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Percutaneous Fenestration of a Spinal Arachnoid Web Using an Intrathecal Catheter: Effect on Cerebrospinal Fluid Flow and Clinical Status

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Key words
- Arachnoid granulation
- Cerebrospinal fluid
- Hydrocephalus
- Lumbar approach
- Lumbar catheter

Abbreviations and Acronyms
CSF: Cerebrospinal fluid
FLAIR: Fluid-attenuated inversion recovery
MRI: Magnetic resonance imaging

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■ BACKGROUND: **Spinal arachnoid webs are a rare anatomic entity manifesting as neuropathic back pain, compressive myelopathy, radiculopathy, and hydrocephalus. Typical treatments include hemilaminectomy or full laminectomy with durotomy and microsurgical resection, which can result in secondary scarring and recurrent blockage of cerebrospinal fluid (CSF) flow perpetuating the cycle.**

■ CASE DESCRIPTION: **A 66-year-old woman presented with progressively worsening gait and memory. Magnetic resonance imaging demonstrated an arachnoid web in the high thoracic region, causing CSF flow obstruction and hydrocephalus. A standard lumbar drainage catheter was introduced percutaneously into the lumbar thecal sac and advanced in a cephalad direction, across the arachnoid web, to the high thoracic region. The patient underwent continuous CSF drainage through this catheter for a total of 3 days, displaying measurable clinical improvement that persisted at the 3-month follow-up visit. Phase-contrast magnetic resonance imaging demonstrated interval reconstitution of dorsal synchronous CSF flow at the second thoracic vertebral level, both on day 3 and at the 3-month control imaging study.**

■ CONCLUSIONS: **This minimally invasive approach seems useful in achieving restoration of spinal fluid flow at the thoracic region when the underlying blockage results from an arachnoid web and leads to quantifiable clinical improvement.**

Spinal arachnoid webs constitute a rare anatomic entity characterized by an abnormal thickening of intradural arachnoid tissue expressed as bands bridging to the pial surface of the dorsal aspect of the spinal cord.[1,2] Typically, they present with neuropathic back pain, compressive myelopathy, radiculopathy, and/or hydrocephalus.[1] Historically, their treatment has comprised either 1) microsurgical resection of the arachnoid web via full or hemilaminectomy followed by durotomy or 2) small hemilaminectomy followed by endoscopic movement or resection.[3,4] We report a case where recanalization of a high thoracic region arachnoid web was achieved using a percutaneous approach via the manipulation of a lumbar drainage catheter under fluoroscopic guidance. Our local Institutional Review Board approved the retrospective review of the records and reporting of this patient's case.

CASE DESCRIPTION

Clinical History

A 66-year-old woman presented with progressively worsening falls accompanied by memory deficits over a period of approximately 3 weeks. She had a history of coronary artery disease, having previously undergone both bypass grafting and percutaneous intervention, and had peripheral vascular disease, with a prior bilateral aorto-femoral arterial bypass. The patient had some difficulty ambulating secondary to a chronic infection of her right prosthetic hip joint and required a walker for ambulatory support. She reported sensations of numbness and tingling in both lower extremities, equilibratory ataxia worsened by standing with her eyes closed, and infrequent episodes of fecal incontinence.

Neurologic Examination

The patient displayed hyperreflexia of both quadriceps yet absent gastrocnemius reflexes. In addition, there was evidence of loss of distal position and vibration sense in both lower limbs. Her gait lacked coordination, she was unable to walk with her feet in tandem, and she was unable to maintain her stance upon closing of her eyes. At baseline, the results of standardized assessments of functional mobility and cognitive function (i.e., Tinetti Mobility Assessment[5] score, Timed UP

Table 1. Summary of All Results of Functional Mobility and Cognitive Assessments Before and Following Treatment

		Preoperative	Postoperative			
	Normative Reference	Day −1	Day 1	Day 2	Day 3	Month 3
TMA[5]	High fall risk ≤ 18	24	20	14	18	15
TUG[6] (seconds)	Normal 8.1*	22	19	14.75	14.61	17.59
5× STS[7] (seconds)	Normal = 11.4 & fall risk ≥ 12*	20	35	14.21	15.30	15.13
MoCA[8]	Scale of 0–30	22	16	21	N/A	23

TMA, Tinetti Mobility Assessment score; TUG, Timed UP and GO; 5×STS, 5 times sit to stand; MoCA, Montreal Cognitive Assessment.
*Age and gender adjusted.

and GO[6] score, 5× Sit to Stand[7] score, and Montreal Cognitive Assessment[8] score) demonstrated the degree of her impairment (Table 1).

Magnetic Resonance Imaging Studies

The patient underwent conventional magnetic resonance imaging (MRI) of the head (encompassing 2-dimensional T2-weighted fluid-attenuated inversion recovery [FLAIR], diffusion-weighted imaging, susceptibility-weighted imaging, and 3-dimensional T1-weighted and T2-weighted FLAIR sequences, MRI of the cervical and thoracic spine including T1-weighted, T2-weighted, short-TI inversion recovery, 3-dimensional T2-weighted, and axial T1-weighted and T2-weighted series). In addition, we also carried out cerebrospinal fluid flow (CSF) studies of the brain and spine using phase-contrast MRI with the patient in supine position, using either a 3T or 1.5T magnetic resonance system (Magnetom Skyra or Aera, respectively; Siemens Medical Solutions USA, Inc. Malvern, Pennsylvania, USA). The thoracic spine assessed using sagittal T2 3-dimensional sampling perfection with application optimized contrasts using different flip angle evolution acquisitions (repetition time/echo time 1500/139; field of view 230 mm; isotropic voxel size 0.9 × 0.9 × 0.9 mm; number of excitations 1.0). Extracranial CSF flow was evaluated using sagittal PC MRI with 20 cardiac gated steps, repetition time/echo time 50.12/8.4; field of view 220 mm; voxel size 0.9 × 0.9 × 6.0 mm; number of excitations 1.00; flip angle 10 degrees; velocity encoding of 5, 10, and 15 cm/second; resolution 256 × 256. The brain displayed ventriculomegaly and increased transependymal T2 FLAIR changes, compared with a prior examination from January 2017 (Evans Index = 0.36)[9] (Figure 1A). The neuraxis showed indentation of the upper thoracic spinal cord, ventral cord displacement without an obvious intradural mass, and heterogeneous CSF flow voids, raising concern for a dorsal thoracic arachnoid web (see Figure 1B and C). Neoplasm was considered unlikely due to 1) absence of abnormal areas of contrast enhancement or abnormal signal within the spinal cord and 2) absence of osteolysis, cortical disruption, or deformation of vertebral body on the postprocedural computed tomography myelography (Figure 2). The preprocedural CSF flow study revealed loss of normal ventral CSF flow with asynchronous flow caudal to T2 vertebral level and asynchronous dorsal cerebrospinal fluid flow cranial to the T2 vertebral level (see comparison studies later).[10-14]

Fenestration Procedure

Following placement of the patient in the prone position, we introduced a 14-gauge Tuohy spinal needle under local anesthesia at the L2-L3 interspace (left parasagittal line, 10 degrees cephalad) into the subarachnoid space. After spontaneous release of clear and colorless CSF, we injected 3 mL of Iohexol (Omnipaque 350, GE Healthcare, Inc. Waukesha, Wisconsin, USA), and a dispersion pattern within the cerebrospinal fluid confirmed the subarachnoid location of the needle. We then introduced a standard lumbar drainage catheter (Codman Lumbar Drainage Catheter Kit II, Integra LifeSciences, Inc. Princeton, New Jersey, USA) over the 80-cm precoiled hydrophilic guidewire and advanced it in a cephalad direction under fluoroscopic guidance to and through the area of resistance (Figure 3), the presumed arachnoid web. We then injected an additional 20 mL of the same contrast agent, tilting the table to a Trendelenburg position, with radiographic confirmation of contrast in the cervical and high thoracic regions, confirming fenestration through the thoracic arachnoid web. Finally, we connected the catheter to an external volume limiting drainage system (LimiTorr, Integra LifeSciences, Inc., Princeton, New Jersey, USA).

Postprocedural Care

Computed tomography myelogram, obtained immediately following completion of the procedure, demonstrated intrathecal contrast opacification all the way up to the cervical spine level (Figure 2), while the dorsal cord surface indentation at the thoracic remained evident. The lumbar drainage catheter was clearly visible, with its tip terminating at the level of the second thoracic vertebra. We continued to drain CSF at a rate of 10 mL/hour for 72 hours[15,16] while simultaneously undertaking serial examinations on a daily basis (see Table 1). Overall, we drained an average of 200–250 mL of CSF per day and removed the catheter on the third day without problems or complications. The results of the same standardized tests of functional mobility and cognitive function suggested some degree of measurable improvement (see Table 1). Moreover, postoperative CSF flow imaging on the third day after the procedure demonstrated interval reconstitution of dorsal synchronous CSF flow at the thoracic level (Figure 4).

Postdischarge Care

After discharge, the patient required 2 separate readmissions within a matter of 4–6 weeks: 1 for an acute coronary syndrome and another for pneumonia. At the

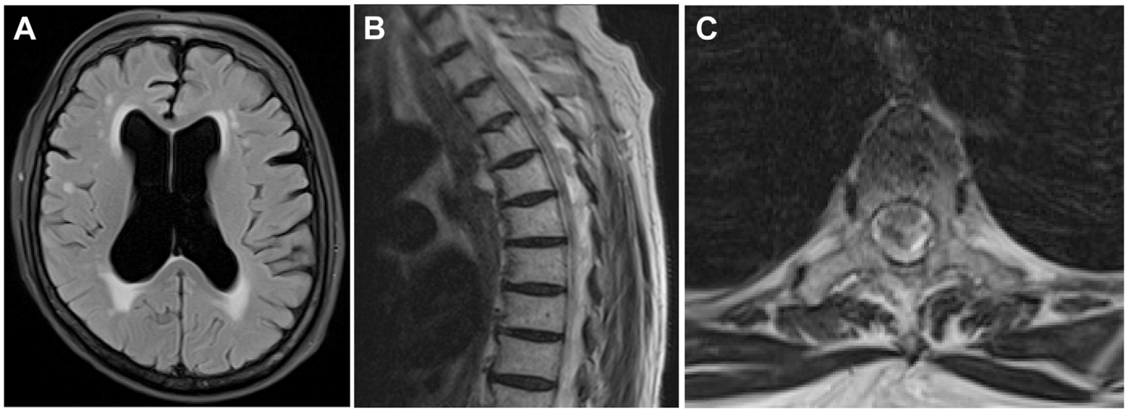

Figure 1. Axial T2 fluid-attenuated inversion recovery (FLAIR) magnetic resonance imaging (MRI) of the brain shows ventriculomegaly and evidence of transependymal T2 FLAIR cerebrospinal fluid signal. Evan Index = 0.36 is suggestive of hydrocephalus (**A**). T2 sagittal MRI of the thoracic spine shows dorsal indentation of the cord ("scalpel sign") at the level of the arachnoid web (**B**). T2 axial MRI of the thoracic spine at the same level further confirms distortion of the cord (**C**).

3-month clinic visit, however, the patient reported improved ambulation and less dependency on the use of a walker. But her scores on the standardized tests continued to show mixed results. At this time, repeat control imaging demonstrated stable CSF flow dynamics (see **Figure 4**). In addition, the normal convex morphology of the ventral aspect of the subarachnoid space had been restored at the level of the arachnoid web (**Figure 5**). At the 5-month telehealth clinic visit (due to restrictions on in-person visits imposed by the Coronavirus Disease 2019 epidemic), the patient reported continued improvement in cognition and ambulation.

DISCUSSION

The beneficial effect of percutaneous fenestration of a thoracic arachnoid web,

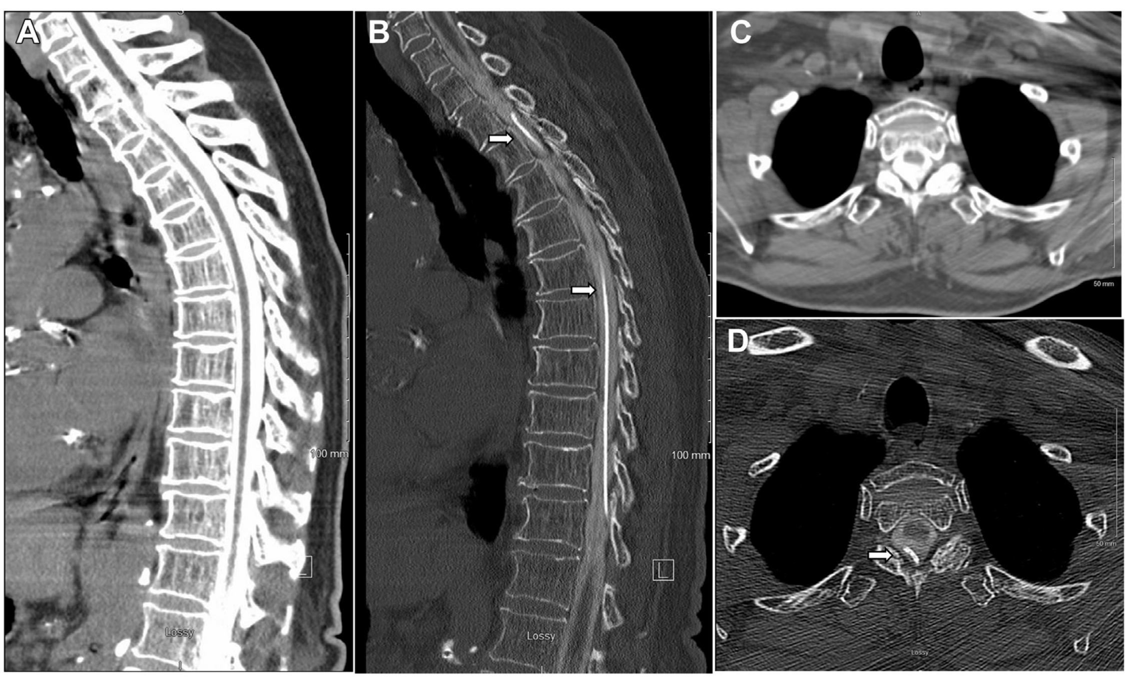

Figure 2. Postprocedural computed tomography myelography demonstrates contrast opacification past the thoracic arachnoid web consistent with canalization (**A** and **C**). The lumbar drainage catheter can be visualized on sagittal and transverse views (*arrows;* **B** and **D**, respectively).

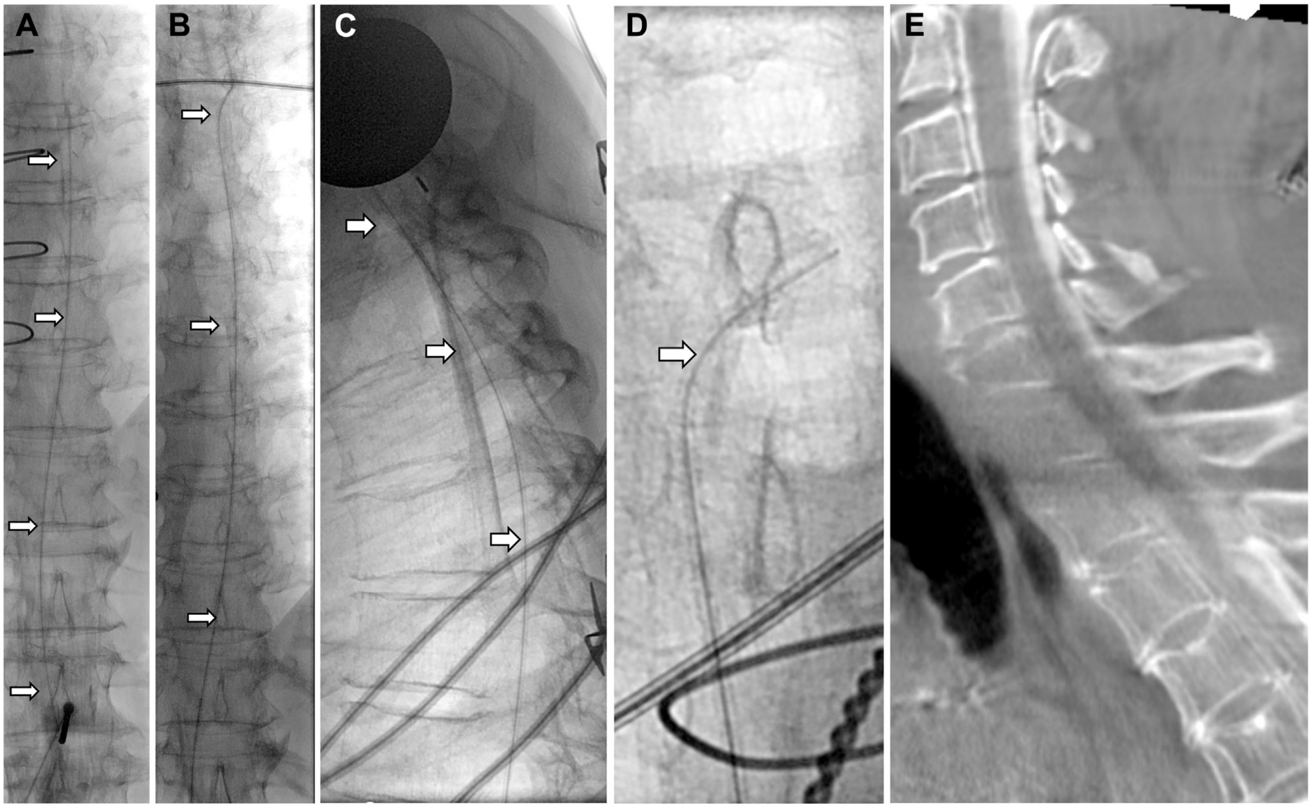

Figure 3. Placement of lumbar drainage catheter (*arrows*) under fluoroscopic guidance. Anteroposterior (**A** and **B**), lateral (**C**), and distal catheter−end views (**D**). Canalization through the dorsal aspect of cerebrospinal fluid space seen on cone-beam computed tomography intraprocedural images (**E**).

as shown in our case report, must be examined from the perspectives of both feasibility and reasonableness. The anatomic and physiologic impact of the procedure, as documented by the imaging studies (i.e., correction of cord indentation and CSF flow dynamics), are highly suggestive that we achieved the original intent of the intervention. Moreover, a common feature of arachnoid webs is the indentation it causes on the spinal cord surface, a feature clearly present in our patient (see **Figures 1** and **2**).[17] Following the procedure, the degree of indentation decreased (see **Figure 4**) and normal convexity ensued (see **Figure 5**), providing additional evidence of its success.

Thus establishing a channel for improving CSF flow along the neuraxis, thereby reducing the risk of hydraulic pressure on the thoracic cord, with consequent edema, and neurologic dysfunction, seems to go at the core of the pathogenesis of this condition. The fact that this can be accomplished is not altogether surprising, considering published prior experience by means of a combination of mechanical and pharmacologic (i.e., 10% sodium chloride, 1% lidocaine, and betamethasone) strategies for spinal epidural adhesiolysis using a percutaneous needle.[18,19] Building on this concept, recent publications have addressed the possibility of accessing the thoracic and cervical epidural spaces by means of percutaneous lumbar catheter insertion, in both cadavers and patients.[20-25] In addition, several case reports have described how the distal end of lumbar CSF space catheters can inadvertently reach the high cervical or even intracranial subarachnoid space.[26-30]

In examining the procedure, we report 1 or more of 3 basic constituents that may be causally related to its beneficial effects: 1) local mechanical effect, 2) fluid/contrast injection, and/or 3) CSF drainage. However, the question of which one leads to a long-lasting improvement of CSF flow dynamics, or whether the success reflects the summation of all 3 effects, is difficult to answer at this time. In addressing these, 1 at a time, the first question is whether the mechanical manipulation provided via the steel guidewire and siliconized closed tip catheter we used is adequate to lyse the spinal arachnoid web.[31] If this were the case, maneuverability of the catheter would be of utmost importance for consistent procedural success, highlighting a technical aspect in need of improvement. The Codman Lumbar Drainage Catheter (Integra LifeSciences, Inc. Princeton, New Jersey, USA) is 80 cm long, with an inner diameter 0.76 mm, and requires the use of a 14-G Tuohy needle for insertion. It is advanced through the latter over an 85-cm hydrophilic-coated guidewire, and this is removed once the catheter is placed in its final destination. In there lies the obvious limitation: the impossibility of safely

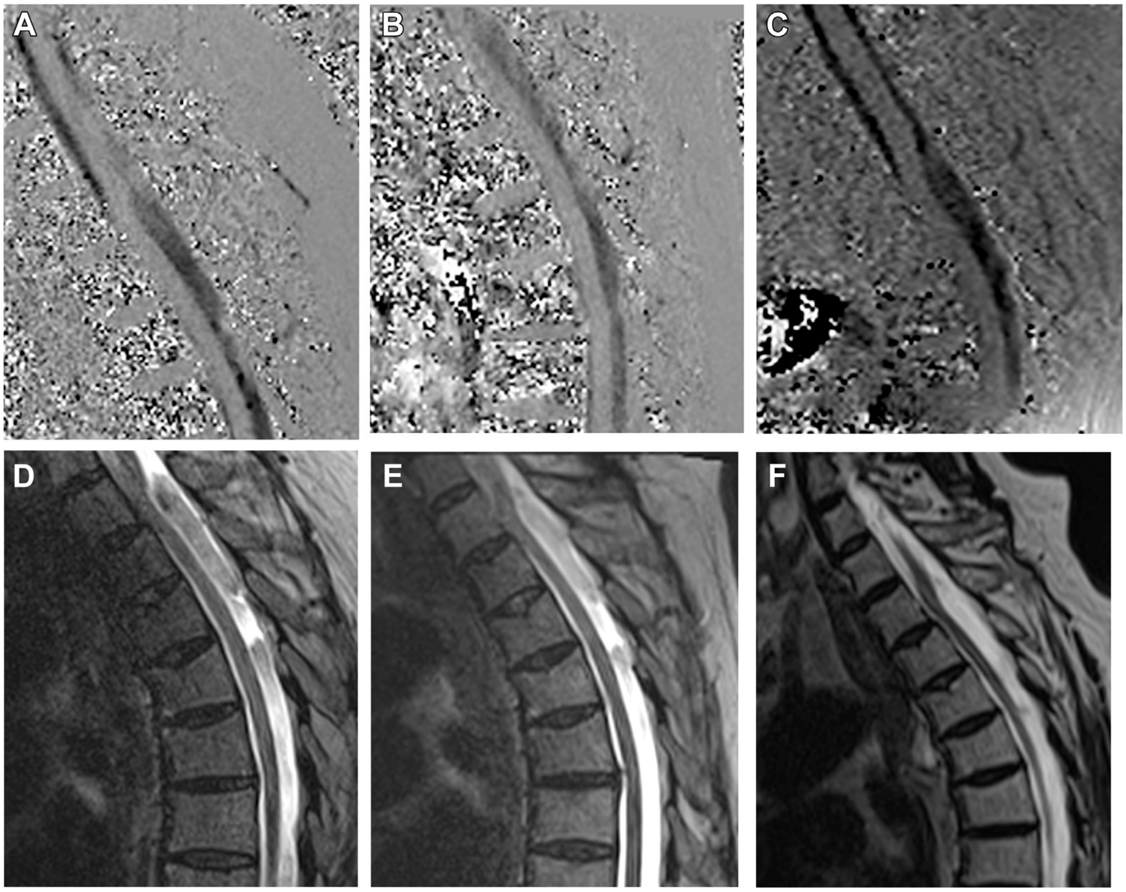

Figure 4. Serial phase contrast cerebrospinal fluid (CSF) flow magnetic resonance imaging (MRI) with velocity encoding 10 cm/second (**A**–**C**). Caudal systolic CSF flow is displayed as shades of black, while cranial diastolic flow is displayed as shades of white. At baseline, a heterogeneous signal consistent with turbulent flow demonstrated asynchronous CSF flow (**A**). Improved (i.e., synchronous) CSF flow following the procedure resulted in a more uniform signal, not only at Day 3 (**B**), but even more so at Day 90 (**C**). However, decreased CSF flow along the ventral surface of the cord continued to be evident. T2 Sampling perfection with application optimized contrasts using different flip angle evolution MRI sequences (**D**–**F**). Higher image resolution of anatomic structures and the CSF flow effect of the web. A heterogeneous T2 signal, indicative of turbulent CSF flow, is readily apparent at baseline (**D**), while increasingly uniform signals were observed at Day 3 (**E**) and Day 90 (**F**).

retracting and reinserting the catheter without the risk of shearing it on the beveled cutting edge of the Tuohy needle.[31] Improved catheter manipulation could be achieved through modifications of the introduction needle, the use of a guide sheath, or the use of stiffer catheters, less likely to fragment, such as standard epidural catheters.[32,33]

Regarding the other 2 procedural constituents, it is plausible that contrast injection within the area of the web could have also led to a local displacing hydraulic force. However, this seems less likely when considering the contrasts exiting via the multiple small side orifices of the lumbar catheter. Along these lines, however, local injection of hypertonic saline within the arachnoid web may provide additional adhesiolysis. Data on the injection of hypertonic saline into the cerebrospinal fluid via lumbar puncture for relief of pain have been available for approximately 4 decades.[34-36] Squire et al[37] reported no adverse neurologic consequences with small injections of sodium chloride into the CSF in concentrations of <10% NaCl. Undesirable effects predominantly included local back pain and transient rise in blood pressure.[37] Higher concentrations of NaCl resulted in severe back pain and sympathetic activation leading to hypertension and, infrequently, cardiac arrhythmias.

Finally, we can also speculate that continuous CSF drainage in the vicinity of arachnoid web may have promoted canalization of the web by creating a pressure gradient for caudal movement of CSF.[10,38] On the other hand, it would be difficult to explain any long-lasting beneficial effect following removal of the drainage catheter. Further modifications in the approach may expand the treatment options for arachnoid web resulting in CSF flow obstruction.

In order to address how reasonable it would be to pursue the future utilization of this procedure, it is important to look at existing alternatives. Most of the available

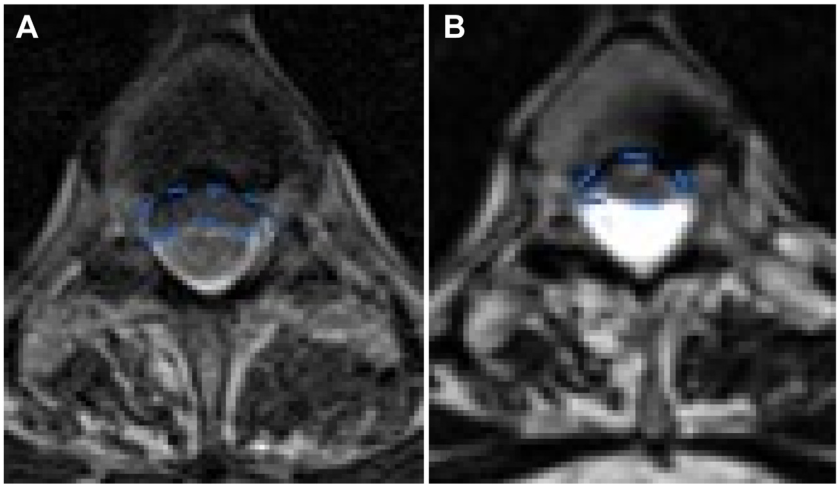

Figure 5. T2 axial magnetic resonance imaging at the level of the arachnoid web, at baseline (**A**) and Day 90 (**B**). Note the decreased mass effect on the cord at the Day 90 follow-up examination. There is a normal convex morphology in the postprocedural image (**B**), compared with the concave morphology toward the vertebral body in (**A**). Cerebrospinal fluid (CSF) flow artifact darkened the dorsal CSF spaces.

information regarding treatment of similar spinal lesions derives from the management of epidural fibrosis resulting from spinal surgery. This can be sufficiently severe to result in cord impingement, edema and, eventually, the appearance of a cyst or syrinx.[39,40] The absence of any of these findings in this case suggests that the arachnoid web was either in its early stages or lacked the characteristics required to progress into aforementioned consequences.[41-44] In this context, Gambacorta et al[23] reported the insertion of a combination of a 5-French angiographic catheter and steerable 0.038″ guidewire at the sacral hiatus, followed by their cephalad advancement within the epidural space in order to mechanically disrupt adhesions. The procedure resulted in relief of pain for >3 months in almost two thirds of 18 consecutive patients, although long-term benefit was not addressed by the authors.[23] Another approach to spinal fibrosis and compressive lesions involves the insertion of an endoscope following laminectomy. In 1 study, a 4.8-mm flexible endoscope with a working channel diameter of 2.0 mm was consistently used to inspect and fenestrate spinal arachnoid cysts.[4] Most authors advocate partial recanalization to avoid mechanical injury to the spinal cord and/or nerve roots given the multifocal adherences among nerve roots, spinal cord, and arachnoid membranes.[4,45,46] All in all, the procedure we described, when viewed in the context of these alternatives, appears to a have a reasonable chance to be improved upon and applied in the future. Avoidance of laminectomy is likely to reduce the extent of postsurgical adhesions, lessening the chances of secondary scarring and recurrent blockage of CSF flow.

We were unable to perform a histologic analysis of the lesion and diagnosis of thoracic arachnoid web, and its differentiation from neoplasm was based on neuroimaging findings.[47,48] The differentiation between obstructive hydrocephalus and normal pressure hydrocephalus was made on initial neuroimaging findings of focal heterogeneous CSF flow voids in the thoracic region suggestive of obstruction. Furthermore, improved (synchronous) CSF flow following the procedure was more suggestive of obstructive hydrocephalus (see **Figure 4**). Clinical improvement sustained over months without insertion of a permanent CSF drainage system such as ventriculoperitoneal or lumbar peritoneal shunt after fenestration procedure also supported a local obstructive pathology.

CONCLUSION

Percutaneous fenestration of a thoracic arachnoid web is feasible and, considering the available alternatives, should be considered a reasonable pathway for the treatment of these lesions.

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