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*Case Report*

# Holocord myelopathy misdiagnosed as neuromyelitis optica spectrum disorder (NMOSD): A unique case of dural arteriovenous fistula at the craniocervical junction along first spinal nerve

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Received: 26 February 2024
Accepted: 25 May 2024
Published: 21 June 2024

**DOI**
10.25259/SNI_138_2024

**Quick Response Code:**

## ABSTRACT

**Background:** Dural arteriovenous fistulas (DAVFs) at the craniocervical junction (CCJ) involving the first spinal nerve represent a particularly rare and challenging subtype of DAVFs, with holocord myelopathy secondary to cerebrospinal DAVFs being an exceedingly rare presentation.

**Case Description:** We report the case of a 70-year-old woman who presented with progressive paraparesis over 2 weeks. Initial magnetic resonance imaging (MRI) of the spine showed extensive holocord myelopathy, leading to a misdiagnosis of inflammatory myelopathy and subsequent inappropriate steroid treatment at a local hospital, which exacerbated her neurological symptoms. On transfer to our institution and further evaluation with MRI and magnetic resonance angiography, a lower thoracic DAVF was initially suspected. However, comprehensive spinal angiography failed to localize the fistula, prompting cranial angiography, which ultimately identified a DAVF at the CCJ along the C1 nerve root, supplied by a small radiculomeningeal branch of the left vertebral artery. Successful management involved coagulation of the proximal draining vein, with follow-up imaging confirming complete fistula obliteration and resolution of the holocord edema.

**Conclusion:** This case highlights the diagnostic and therapeutic challenges associated with DAVFs at the CCJ, particularly when presenting with holocord myelopathy. It underscores the importance of a high index of suspicion and the need for timely, accurate diagnosis and intervention to prevent permanent spinal cord damage in such rare and complex cases.

**Keywords:** Craniocervical junction, Dural arteriovenous fistula, First cervical spinal nerve, Holocord myelopathy, Longitudinally extensive transverse myelitis, Neuromyelitis optica spectrum disorder

## INTRODUCTION

Intracranial dural arteriovenous fistulas (DAVFs) are rare and complex vascular malformations characterized by abnormal connections between meningeal arteries and dural venous sinuses or

cortical veins.[4] Although DAVFs can occur anywhere within the cranial dura, their occurrence at the craniocervical junction (CCJ), especially along the C1 nerve root, poses unique diagnostic and therapeutic challenges.[17]

Despite advancements in neuroimaging and therapeutic techniques, DAVFs located at the CCJ continue to present significant challenges due to the complexity of vascular anatomy in this region, the variability of clinical presentations, and the potential for considerable morbidity and mortality. It is now recognized that arteriovenous fistula (AVFs) of the CCJ should be specifically referred to when they are located at the C1 or C2 levels. High cervical CCJ AVFs can be categorized into four types: DAVF, radicular AVF, epidural AVF, and perimedullary AVF.[15] The primary clinical manifestations of CCJ DAVFs, influenced by the pattern of venous drainage, include acute subarachnoid hemorrhage (SAH), myelopathy, brain stem dysfunction, radiculopathy, and cranial nerve palsies.[10] DAVFs of the CCJ at the C1 spinal nerve represent <2% of all cerebrospinal DAVFs.[7]

Holocord myelopathy, characterized by edema encompassing the entire spinal cord, is a rare but severe clinical entity that can result in significant morbidity if not promptly identified and managed. The occurrence of this condition due to AVFs at intracranial or CCJ locations is exceedingly rare.[5,9] To the best of our knowledge, this report presents the first documented case of a DAVF at the CCJ along the first spinal nerve causing holocord myelopathy due to venous congestion.

## CASE DESCRIPTION

A 70-year-old woman with a history of hypertension, dyslipidemia, and chronic neck pain for 3 years was admitted to a local hospital after experiencing progressive paraparesis over 2 weeks. She reported accompanying neck and back pain but no visual or bulbar symptoms nor a history of trauma. Two days before her hospital admission, she developed bowel and bladder dysfunction. Magnetic resonance imaging (MRI) with a 1.5 Tesla scanner of the entire spine revealed an abnormal T2 hyperintensity affecting both the gray and white matter, sparing only the peripheral regions of the spinal cord, extending from the cervicomedullary junction to the conus medullaris, indicative of holocord edema. In addition, disc herniation and thickening of the ligamentum flavum were observed, causing moderate to severe spinal stenosis at the levels of C3–4, C4–5, C5–6, and C6–7. No abnormal flow voids were reported in the radiological analysis [Figures 1 and 2]. Lumbar puncture showed opening/closing pressures of 13/10 mmH2O, and cerebrospinal fluid (CSF) analysis revealed 0 red blood cells, 79 white blood cells with 3% polymorphonuclear cells and 97% lymphocytes, a glucose level of 71 mg/dL (with a corresponding blood sugar level of 199 mg/dL), and a protein concentration of 155.3 mg/dL. The initial diagnosis considered was longitudinally extensive transverse myelitis (LETM), with neuromyelitis optica spectrum disorder (NMOSD) being the most probable cause. The serum antiaquaporin-4 immunoglobulin G (AQP4-IgG) antibody was negative. The patient was managed with methylprednisolone pulse therapy for 5 days, but the power in her lower limbs progressively deteriorated from grade 3 to grade 2. Consequently, she was referred to a specialized facility for plasma exchange treatment. The consulting neurologist at the facility questioned the LETM diagnosis and transferred the patient to our institute for further evaluation and management.

On neurological examination at our institute, evidence of spastic paraparesis was noted, with muscle strength rated at 1–2/5. In addition, the patient lacked pinprick sensation below

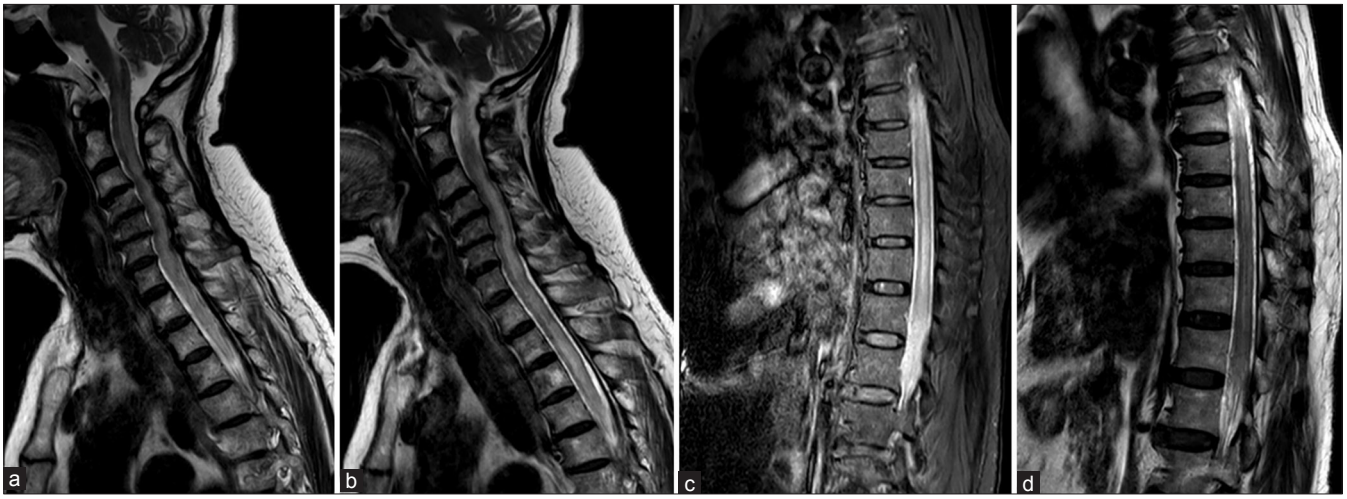


**Figure 1:** 1.5 Tesla Magnetic resonance imaging of the whole spine obtained 2 weeks after initial symptom of progressive paraparesis. (a-d) Sagittal T2-weighted images of cervical, thoracic, and lumbar spine show abnormal hyperintensity, representing spinal cord edema of the whole spinal cord. There are disc herniation and spinal stenosis at the level of C3-4, C4-5, C5-6, and C6-7.

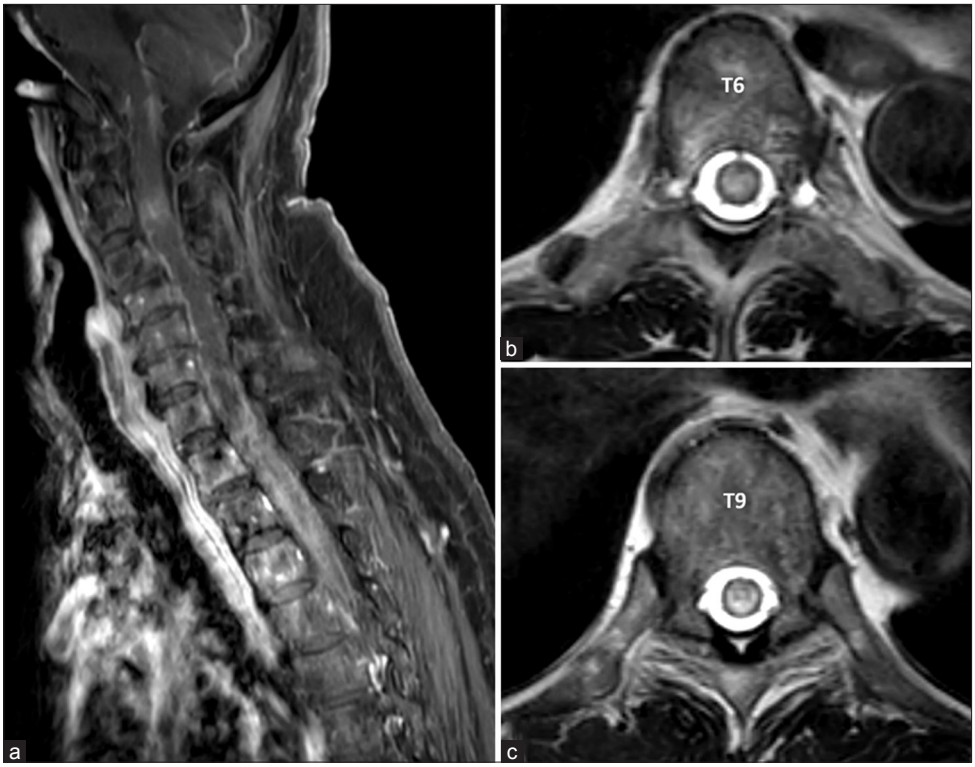


**Figure 2:** 1.5 Tesla Magnetic resonance imaging of spine obtained 2 weeks after initial symptom of progressive paraparesis. (a) Sagittal contrast-enhanced T1-weighted image of cervicothoracic spine shows patchy enhancement of spinal cord. (b, c) Axial T2-weighted images of T6 and T9 levels reveal spinal cord edema with sparing of peripheral white matter.

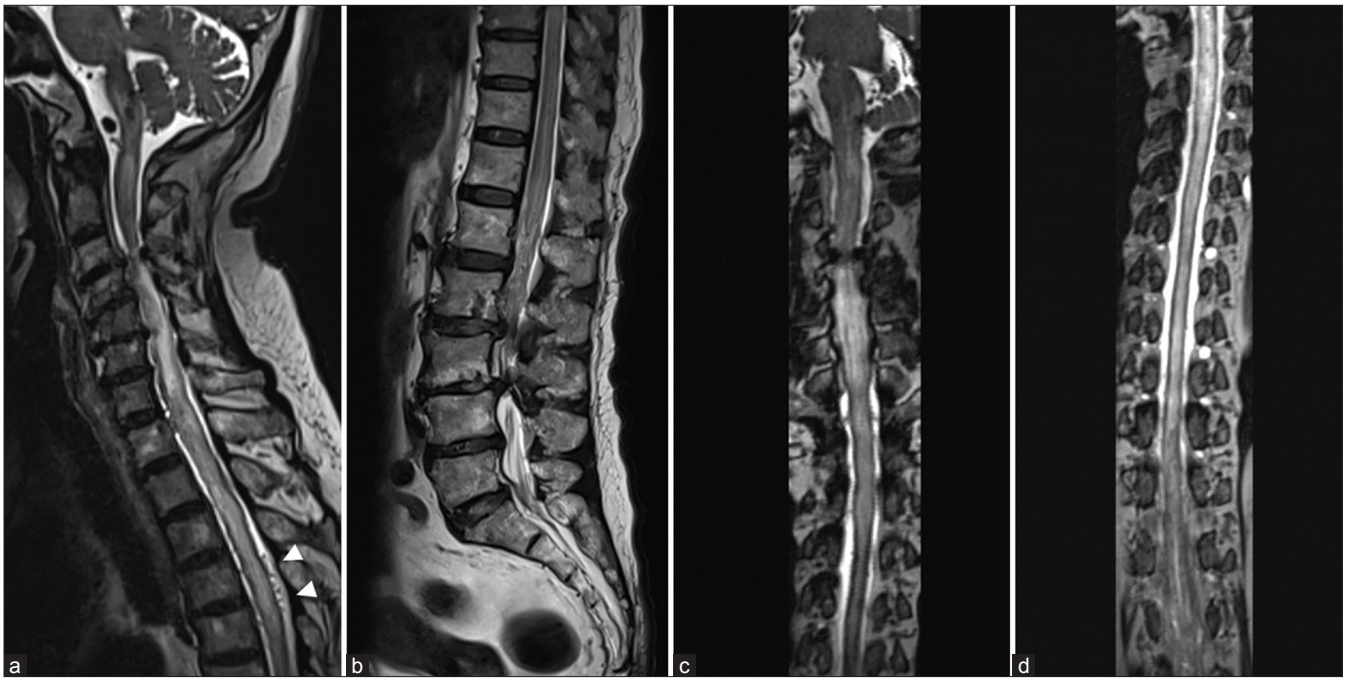


**Figure 3:** 3 Tesla Magnetic resonance imaging of the whole spine obtained 1 month later. (a, b) Sagittal and (c, d) coronal 3D T2-SPACE images of cervicothoracic and thoracolumbar spine reveal the progression of venous congestion extending from lower brainstem to conus medullaris with subtle perimedullary flow voids (denoted by arrowheads in figure 3a). There are disc herniation and severe spinal stenosis at the level of C3-4, L3-4, and L4-5. SPACE: Sampling perfection with application-optimized contrasts using different flip angle evolution.

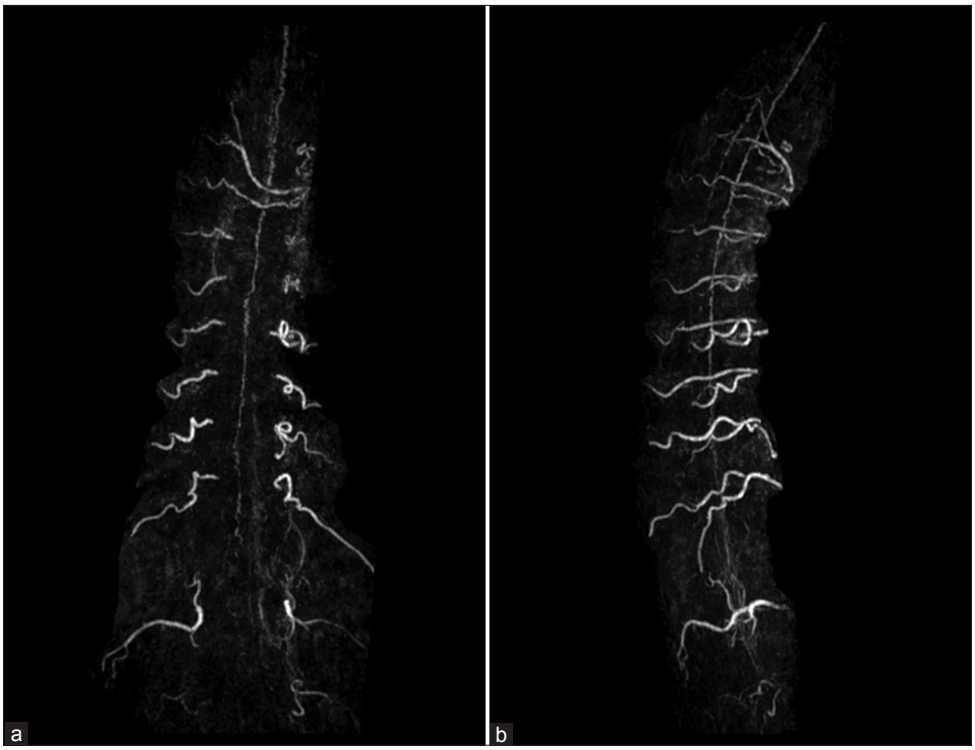


**Figure 4:** (a) Coronal and (b) sagittal maximum intensity projection images from contrast-enhanced magnetic resonance angiography of the whole spine demonstrate dilated and tortuous veins mainly along the anterior surface of the spinal cord extending from the conus medullaris to the cervical level, suspecting left-sided spinal dural arteriovenous fistula at lower thoracic level.

the T6 level and showed impaired proprioception below the knees. A follow-up MRI using a 3 Tesla scanner and 3D T2-weighted sampling perfection with application-optimized contrasts using different flip angle evolution (SPACE) conducted 1 month after the initial symptoms emerged showed the spinal cord edema extending up to the lower brainstem, with subtle perimedullary flow voids at the thoracic level. The imaging also confirmed severe spinal stenosis at L2–3 and L3–4 levels due to disc herniation and ligamentum flavum thickening [Figure 3]. Contrast-enhanced magnetic resonance angiography (MRA) of the entire spine revealed tortuous and enlarged intradural vessels along the anterior surface of the spinal cord, from the conus medullaris to the cervical level, suggesting a left-sided spinal DAVF at the lower thoracic level [Figure 4]. Despite whole spinal angiography, the precise location of the fistula remained unidentified. The decision was made to proceed with intracranial angiography, which fortunately revealed a left DAVF at the CCJ. This fistula was supplied by the radiculomeningeal branch of the left vertebral artery at the C1 level, with draining veins extending to the medulla and the entire spinal cord through the dilated left lateral medullary vein [Figure 5].

Given the challenging nature of the fistula's small and tortuous feeding artery, surgical intervention was deemed necessary. The patient underwent a left suboccipital craniotomy and C1 hemilaminectomy in a right lateral decubitus position. The vertebral artery and proximal draining vein were identified, and the proximal draining vein's disconnection was confirmed with intraoperative indocyanine green angiography, which showed no fluorescent flow post-coagulation [Figure 6]. The patient's postoperative recovery was smooth, and follow-up angiography 2 weeks later confirmed the complete elimination of the fistula [Figure 7a]. Further, MRA of the left vertebral artery and MRI of the entire spine 4 months post-surgery showed complete resolution of venous congestion and no recurrence of the fistula [Figures 7b and 8]. Remarkably, the patient regained the ability to walk with a walker 4 months postoperation and experienced almost complete resolution of her bowel and bladder dysfunction at the 6-month follow-up.

## DISCUSSION

Our patient was initially misdiagnosed radiologically as having LETM, a condition characterized by a hyperintense intramedullary signal on spinal MRI that extends beyond three vertebral segments. NMOSD, which predominantly affects females, is a leading cause of LETM. Other causes of LETM include multiple sclerosis, myelin oligodendrocyte glycoprotein antibody disorders, acute disseminated

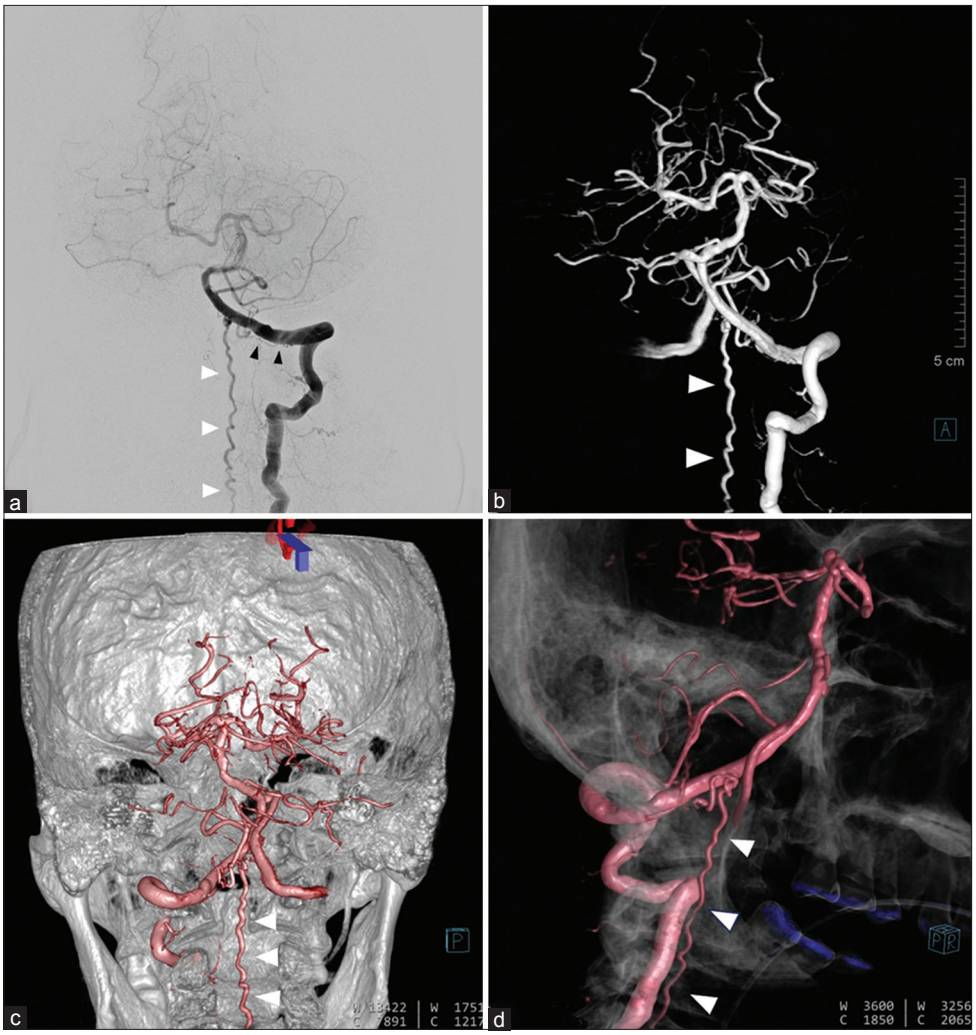


**Figure 5:** (a) Anteroposterior view of the left vertebral artery (VA) injection reveals the left dural arteriovenous fistula of craniocervical junction supplied by the radiculomeningeal branch (black arrowheads) of left VA from C1 level with draining veins extending rostrally to the medulla, and caudally to the cervical cord (white arrowheads) through dilated left lateral medullary vein. (b) Anteroposterior, (c) posteroanterior, and (d) lateral views of 3D reconstruction images of the left VA clearly demonstrate an enlarged and tortuous anterior spinal vein (white arrowheads).

encephalomyelitis, spinal cord infarction, parainfectious myelopathy, paraneoplastic myelitis, and spinal DAVF.[1,13,16] Holocord involvement, which affects both gray and white matter while sparing the peripheral white matter rim, may be indicative of NMOSD.[2] In addition, conventional MRI in our case showed intramedullary contrast enhancement without peri medullary flow voids, and CSF analysis revealed pleocytosis and elevated protein levels, suggesting inflammatory myelopathy. However, regardless of AQP4-IgG serologic status, NMOSD should be diagnosed when criteria are fulfilled, and alternative diagnoses for the clinical syndrome have been excluded.[19]

The acute clinical deterioration following methylprednisolone pulse therapy in our patient highlights a crucial diagnostic consideration. Such worsening after steroid administration may suggest the presence of a spinal DAVF, warranting further imaging to confirm the diagnosis. This is especially relevant in the setting of spinal DAVFs located in the upper cervical spine or Cognard type V fistulas, intracranial DAVFs draining into peri medullary veins, in which progression of myelopathy could result in acute tetraparesis or respiratory failure.[6,11] The exact mechanism for the progression of spinal DAVF symptoms after intravenous administration of steroids remains unclear. It is probably related to transient mineralocorticoid-induced hypervolemia and venous hypertension. Steroids could reduce venous egress from the spinal cord, thus exacerbating venous hypertension by reducing the capillary permeability of the blood–spinal cord

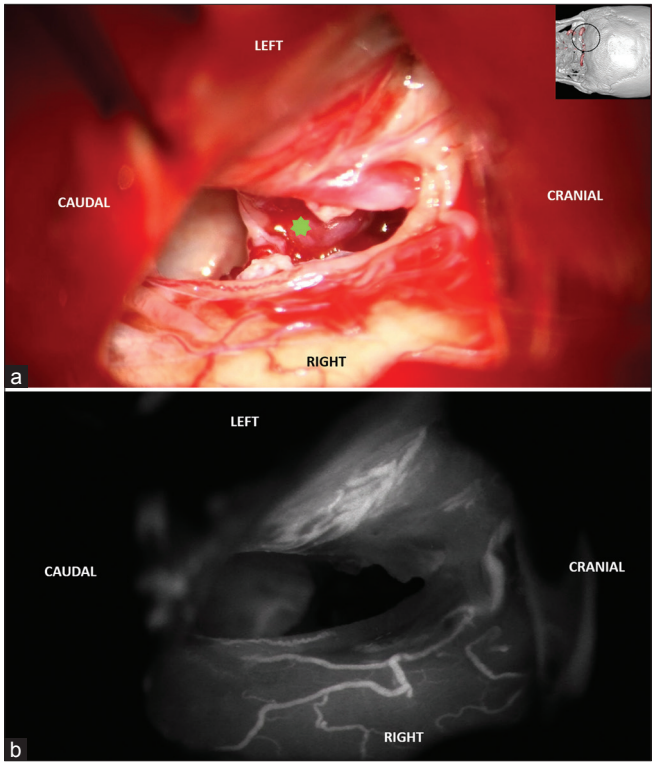


**Figure 6:** (a) Intraoperative photograph during surgery on the right lateral decubitus position after opening the dura. The proximal draining vein (green asterisk) is identified after the dissection of the first denticulate ligament. (b) After coagulation and disconnection of the draining vein, intraoperative indocyanine green angiography confirms the absence of fluorescent flow through the draining vein.

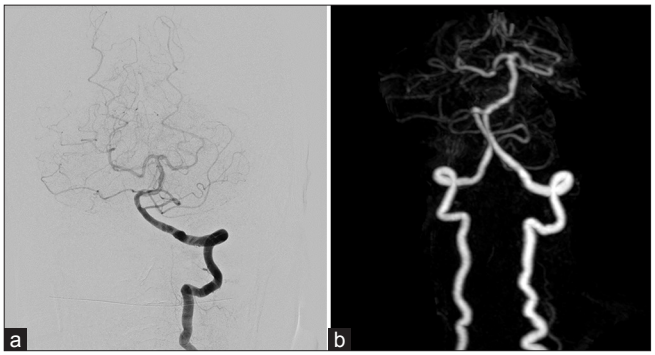


**Figure 7:** (a) Anteroposterior view of the left vertebral artery injection obtained 2 weeks after surgery confirms complete obliteration of the fistula. (b) Coronal maximum intensity projection image from contrast-enhanced magnetic resonance angiography of the vertebrobasilar system obtained 4 months after operation also reveals no residual fistula.

barrier. Or symptom progression could be due to steroid-induced thrombosis and inhibition of thrombolysis.[11,18]

Utilizing 3T MRI with 3D T2-weighted SPACE allowed for the detection of perimedullary flow voids in our patient, raising suspicion for a spinal DAVF. This imaging technique offers high spatial resolution without the need for contrast, improving the sensitivity in detecting spinal DAVFs and aiding in differential diagnosis from conditions like acute transverse myelitis.[12] The patients harboring spinal DAVFs, typically middle-aged men, commonly manifest with progressive myelopathy induced by chronic venous hypertension. Spinal DAVFs affect primarily the lower thoracic and upper lumbar spine and are located within the dorsal surface of the dural root sleeve in the intervertebral foramen.[3] Despite initial suspicion of a lower thoracic DAVF by MRA in our case, comprehensive spinal angiography failed to identify the fistula site. Cranial angiography, prompted by cervical cord involvement, successfully located the fistula at the CCJ supplied by the left vertebral artery.

DAVFs of the CCJ along the C1 spinal nerve are a rare and distinct subtype. These fistulas create an abnormal direct connection between the arterial and venous systems, bypassing the capillary network and resulting in blood flowing directly from high-pressure arterial vessels into lower-pressure venous channels, leading to venous hypertension or congestion.[17] The drainage pattern of DAVFs along the C1 nerve root determines their clinical manifestation. C1 spinal nerve DAVFs with downward drainage mainly result in congestive myelopathy, whereas those with upward drainage usually result in SAH, which is mainly caused by venous aneurysms. Venous congestion or edema of these fistulas usually involves the cervical spinal cord and/or lower brainstem.[7]

Interestingly, holocord edema occurred in our patient with C1 spinal nerve DAVF, probably low-flow shunt due to a single small feeder from the radiculomeningeal branch of VA. The mechanism of holocord edema remains unclear. Due to probably a long-standing lesion in our patient, the sustained high venous pressure may disrupt the blood-spinal cord barrier, and subsequent edema can trigger an inflammatory response within the spinal cord, resulting in further damaging of neural tissue and exacerbating edema that worsens the extent of myelopathy. The draining veins may extend downward as far as a lumbosacral region to reach the outlet.[5,9] In addition, we found severe spinal canal stenosis of the cervical and lumbar spine in our patient. Long-standing compression of the spinal cord from spinal canal stenosis can alter the normal flow of CSF around the spinal cord, potentially contributing to increased spinal cord pressure and edema. Furthermore, the narrowed spinal canal may compromise the vascular supply to the spinal cord, particularly the venous outflow, leading to increased venous pressure and exacerbating venous congestion.[8,14]

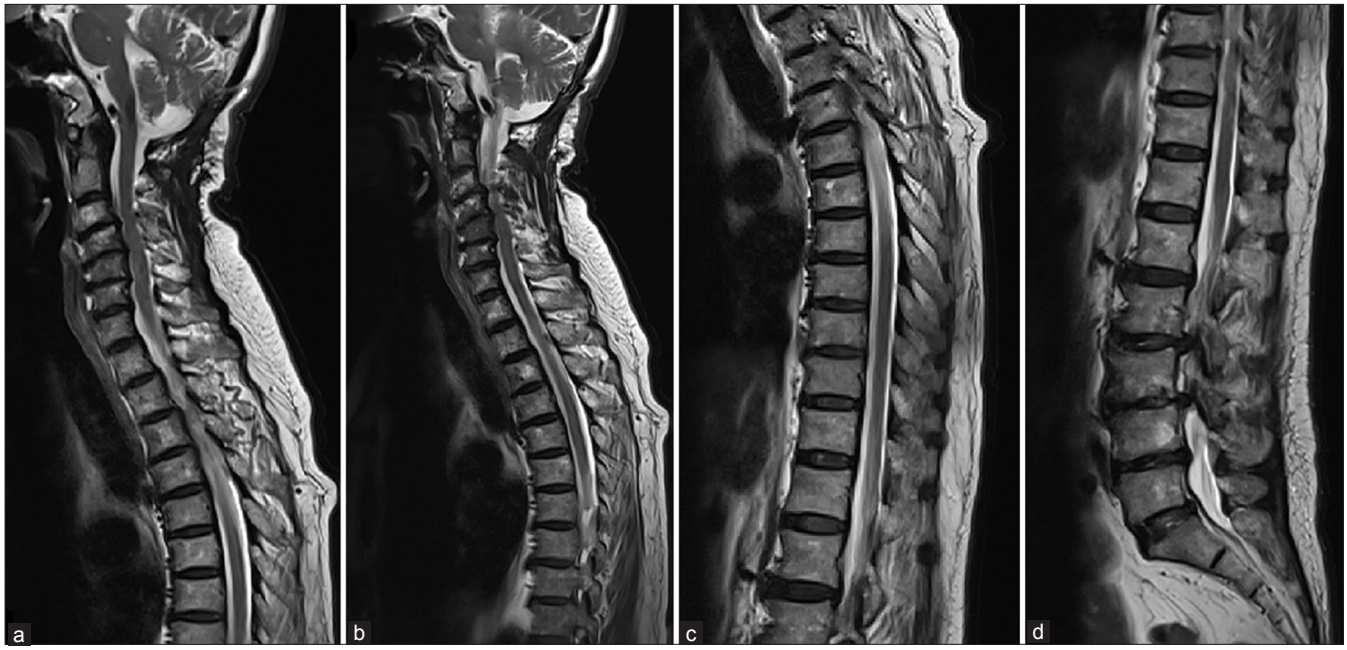


**Figure 8**: 3 Tesla Magnetic resonance imaging obtained 4 months after surgery. Sagittal T2-weighted images of (a and b) cervical, (c) thoracic, and (d) lumbar spine reveal complete resolution of venous congestion and disappearance of abnormal flow voids.

Most high cervical AVFs can be effectively treated with open surgery. Endovascular treatment remains challenging due to a high rate of incomplete obliteration and complications, and it can only be performed in superselective AVFs with simple angioarchitecture. Appropriate treatment can lead to a good prognosis.[10,15] Surgical treatment by interruption of the intradural draining vein should be the treatment of choice for C1 spinal nerve DAVFs.[7] Our patient's successful recovery, despite the initial delayed diagnosis, underscores the importance of prompt and appropriate intervention in reversing the effects of holocord edema.

## CONCLUSION

DAVF at the CCJ involving the first spinal nerve, coupled with holocord myelopathy, represents an exceedingly rare clinical entity with a propensity for rapid progression and severe outcomes. This case underscores the critical importance of early and accurate diagnosis, alongside prompt therapeutic intervention, to mitigate the risk of irreversible spinal cord damage. The complicating factor of spinal canal stenosis, by altering CSF dynamics, may further aggravate the condition, acting in concert with the longstanding venous hypertension induced by a C1 nerve root DAVF. This synergistic interaction underscores a complex pathophysiological mechanism, highlighting the need for a comprehensive diagnostic approach to identify and effectively manage such challenging cases, thereby preventing the devastating consequences of untreated spinal DAVFs.

### Ethical approval

The Institutional Review Board has waived the ethical approval for this study.

### Declaration of patient consent

Patients' consent not required as patients' identities were not disclosed or compromised.

### Financial support and sponsorship

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.

## REFERENCES

1. Chandrasekar S, John J, Satapathy AK. Longitudinally extensive transverse myelitis: One disease, variable outcomes-a

case series. J Neurosci Rural Pract 2022;13:339-42.
2. Hayashida S, Masaki K, Matsushita T, Watanabe M, Yamasaki R, Murai H, *et al*. Holocord involvement with sparing of the peripheral white matter rim in longitudinally extensive spinal cord lesions of neuromyelitis optica. Clin Exp Neuroimmunol 2015;6:78-9.
3. Iampreechakul P, Polpong P, Wangtanaphat K, Lertbutsayanukul P, Wattanasen Y, Siriwimonmas S. Acquired lumbosacral spinal Dural arteriovenous fistula in association with degenerative lumbosacral disc herniation and spinal canal stenosis: Report of two cases and review of the literature. Asian J Neurosurg 2020;15:1059-67.
4. Iampreechakul P, Wangtanaphat K, Chuntaroj S, Wattanasen Y, Hangsapruek S, Lertbutsayanukul P, *et al*. Spontaneous complete regression of malignant cavernous sinus Dural arteriovenous fistula following partial transarterial embolization with liquid embolic material: Report of two cases. Surg Neurol Int 2023;14:307.
5. Iampreechakul P, Wangtanaphat K, Hangsapruek S, Wattanasen Y, Lertbutsayanukul P, Siriwimonmas S. Acquired Chiari malformation Type I and holocord syringomyelia associated with a high-flow supratentorial fistulous arteriovenous malformations: A case report and literature review. Surg Neurol Int 2022;13:217.
6. Iampreechakul P, Wangtanaphat K, Lertbutsayanukul P, Wattanasen Y, Siriwimonmas S. Spontaneous closure of a cavernous sinus Dural arteriovenous fistula with spinal perimedullary drainage (Cognard V) during attempted transvenous embolization. Asian J Neurosurg 2019;14:1268-74.
7. Iampreechakul P, Wangtanaphat K, Wattanasen Y, Hangsapruek S, Lertbutsayanukul P, Siriwimonmas S. Dural arteriovenous fistula of the craniocervical junction along the first cervical nerve: A single-center experience and review of the literature. Clin Neurol Neurosurg 2023;224:107548.
8. Kim CH, Chung CK, Kwon BJ, Kim HJ. Holocord myelopathy with thoracic stenosis: Case report and hypothesis. Spinal Cord 2003;41:696-9.
9. Lee JY, Cho YD, Kwon BJ, Han MH. Dural arteriovenous fistula at the foramen magnum with holocord myelopathy: Case report. Neurointervention 2010;5:53-7.
10. Li J, Lin F, Zhu J, Zhuo L, Chen F, Dai L, *et al*. Enhanced treatment options for Dural arteriovenous fistulas at the craniocervical junction: Endovascular embolization versus microsurgery? A single-center 23-year experience. World Neurosurg 2024;182:e414-30.
11. Nasr DM, Brinjikji W, Rabinstein AA, Lanzino G. Clinical outcomes following corticosteroid administration in patients with delayed diagnosis of spinal arteriovenous fistulas. J Neurointerv Surg 2017;9:607-10.
12. Ouyang F, Wu Q, Chen Y, Yin M, Liu J, Lv L, *et al*. The value of 3D T2-weighted SPACE sequence in the differential diagnosis of spinal arteriovenous fistula and acute transverse myelitis. Eur Spine J 2023;32:4111-7.
13. Paudel S, Nepal G, Guragain S, Shah S, Paudel BS, Ojha R, *et al*. Longitudinally extensive transverse myelitis: A retrospective study differentiating neuromyelitis optica spectrum disorder from other etiologies. Cureus 2021;13:e13968.
14. Punia P, Chugh A, Gotecha S, Lachake A. Single-level ossified ligamentum flavum causing a holocord syrinx: Illustrative case. J Neurosurg Case Lessons 2023;6:CASE23340.
15. Su H, Yu J. Treatment of high cervical arteriovenous fistulas in the craniocervical junction region. Front Neurol 2023;14:1164548.
16. Tsurubuchi T, Matsumura A, Nakai K, Fujita K, Enomoto T, Iwasaki N, *et al*. Reversible holocord edema associated with intramedullary spinal abscess secondary to an infected dermoid cyst. Pediatr Neurosurg 2002;37:282-6.
17. Wada K, Tanei T, Hattori K, Hatano H, Fujitani S, Ito R, *et al*. Unique vascular structures of a radicular arteriovenous fistula at the craniocervical junction along the first cervical spinal nerve: A case report. Surg Neurol Int 2023;14:85.
18. Whittam D, Huda S, Gibbons E, Pullicino R, Solomon T, Chandran A, *et al*. A case series of intracranial Dural arteriovenous fistulae mimicking cervical myelitis: A diagnosis not to be missed. J Neurol 2021;268:4680-6.
19. Wingerchuk DM, Banwell B, Bennett JL, Cabre P, Carroll W, Chitnis T, *et al*. International consensus diagnostic criteria for neuromyelitis optica spectrum disorders. Neurology 2015;85:177-89.

**How to cite this article:** Iampreechakul P, Sopchokchai I, Wangtanaphat K, Chuntaroj S, Wattanasen Y, Hangsapruek S, *et al*. Holocord myelopathy misdiagnosed as neuromyelitis optica spectrum disorder (NMOSD): A unique case of dural arteriovenous fistula at the craniocervical junction along first spinal nerve. Surg Neurol Int. 2024;15:209. doi: 10.25259/SNI_138_2024