot, supported by interventional neuroradiology techniques to administer the agent directly at the thrombosis site. Studies have reported the effectiveness of emergent decompressive craniectomy in patients with recent onset of dural sinus thrombosis, leading to good results, especially in cases where cerebral hernia is present.

INTRODUCTION

Dural sinuses thrombosis (DST) remains a rare event [1], more frequently afflicting young adults and children, with an estimated incidence of 3 to 4 cases per 1,000,000 inhabitants for adults and 7 per 1,000,000 for children [2]. Approximately 75% of patients affected are women, outnumbering men with a ratio of 3:1 [3]. The incidence resulting from traumatic brain injury (TBI) remains unknown; some experts suggest it is underdiagnosed because clinicians frequently omit this diagnosis during TBI evaluations. Symptoms associated with dural venous sinus thrombosis vary, ranging from mild headaches to severe neurological deficits, including coma, due to elevated intracranial pressure associated with ischemic and/or hemorrhagic events [4]. Risk factors exacerbating the prognosis of DST patients include age over 37 years, altered mental status, brain hemorrhage, and coma, among others. Presence of seizures, altered consciousness, and coma heightens mortality rates in patients [5]. Typically, medical treatment is the first choice for this condition; however, when patients do not show improvement with medical treatment, experts suggest decompressive craniectomy as the preferred surgical intervention. The prognosis relies heavily on clinical presentation and imaging studies [6]. This article outlines the risk factors, pathogenesis, clinical manifestations, evaluation, diagnosis, treatment, and prognosis of dural sinus thrombosis, along with the application of decompressive craniectomy.

A non-systematic literature search explored PubMed and SCOPUS databases until June 2023, utilizing keywords such as "Decompressive craniectomy," "Dural venous sinus thrombosis," and "Traumatic Brain Injury," in addition to their synonyms in both English and Spanish. All types of publications containing evidence or data related to dural venous sinus thrombosis were included. Exclusion criteria involved articles lacking full text. Grey literature sources were also consulted, culminating in the consideration of 48 articles.

Risk factors

Certain factors promote DST when a TBI occurs; in fact, prothrombotic risk factors or direct causes are found in 85% of patients with sinus thrombosis [7]. In the international study of dural sinus and cerebral vein thrombosis, involving 624 adults from 21 countries, researchers identified genetic or acquired thrombophilia and the use of oral contraceptives as the most common risk factors, potentially explaining the female predominance of this condition [3,7].

Other conditions that contribute to DST include neoplasms, central nervous system (CNS) alterations (arteriovenous and dural fistulas), hematological conditions, nephrotic syndrome, systemic vasculitis, infections of the central nervous system (bacterial meningitis, cerebral malaria) [8,9], inflammatory bowel disease [7], medications (cisplatin methotrexate, steroids) [10], neurological surgery, lumbar puncture, pregnancy, and the puerperium [9]. Despite the extensive list of risk factors, approximately 20% of cases are considered idiopathic [3,4,7,11]. Moreover, the use of oral contraceptives and coagulopathies contribute to the increased occurrence of this condition [5].

Pathogenesis

In cases of TBI involving skull fractures or intracranial hematomas, thrombosis can occur either due to direct compression of the sinus or endothelial damage within it. This endothelial damage activates the coagulation system, leading to sinus occlusion. DST rarely occurs in the absence of cranial suture diastasis; when it does, it implies that the associated mechanism involves endothelial damage within the venous sinus [12]. The brain contains abundant thromboplastin, released after injury, creating an abnormal hypercoagulable state that results in platelet and erythrocyte destruction followed by thrombus formation [12].

Normally, cerebrospinal fluid (CSF) drains into the superior sagittal sinus through arachnoid villi. Thrombosis in these sinuses increases venous pressure, disrupting the CSF absorption mechanism, consequently raising intracranial pressure [2]. This condition can lead to cytotoxic and interstitial edema [13] and localized venous infarction. The outcome includes dilated veins, edema, ischemic neuronal damage, petechial hemorrhages, which can merge to form bruises [2].

Two theories have been proposed: Cerebral vein thrombosis (CVT) causing local effects due to venous obstruction and venous sinus thrombosis (VST). These events are often considered to occur simultaneously. CVT results in cytotoxic and vasogenic edema around venous vessels, accompanied by venous infarcts, while VST leads to increased venous pressure and decreased CSF absorption, elevating intracranial pressure (ICP) [5]. The most frequently affected sinuses, in order, are the transverse sinus, sagittal sinus, sigmoid sinus, and straight sinus [13,14]. Coexisting involvement of multiple sinuses is common [2].

Clinical manifestations

Patients primarily experience headaches, which vary in intensity from mild to severe and are not yet considered pathognomonic for DST [3,7]. Other nonspecific symptoms include nausea, vomiting, and papilledema [7,12]. The frequency of these symptoms is as follows: headaches (70-95%) [3,5], seizures (39.3%), paresis (37.2%) [3], papilledema (28.3-41%) [3,5], altered mental state (22%), aphasia (19.1%), stupor or coma (13.9%), diplopia (13.5%), and visual deficit (13.2%) [3]. Involvement of the deep venous system results in altered consciousness, abnormal pupillary reactions, and eye movement abnormalities [5].

Clinical evaluation

Conducting a comprehensive neurological examination is crucial to detect signs and symptoms as well as to identify the presence of fractures, which should be actively investigated [4]. This approach enables a more accurate and timely diagnosis, leading to improved patient outcomes [7]. Patients with elevated intracranial pressure often experience isolated symptoms, typically manifested as severe headaches and diplopia, especially when intracranial pressure is significantly elevated due to compression of the sixth cranial nerve. Examination of the fundus reveals papilledema and transient visual impairment, which can become permanent if the underlying condition is not promptly addressed [2].

Diagnosis

The diagnosis of this condition relies on imaging studies. Initially, computed tomography (CT) without contrast is employed [5,15]. This scan reveals edema and areas of hyperdensity indicating a hemorrhagic infarction (present in 40% of cases). Additionally, it identifies specific signs, such as the 'cord sign,' an area of hyperdensity with a thrombosed cortical vein in the transverse sinus region [14,16], and the 'empty delta sign,' a triangular area of enhancement with a relatively attenuated center, seen in the superior sagittal sinus. This sign, observed in about 28.6% of patients, is considered pathognomonic for sinus thrombosis and is associated with a poor prognosis [12]. Its appearance is likely due to increased flow in the large collateral dural venous circulation surrounding the thrombosed sinus, resulting in a central region of low attenuation [17]. However, the absence of these findings does not rule out the diagnosis; abnormalities are not reported in over 25% of cases [7]

Magnetic resonance imaging (MRI) is considered one of the most effective methods for diagnosing this condition as it allows visualization of intracranial vasculature, providing precise information about the location and timing of the thrombus within the dural sinus [7]. In the subacute phase, the thrombus is easily identifiable, particularly on T1-weighted images, with the signal becoming intensely hyperintense around day 15 on both T1 and T2-weighted images, a critical period for diagnosis [17]. In the acute phase, the thrombus appears isodense with the brain on T1-weighted images and low-signal on T2-weighted images. This appearance can be confused with blood flow; however, magnetic resonance imaging with venography (MRV) can confirm the absence of flow [13,15]. Contrasted T2 images have demonstrated higher sensitivity compared to T1 or regular T2. Yet, due to the potential for flow artifacts in MRI and MRV, particularly in cases where deep venous infarction or cortical venous thrombosis is suspected, high-resolution endoluminal techniques such as phlebography or conventional CT are recommended [13].

Digital subtraction angiography, the gold standard in diagnosis, is invasive and challenging to access, making it a last resort used only when there are doubts about the diagnosis that cannot be resolved through other methods [5,12,13,15]. It is also employed in cases of suspected long-standing DST with unclear MRI images [18].

Although the D-dimer test has been proposed to assess DST risk in emergency department patients, with reported sensitivity of 97.1%, negative predictive value of 99.6%, specificity of 91.2%, and positive predictive value of 55.7%, it is not a routine procedure. Its results can be influenced by coexisting pathologies, and it is not universally applicable [7].

Treatment

The treatment strategy revolves around three key aspects: managing intracranial pressure, preventing seizures, and administering antithrombotic treatment. The goal of this therapy is to halt the underlying thrombotic process and prevent venous thrombosis from other sites that could potentially worsen the clinical condition [1].

Traditionally, heparin anticoagulation has been the primary treatment, occasionally used irrespective of the presence of bleeding [5,19,20]. Additionally, monitored long-term use of warfarin has been reported [4,13,15] to prevent overdose [21]. Caution is necessary for patients immediately post-surgery following a TBI, as anticoagulation is generally contraindicated during the postoperative period. This caution is crucial to prevent DST progression. Hence, it is imperative to consider the possibility of DST in the presence of a TBI, especially if there are associated risk factors [4].

The use of thrombolytic agents for rapid clot dissolution, supported by interventional neuroradiology techniques delivering the agent locally at the thrombosis site, has emerged as a therapeutic option. Although there are no randomized, double-blind, placebo-controlled studies supporting thrombolysis as the first-line therapy for cerebral venous sinus thrombosis in comparison to unfractionated heparin, numerous case reports and a single non-randomized study have demonstrated its comparative safety and effectiveness, particularly in rescuing patients who deteriorate rapidly despite unfractionated heparin treatment. This practice should be limited to experienced centers [22]. It is indicated for patients experiencing progressive deterioration unresponsive to anticoagulant therapy, aiming for rapid recanalization of the obstructed sinus [11,15]. When administered within 72 hours of diagnosis, thrombolytic therapy achieves complete recanalization in 56.5% of cases and partial recanalization in 43.5%. Commonly used thrombolytic agents include urokinase (73.7%), tissue activator of recombinant plasminogen (tPA) (21.5%), and thrombectomy or angioplasty (12.2%) [11].

In a retrospective study analyzing 25 patients with DST leading to venous congestion in the brain, anticoagulation therapy alone resulted in a stable course. Patients who received thrombolytic therapy experienced more adverse effects, and those initially undergoing thrombectomy showed clinical deterioration. This highlights the benefits of antithrombotic therapy as the primary approach and the potential role of thrombectomy and thrombolytic therapy in central venous congestion development [23]. Anticoagulant therapy alone does not seem appropriate in these patients when cerebral venous congestion occurs, possibly due to collateral flow loss [23]. Therefore, in cases where patients deteriorate clinically despite adequate anticoagulation, consideration of local or systemic thrombolysis is recommended. There is no consensus on the optimal medication, dosage, route, or method of administration [7].

Prognostic aspects

This condition is regarded as a severe event with high associated mortality. It leads to progressive patient deterioration or a lack of improvement in the clinical condition, potentially resulting in severe neurological complications or death if not promptly treated [4,7,8,9,10,11,12,13]. Although specific mortality rates below 10% have been reported, 17% of survivors exhibit neurological deficits, and these individuals may require long-term rehabilitation due to lasting sequelae. It is advisable to conduct neuroimaging follow-ups at least one year after the event. Some cases experience increased intracranial pressure, leading to optic nerve compression and visual disorders. Hence, regular ophthalmology follow-ups are recommended [13].

Decompressive craniectomy

Decompressive craniectomy (DC) is a surgical technique that involves removing a portion of the skull to facilitate brain expansion, thus mitigating increased ICP and edema while controlling this pathological process [24,25]. DC enhances oxygen supply and perfusion pressure, proving beneficial in reducing ICP in various conditions such as severe head injury, stroke, and subarachnoid hemorrhage [24,25]. It has also demonstrated usefulness in DST cases unresponsive to medical interventions [26]. While randomized studies confirming the benefits of DC in DST management are lacking [5], Stefani et al [27] reported its efficacy in patients with cerebral hernia due to DST, especially in recent clinical onsets, yielding positive outcomes [27]. Patients who underwent DC in this study experienced favorable recoveries and positive functional results. Additionally, they noted improved outcomes when DC was combined with full doses of heparin administered 24 hours post-surgery [28]. Similar results have been reported in other cases, although these findings are not conclusive [29-31].

Despite the existing gap in understanding the utility of such techniques in cerebrovascular disorders and traumatic brain injuries, these methods have the potential to enhance morbidity rates, reduce mortality, decrease disability, and alleviate the burden of neurological diseases [32-35]. Furthermore, advancements in science and technology, particularly in robotic neurosurgery, offer promising avenues to maintain and restore the functional capacity and quality of life for affected individuals [36-38].

CONCLUSIONS

Traumatic brain injury constitutes a risk factor for dural venous sinus thrombosis development. Accurate diagnosis and timely management of this complication can be achieved through a thorough clinical history and imaging studies. This is particularly crucial in young patients with recent head trauma who exhibit symptoms of intracranial hypertension. In such cases, it is essential to rule out neurosurgical pathology or intracranial hematomas adjacent to venous structures. The prognosis is contingent upon the treatment provided and the involvement of other structures in the traumatic brain injury.

REFERENCES

1. Harrahill M. An Unusual Case of Cerebral Venous Sinus Thrombosis in a Trauma Patient. J Emerg Nurs. 2018; 37(2):203–4. doi: 10.1016/j.jen.2010.11.014
2. Stam J. Thrombosis of the cerebral veins and sinuses. N Engl J Med. 2005; 352(17):1791–8. doi: 10.1056/NEJMra042354
3. Ferro JM, Canhao P, Stam J, Bousser MG, Barinagarrementeria F. Prognosis of cerebral vein and dural sinus thrombosis: results of the International Study on Cerebral Vein and Dural Sinus Thrombosis (ISCVT). Stroke. 2004; 35(3):664–70. doi: 10.1161/01.STR.0000117571.76197.26
4. Dobbs TD, Barber ZE, Squier WL, Green AL. Cerebral venous sinus thrombosis complicating traumatic head injury. J Clin Neurosci Off J Neurosurg Soc Australas. 2012; 19(7):1058–9. doi: 10.3389/fneur.2022.1079579
5. Tadi P, Behgam B, Baruffi S. Cerebral Venous Thrombosis. [Updated 2023 Jun 12]. In: StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing; 2023 Jan-. Available from: https://www.ncbi.nlm.nih.gov/books/NBK459315/
6. Verbel LP, Zambrano T, Fern L, Barcel OE, Mar L. Cerebral venous sinus thrombosis, an unusual manifestation of protein S deficiency in a young patient. Acta Neurol Colomb. 2016; 32(5):305–9. doi: 10.22379/24224022112
7. Fischer C, Goldstein J, Edlow J. Cerebral venous sinus thrombosis in the emergency department: retrospective analysis of 17 cases and review of the literature. J Emerg Med. 2010; 38(2):140–7. doi: 10.1016/j.jemermed.2009.08.061
8. Krishnan A, Karnad DR, Limaye U, Siddharth W. Cerebral venous and dural sinus thrombosis in severe falciparum malaria. J Infect. 2004; 48(1):86–90. doi: 10.1016/s0163-4453(03)00130-0
9. Filippidis A, Kapsalaki E, Patramani G, Fountas KN. Cerebral venous sinus thrombosis: review of the demographics, pathophysiology, current diagnosis, and treatment. Neurosurg Focus. 2009; 27(5): E3. doi: 10.3171/2009.8.FOCUS09167
10. Karam C, Koussa S. Cerebral dural sinus thrombosis following cisplatin chemotherapy. J Clin Neurosci. 2008; 15(11):1274–5. doi: 10.1016/j.jocn.2008.01.015
11. Hocker SE, Dafer RM, Hacein-Bey L. Successful delayed thrombolysis for cerebral venous and dural sinus thrombosis: a case report and review of the literature. J Stroke Cerebrovasc Dis. 2008; 17(6):429–32. doi: 10.1016/j.jstrokecerebrovasdis.2008.07.001
12. Lakhkar B, Lakhkar B, Singh BR, Agrawal A. Traumatic dural sinus thrombosis causing persistent headache in a child. J Emergencies, Trauma Shock. 2010; 3(1):73–5. doi: 10.4103/0974-2700.58658
13. Dlamini N, Billinghurst L, Kirkham FJ. Cerebral venous sinus (sinovenous) thrombosis in children. Neurosurg Clin N Am. 2010; 21(3):511–27. doi: 10.1016/j.nec.2010.03.006
14. Teasdale E. Cerebral venous thrombosis: making the most of imaging. JR Soc Med. 2000; 93(5):234–7. doi: 10.1177/014107680009300505
15. Kubiak BD, Albert SP, Tandoh MA, Fortune JB, Cunningham PRG. Transverse sinus thrombosis after internal jugular vein ligation. J Emerg Med. 2012; 43(1):e5-9. doi: 10.1016/j.jemermed.2009.05.022
16. Vijay RKP. The Cord Sign. Radiology. 2006; 240(1):299–300. doi: 10.1148/radiol.2401031739
17. Read EJY. The Empty Delta Sign. Radiology. 2002; 224(3):788–9. doi: 10.1148/radiol.2243990978
18. Ayanzen RH, Bird CR, Keller PJ, McCully FJ, Theobald MR, Heiserman JE. Cerebral MR venography: normal anatomy and potential diagnostic pitfalls. AJNR Am J Neuroradiol. 2000; 21(1):74–8.
19. Shafqat S, Kamal AK, Wasay M. Heparin in the treatment of cerebral venous thrombosis. J Pak Med Assoc. 2006; 56(11):541–3.
20. de Bruijn SF, Stam J. Randomized, placebo-controlled trial of anticoagulant treatment with low-molecular-weight heparin for cerebral sinus thrombosis. Stroke. 1999; 30(3):484–8. doi: 10.1161/01.str.30.3.484
21. Matsushige T, Nakaoka M, Kiya K, Takeda T, Kurisu K. Cerebral sinovenous thrombosis after closed head injury. J Trauma. 2009; 66(6):1599–604. doi: 10.1097/TA.0b013e3181a3a8e6
22. Kamal AK. Thrombolytic therapy in cerebral venous sinus thrombosis. J Pak Med Assoc. 2006; 56(11):538–40.

23. Tsai FY, Kostanian V, Rivera M, Lee KW, Chen CC, Nguyen TH. Cerebral venous congestion as indication for thrombolytic treatment. Cardiovasc Intervent Radiol. 2007; 30(4):675–87. doi: 10.1007/s00270-007-9046-1
24. Gopalakrishnan MS, Shanbhag NC, Shukla DP, Konar SK, Bhat DI, Devi BI. Complications of Decompressive Craniectomy. Front Neurol. 2018; 9:977. doi: 10.3389/fneur.2018.00977
25. Grille P, Tommasino N. Decompressive craniectomy in severe traumatic brain injury: prognostic factors and complications. Rev Bras Ter Intensiva. 2015; 27(2):113-8. doi: 10.5935/0103-507X.20150021
26. Rajan Vivakaran TT, Srinivas D, Kulkarni GB, Somanna S. The role of decompressive craniectomy in cerebral venous sinus thrombosis. J Neurosurg. 2012; 117(4):738-44. doi: 10.3171/2012.6.JNS11102
27. Stefini R, Latronico N, Cornali C, Rasulo F, Bollati A. Emergent decompressive craniectomy in patients with fixed dilated pupils due to cerebral venous and dural sinus thrombosis: report of three cases. Neurosurgery. 1999; 45(3):626–30. doi: 10.1097/00006123-199909000-0003
28. Elsherbini MM, Badr H, Khalil AF. Efficiency of decompressive craniectomy as a line of management of severe cerebral venous thrombosis. J Cerebrovasc Endovasc Neurosurg. 2022; 24(2):129-136. doi: 10.7461/jcen.2022.E2021.07.012
29. Isan P, Mondot L, Casolla B, Fontaine D, Almairac F. Post-traumatic cerebral venous sinus thrombosis associated with epidural hematoma: A challenging clinical situation. Neurochirurgie. 2022; 68(5):e40-e43. doi: 10.1016/j.neuchi.2021.12.012
30. Pikis S, Moscovici S, Itshayek E, Cohen JE. Cerebral sinodural thrombosis following minor head injury in children. J Clin Neurosci. 2013; 20(4):481-4. doi: 10.1016/j.jocn.2012.09.009
31. Ulivi L, Squitieri M, Cohen H, Cowley P, Werring DJ. Cerebral venous thrombosis: a practical guide. Pract Neurol. 2020; 20(5):356-367. doi: 10.1136/practneurol-2019-002415
32. Ortega-Sierra MG, Durán-Daza RM, Carrera-Patiño SA, Rojas-Nuñez AX, Charry-Caicedo JI, Lozada-Martínez ID. Neuroeducation and neurorehabilitation in the neurosurgical patient: programs to be developed in Latin America and the Caribbean. J Neurosurg Sci. 2022; 66(3):271-272. doi: 10.23736/S0390-5616.21.05439-4
33. Lozada-Martínez I, Maiguel-Lapeira J, Torres-Llinás D, Moscote-Salazar L, Rahman MM, Pacheco-Hernández A. Letter: Need and Impact of the Development of Robotic Neurosurgery in Latin America. Neurosurgery. 2021; 88(6):E580-E581. doi: 10.1093/neuros/nyab088
34. Muñoz-Baez K, del Castillo AM, García-Araujo HJ, Padrón-Echenique CJ, Martínez-Bohórquez JM, Lozada-Martínez ID, et al. Latin American collaboration in global neurosurgery: Challenges and difficulties persist. International Journal of Surgery Open. 2021; 33:100355. doi: 10.3171/2022.1.JNS2232
35. Chacón-Aponte AA, Durán-Vargas ÉA, Arévalo-Carrillo JA, Lozada-Martínez ID, Bolaño-Romero MP, Moscote-Salazar LR, et al. Brain-lung interaction: a vicious cycle in traumatic brain injury. Acute Crit Care. 2022; 37(1):35-44. doi: 10.4266/acc.2021.01193
36. Silva-Rued ML, Ramírez-Romero A, Guerra-Maestre LR, Forero-Hollmann ÁM, Lozada-Martínez ID. The need to develop specialized surgical centers: the evidence that surgical diseases cannot wait. Int J Surg. 2021; 92:106036. doi: 10.1016/j.ijsu.2021.106036
37. Blanco-Teherán C, Quintana-Pájaro L, Narvaez-Rojas A, Martínez-Pérez R, García-Ballestas E, Moscote Salazar L, et al. Evidence-based medicine in neurosurgery: why and how? J Neurosurg Sci. 2022; 66(1):49-53. doi: 10.23736/S0390-5616.21.05331-5
38. Lozada-Martinez ID, Ortega-Sierra MG, Hernández-Morales EY, Gonzales-Méndez R, Mejias-Riverón K, Argüello-Manrique M, et al. Letter to the Editor. Latin American collaboration in international neurotrauma registries: a strategy from the academy. J Neurosurg. 2022; 11:1-2. doi: 10.3171/2022.1.JNS2232.

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Plagiarism in all its forms constitutes unethical publishing behaviour and is unacceptable.

Acceptable percentage of resemblance - 5%.
Duplicate content in research papers shall be considered only up to 5% of the total content.

For Romanian Neurosurgery the publication ethics and publication malpractice statement are consistent with the recommendations and guidelines of the Committee on Publication Ethics, the World Association of Medical Editors, the International Committee of Medical Journal Editors and Consolidated Standards of Reporting Trials.

Links:
Committee on Publication Ethics
(COPE): http://www.publicationethics.org
World Association of Medical Editors
(WAME): http://www.wame.org
International Committee of Medical Journal Editors
(ICMJE): http://www.icmje.org

2. Enclosed Letter

In addition to the manuscript, the Editorial Board should receive an enclosed letter containing the exclusive reservation of copyright guaranteed by all authors whose manuscripts have already been accepted. If the paper was completely or partially published or exposed previously, a copy or a photocopy of it should be also sent. The technical reports should contain a declaration concerning the financial sources that cover the costs necessary for instruments and methodology acquisition.
In order to illustrate different cases, photos of identifiable patients will not be published without their legal consent or that of their legal representative. The letter containing this consent together with the manuscripts should be sent to the editorial office.
If the author wishes his unpublished manuscripts returned, please note this in the enclosed letter.

3. Sending of manuscripts

The manuscript sent for publishing must be submitted in English.

Authors shall ensure that the article has been spell and grammar checked prior to the submission.

The manuscript will be typed without formatting, with 1-line space. Please enclose one copy of the manuscript, tables, graphics and photos. After publishing, the paper and pictures become the property of Romanian Neurosurgery.

There are no article processing charges (NO APCs) and no article submission charges.

4. Manuscript elaboration

Paper sent for publishing should be in accordance with international standards of manuscript submittance. These standards are mentioned in "British Medical Journal" 1988; 296: 404-405 or in "Annals of Internal Medicine" 1988; 108:258-265. The authors are responsible for the accuracy of the information contained in the essay.

4.1. The title page should contain the whole title of the essay and complete names of authors with their academical degrees. If it is necessary, the department, the hospital or the institution where the search has been undertaken, should be also mentioned.

4.2. Please include an additional page containing the title of the essay and the author responsible for correcting of any and of all mistakes and for maintaining correspondence. The address, phone and fax number should be included (e-mail be available).

4.3. A summary, no longer than 300 words, should be written on a separate page. Key-words, no more than 7, should be listed in alphabetical order on the same page. The use of keywords should be approved by the "Index Medicus".

4.4. Text. The introduction should specify the purpose of the paper. The content and the method should give a minute account of the work methodology so that the experiment conclusion could be reproduced and checked up on in other centres. The experiments and medical studies performed on human beings should respect the principles specified in "The Declaration of Helsinki", whereas the experiments done on animals should be in accordance with "The Principles Charta of Animal's Care and Use". The results should not contain references to previous studies. The discussions should reflect the main features of the research.

5. References

- typed on 1 line;
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- unpublished data and personal papers should be quoted inside the text and not in the bibliography;
- entries to the bibliography should appear in the following order: the authors, the title of the essay, the title of the periodical (abbreviated according to the list of abbreviation specified in the "Index Medicus"), the volume number, the page number and the data publication.

6. Tables and pictures
There should be 1 copy sent. Each table with its own title should be submitted on separate pages. The photos, radiographies, CT scans should be labelled on the back with the number of each picture, corresponding with the number included inside the text, and the author's name. The label will be placed on the top of the picture. The drawings may be sent on vellum paper, tracing paper or transparent paper. The use of pictures belonging to other publications is accepted, only if mentioning the original source. Further, the partial use of any previously published text is accepted with the approval of its author and editor. All pages should be consecutively numbered, starting with the title page.

7. Abbreviations
Abbreviations should be consistently used throughout the text and established in a fixed form from the beginning.

8. Submission
Manuscripts should be sent using the online submission platform or to the Editor:
Dr Vicentiu Saceleanu, MD, PhD
(vicentiu.saceleanu@ulbsibiu.ro)

9. Disclaimer
The editors disclaim any responsibility for opinions expressed in the papers.

10. The review process
After the manuscript submission, the peer review process is broken down into the following steps:
1. The Editor assigns Reviewers to the manuscript.
2. The Reviewers review the manuscript.
3. The Editor drafts a decision to be sent to the author/authors.

The review process takes between three weeks and two months.