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Case Report

Minimally invasive tubular approach to intramedullary cavernous malformations

Maia Sophia Kantorowski[1], James Benning Walker[1,2]

[1]Department of Neurosurgery, FirstHealth of the Carolinas, Pinehurst, [2]Department of Neurosurgery, University of North Carolina at Chapel Hill, North Carolina, United States.

E-mail: *Maia Sophia Kantorowski - mkantorowski@firsthealth.org; James Benning Walker - jbwalker@firsthealth.org

***Corresponding author:**
Maia Sophia Kantorowski,
Department of Neurosurgery,
FirstHealth of the Carolinas,
Pinehurst, North Carolina,
United States.

mkantorowski@firsthealth.org

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ABSTRACT

Background: Advancements in minimally invasive spinal surgery have led to an expansion of targeted pathologies as well as improvements in surgical outcomes compared to their conventional counterparts through open laminectomy; however, this technique is rarely mentioned in the literature for intrinsic cord lesions. The authors present a novel minimally invasive, dorsolateral, and expandable tubular approach for the resection of an intradural, intramedullary thoracic cavernous malformation (CM).

Case Descriptions: A 52-year-old male patient presented with rapidly progressive myelopathy and loss of ambulatory capabilities, with which magnetic resonance imaging revealed a hemorrhagic CM within the thoracic spinal cord. The CM was successfully resected through a minimally invasive tubular approach utilizing a dorsal root entry zone myelotomy. Postoperative imaging confirmed gross resection. His motor examination rapidly recovered, and he remains ambulatory with the use of a cane at a 2-year follow-up.

Conclusion: This novel minimally invasive approach is a promising technique for well-selected cases of symptomatic spinal CMs. Further exploration and potentially randomized studies are necessary to fully affirm the tubular approach's suitability for the treatment of intradural intramedullary CMs compared to conventional techniques.

Keywords: Angioma, Cavernoma, Cavernous malformation, Dorsolateral myelotomy, Intradural intramedullary, Minimally invasive

INTRODUCTION

Cavernous malformations (CMs) are vascular malformations consisting of a single layer of endothelium and lacking a complete vascular wall, which may manifest in any part of the central nervous system.[1,2,8,10] Within the general population, CMs are estimated to have a prevalence of 0.4–0.6%, with intracranial lesions being more common. Spinal cord cavernomas are rare, which account for only 5-12% of cases. It has been thought that CMs of the spinal cord result in poorer outcomes compared to those residing in the brain hemispheres.[2]

Surgical resection is clinically favored when CMs present symptomatically. Mini-open techniques to resect these lesions have not been as heavily researched or explored as compared to the traditional approaches, especially in the consideration of CMs.[14] Conventionally, these lesions are treated through traditional open multilevel laminectomies, which can result in significant postoperative pain, excessive blood loss, as well as other complications, including

pseudomeningoceles and cerebrospinal fluid (CSF) leaks. Recent advances in minimally invasive approaches have produced comparable outcomes and suggest multiple advantages.[14] Since the advent of tubular minimally invasive spinal (MIS) surgery, the application of this technique has expanded from first microdiskectomies to transforaminal interbody fusions and then subsequently to intradural extramedullary tumors.[3,11,12] There has been a much slower adaptation of this technique for intramedullary lesions and specifically CMs, presumably due to perceived concerns of neurologic injury due to intraoperative visual disorientation or technical complexities in performing a midline myelotomy through such a constrained approach.

Here, we present a case of a symptomatic intramedullary CM, resected utilizing a minimally invasive approach incorporating a dorsolateral myelotomy through an expandable tubular retractor. To the best of our knowledge and based on our comprehensive expanded literature search, this is the first case detailed of such an approach. This case suggests the possibility of success in intervention and outcome using less invasive techniques for spinal CM management.

HISTORY AND CLINICAL PRESENTATION

A 52-year-old Hispanic male without significant medical history, except for a recent COVID-19 illness, presented to the emergency room with a 3-week history of loss of ambulatory mobility and progressive severe bilateral lower extremity weakness. His weakness was greater on the right with a T9 sensory level with saddle anesthesia and altered proprioception. In addition, on examination, he was noted to have 3/5 strength in the left lower extremity and 2/5 strength in the right lower extremity, with marked hyperreflexia and spasticity also noted worse on the right. On further workup, magnetic resonance imaging (MRI) demonstrated an expansile 1.8 × 1.0 cm intramedullary hemorrhagic lesion at the T8 region consistent with a CM. This lesion extended to the dorsal and dorsolateral region on axial images [Figure 1a and b].

Intervention and operative technique

Given the concern of rapid neurological decline and the focal nature of the lesion that presented to the dorsolateral surface, the decision was made to pursue urgent surgical resection through a minimally invasive technique utilizing an expandable retractor.

The patient was placed in a prone position atop a radiolucent Jackson table after induction of general anesthesia with avoidance of long-acting paralytics. Motor- and somatosensory-evoked potential leads were placed, and baseline waveforms were obtained. The superior T8 level was localized by placing multiple spinal needles counting from the proximal L5 to S1 disc space in order to identify the T8 pedicle on a lateral fluoroscopic image. After the use of a local anesthetic, a 3 cm incision was made 3 cm right of the midline and opened. Using Bovie electrocautery, the thoracolumbar fascia was incised, and serial dilation was employed to place a 18 mm Stryker Phantom Retractor System® with a slight lateral to medial trajectory. With the aid of an operative microscope, the right-sided soft tissues of the T7 and T8 lamina were removed, and subsequently, a right T8 hemilaminectomy was performed on the inferior T7 and superior T8 lamina through a high speed drill. A small portion of the ligamentum flavum was removed; however, the T8 spinous process was undercut, exposing the thecal sac while sparing the interlaminar and supraspinous ligaments. The dura was then opened with a #11 scalpel blade and tacked up with Nurolon® suture. The arachnoid was then dissected, and dorsal rootlets and dentate ligament were identified. This allowed for the visualization of the pial surface as well as the expansile lesion marked by subacute and chronic blood products [Figure 2]. A one

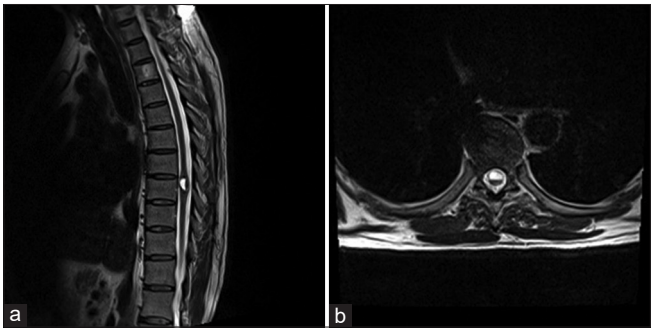

Figure 1: (a) Preoperative T2 mid-sagittal magnetic resonance imaging (MRI) reveals the 1.8 × 1.0 cm expansile cavernoma with a fluid level, suggesting recent hemorrhage. (b) Preoperative T2 axial MRI demonstrated the same lesion.

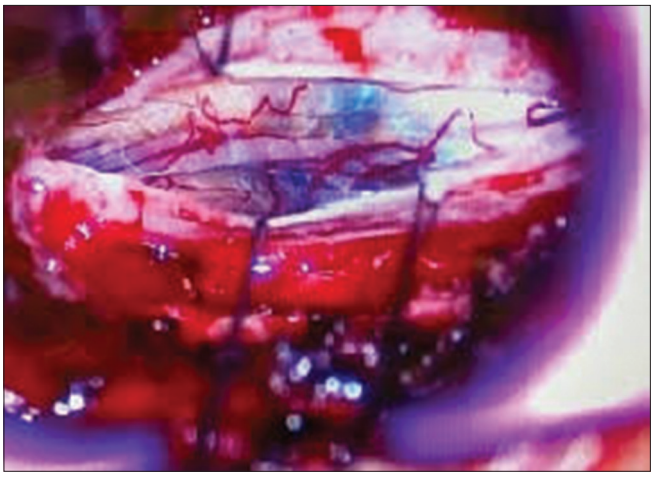

Figure 2: An intraoperative owl's eye view through the tubular retractor visualizing the intramedullary lesion. The dorsal rootlets are clearly visualized, demarcating the dorsal root entry zone.

centimeter longitudinal myelotomy was made along the dorsal root entry zone (DREZ) with a diamond knife under high-power magnification [Figure 3]. The cavity was entered immediately beneath the pia, pressurized subacute and chronic blood products were evacuated, and the CM was carefully dissected from the spinal cord using microscopic techniques and careful dissection. The hemosiderin stained gliotic tissue was left intact. Hemostasis was obtained, and the dura was then approximated with 4-0 Nurolon suture and Anastoclips®. Duraseal® was then placed along the durotomy to buttress the closure. No CSF leak was observed with a Valsalva maneuver. The retractor was then removed, and the incision was closed in a standard fashion. Final pathology confirmed a CM.

The patient's strength improved in the immediate postoperative period. He was discharged home on postoperative day 9, ambulating with a walker, after participation in daily inpatient physical therapy. No postoperative complications were encountered, including the absence of CSF leakage or infection. He noticed a significant improvement in lower extremity weakness with good pain control. At his 18th month follow-up, he was noted to be ambulating with a cane with 5/5 strength in the left lower extremity and 4/5 strength in the right lower extremity, with some residual spasticity noted on the right. His sensation had improved in his bilateral lower extremities with excellent bladder control. An MRI of the thoracic spine at his last follow-up demonstrated total resection of the CM with a small area of residual myelomalacia with hemosiderin staining and mild focal cord atrophy [Figure 4a and b].

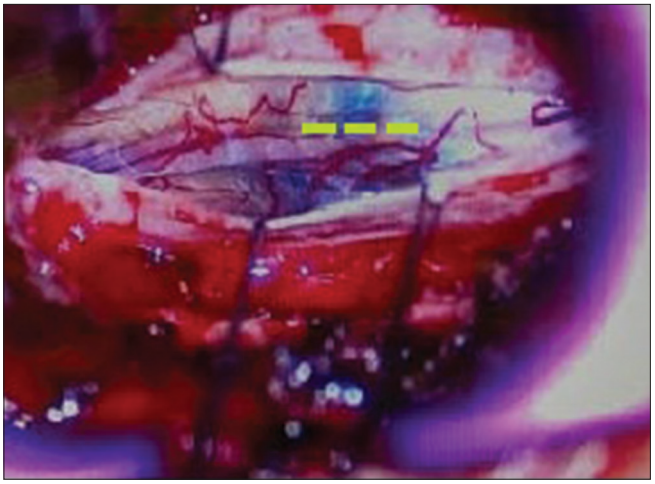

Figure 3: The dashed line in this figure represents the location of the myelotomy made just lateral and longitudinal to the fasciculus gracilis along the dorsal root entry zone.

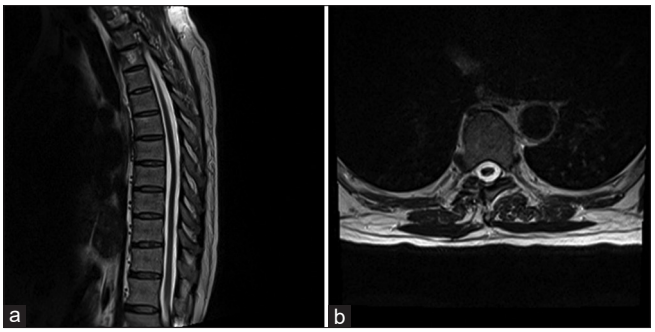

Figure 4: (a) Postoperative T2 mid-sagittal magnetic resonance imaging (MRI) at 18 month follow-up reveals resection of the lesion with small region of hemosiderin deposition. (b) Postoperative T2 axial MRI at same 18 month follow-up.

Literature search

We utilized the PUBMED search engine with the keywords *"cavernous malformation," "spinal," "cavernoma," "cavernous angioma," "angiomatous malformation," "minimally invasive," "intramedullary," "dorsolateral," "myelotomy,"* and *"tubular."* This search revealed a total of 52 journal articles. Of these, a total of 25 were deemed relevant as they pertained to either surgery for CMs or were related to intradural surgery for vascular malformations. These individual articles, including case reports and case series, were obtained and reviewed, including a close inspection of each paper's references for potentially relevant articles. Only one paper was discovered that mentions the resection of a CM through a minimally invasive approach; however, this was achieved through a unique midline interspinous approach.[14]

DISCUSSION AND REVIEW OF THE LITERATURE

Intramedullary spinal CMs can present as both serious and challenging pathologies, but neurological recovery is possible with total resection. With any spinal cord lesion, it is essential to pursue a surgical approach in which the lesion is not only adequately visualized but also minimizes the amount of disruption to the neighboring osseous, muscular, ligamentous, and meningeal structures. Interestingly, descriptions involving the incorporation of minimally invasive techniques for intramedullary spinal lesions are extremely sparse, especially CMs. A large amount of cited reports favor the traditional approach of open multilevel bilateral laminectomy or laminoplasty for the resection of CMs, presumably due to concerns of freedom of motion in case of bleeding, difficulties with dural closure through a narrow corridor, and concerns of visuospatial disorientation through limited access or lack of visualization of the midline as a reference point.[14] As medicine has continued to advance, several reports suggest the potential advantages and positive outcomes of progressively less invasive techniques to treat these conditions, from the implementation of mini-open hemilaminectomies to mini-open midline tubular approaches.[2,13,14]

Comparison of outcomes for minimally invasive spinal surgery versus conventional approaches for extramedullary spinal pathology

The potential advantages of our minimally invasive approach could be evident by the historical comparison of MIS surgery to open surgery for extradural pathology in regard to postoperative outcome measures. The conventional approach for procedures such as the lumbar discectomy and lumbar interbody fusion is widely accepted to be the use of the open laminectomy approach, which has shown good surgical outcomes.[6,7,14] Although the results of traditional open approaches are excellent regarding improvement of neurological or functional outcomes, there remain concerns of extensive postoperative blood loss, spinal deformity, excessive postoperative pain, CSF-related complications, or prolonged hospitalizations. With these concerns in mind, the advantages of MIS surgery are continuously promoted and suggested. Clark *et al*. and Schwender *et al*. were the first to describe the "tubular" approach to multiple facets of neurosurgery, ranging from microdiskectomies to spinal fusions, but initially limited to degenerative disorders.[3,11] Nonetheless, the advantages of the MIS approach were evident early on when compared to traditional surgery. Phan and Mobbs revealed statistically significant improved patient satisfaction rates, less blood loss, lower reoperation rates, and shorter hospital stays in a minimally invasive laminectomy group compared to that of the traditional open laminectomy group for treatment of patients with lumbar stenosis.[9] Similarly, Imada *et al*. cite the advantages of MIS discectomies as well as lumbar interbody fusions for outcome measures of leg pain, disability index, and blood loss when compared to their conventional open counterparts.[5] In general, this cited research provides promising and relative information regarding the advantages of MIS approaches for extramedullary spinal surgery as compared to the conventional open approach.

Literature search regarding historical resection of spinal CMs

According to our literature search, it is surprising that the vast majority of case series and reports regarding CMs are performed through traditional open techniques. As shown in a comparative review by Mitha *et al*., open hemilaminectomy incorporating a DREZ myelotomy and more traditional open bilateral laminectomy incorporating a midline myelotomy were utilized.[7] Complications from both these approaches included serous epidural fluid collections, CSF leaks, and deep venous thrombosis in the early postoperative period. There was no statistically relevant difference in outcomes between the groups, although there was a suggestion that the dorsolateral DREZ group had better improvement in long-term pain. In a case report by Ginalis *et al*., an approach is explained through a multilevel laminectomy at the C2–T2 levels with the employment of a right lateral myelotomy between the DREZ and ventral root entry zone (VREZ) for the total resection of a large intramedullary cervicothoracic CM.[4] Further, clinical reports by Bian *et al*. and Wachter *et al*. describe open surgeries utilizing hemilaminectomies and subsequent entry through the DREZ for the resection of spinal cavernomas – additionally exemplifying a less invasive approach compared to traditional exposures with a reduction in neurological worsening and an increase in improvement rate.[2,13] Although these descriptions still require open midline multilevel lamina exposures, these clinical case reports and series highlight a few of the common approaches that employ less invasive techniques as compared to the traditional bilateral laminectomy for intervention of spinal CMs while also suggesting favorable outcomes and preventing additional morbidity.[2]

The "minimally invasive" tubular approach for spinal cord CMs

Given the advantage of minimizing the degree of bony resection as well as reducing the potentially dead space through smaller incisions, we propose the use of the MIS expandable tubular techniques for the treatment of intradural intramedullary spinal CM in well selected patients. As stated above, descriptions of minimally invasive approaches for intramedullary CM are limited. According to our extensive review, tubular approaches to intramedullary spinal CMs have been rarely reported, with only one peer-reviewed publication found. Winkler *et al*. explain the feasibility of a tubular retractor for the microsurgical resection of a spinal CM, involving a midline interlaminar approach with partial resection of the midline ligamentous structures and incorporating a midline durotomy with a small subcentimeter myelotomy.[14] This involved a two-level laminectomy with the use of an expandable tubular retractor that resulted in a reported good outcome and highlights the importance of further exploration and experimentation in this niche of neurosurgery. Our approach is different from that of Winkler *et al*., as it involves a paramedian muscle splitting approach involving a hemilaminectomy and dorsolateral DREZ approach with the use of a tubular expandable retractor. Although additional less invasive CM resections have been described through open hemilaminectomy techniques, this case study suggests the possibility of a true minimally invasive approach for a spinal intradural, intramedullary CM. Utilizing a smaller incision, potential benefits may include quicker recovery, shorter hospitalization, lower overall blood loss, decreased risk of CSF leak, as well as lower risk for infection. Through our experience with MIS surgery for intradural, extramedullary pathology, we have also found that the use of Anastaclips® has expedited the dural closure portion of the procedure

and has made dural closure much less ominous and more technically proficient. Potential weaknesses of this approach should also be considered. This approach should only be incorporated in well-selected patients. Furthermore, caution should be applied to attempting this technique for any CM, such as cases that span more than one vertebral segment, cases involving obese patients due to the possibility of decreased freedom of movement of surgical instrumentation, and lesions that are not located along the dorsolateral surface. Moreover, as with all MIS approaches, a plan should always be in place to convert to a traditional open approach in the event of intraoperative limitations and difficulties.

CONCLUSION

The resection of intramedullary spinal lesions through minimally invasive approaches is scarcely described in the literature. We have described the presentation and surgical management of an intradural, intramedullary spinal CM using minimally invasive techniques incorporating a DREZ myelotomy. To the best of our knowledge, this is the first described case detailing such an exposure in the literature. This case highlights the practicability of a minimally invasive approach utilizing an expandable tubular retractor for the resection of a hemorrhagic intramedullary spinal CM. This tubular approach is a promising technique that we believe provides a direct and minimally invasive approach to the intramedullary dorsolateral corridor and could offer multiple advantages for outcome and recovery in well-selected patients. To fully explore the suitability and practicality of MIS management of intradural intramedullary CMs, further studies are necessary to validate the reproducibility of this approach.

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Ethical approval

The Institutional Review Board approval is not required.

Declaration of patient consent

The authors certify that they have obtained all appropriate patient consent.

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Nil.

Conflicts of interest

There are no conflicts of interest.

Use of artificial intelligence (AI)-assisted technology for manuscript preparation

The authors confirm that there was no use of artificial intelligence (AI)-assisted technology for assisting in the writing or editing of the manuscript and no images were manipulated using AI.

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