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ORIGINAL RESEARCH

NEUROINTERVENTION

CSF Venous Fistula Transvenous Onyx Embolization: Evaluation of Onyx Migration into the CSF and Potential One-way Physiology

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ABSTRACT

BACKGROUND AND PURPOSE: CSF-venous fistulas (CVF) are abnormal connections between the subarachnoid space and a paraspinal vein. Transvenous Onyx embolization is a recently adopted treatment method for CVF closure, however no studies have specifically evaluated for Onyx migration into the CSF. The purpose of our study was to evaluate patients who underwent transvenous CVF embolization for Onyx migration into the CSF.

MATERIALS AND METHODS: We evaluated 100 patients who underwent transvenous CVF embolization for post-treatment CT of the spine. Images were reviewed for Onyx migration into the CSF at the level of the embolization as well as distally in the lumbar spine. Basic demographic information including age and sex were recorded.

RESULTS: The mean age was 59.2 years (+/- 10.9, 28-88). 68 were female. 48 patients had post-embolization imaging of the treated level, and none had Onyx migration into the CSF at the level of the CVF. 34 patients had imaging of the lumbar spine, and none had Onyx migration distally in the lumbar spine.

CONCLUSIONS: Our study did not find any cases of unintended Onyx migration into the subarachnoid space in patients who underwent transvenous CVF embolization. This speaks to the safety profile of transvenous CVF embolization and suggests possible one-way physiology of CVF that allows for egress from the CSF to the veins only.

ABBREVIATIONS: CVF = CSF venous fistula; DSM = digital subtraction myelography.

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SUMMARY SECTION

PREVIOUS LITERATURE: Previous literature has evaluated transvenous CVF Onyx embolization for adverse outcomes, but not previously for transvenous Onyx migration into the CSF.

KEY FINDINGS: Our study did not find any cases of transvenous Onyx migration into the CSF at the level of the CVF or dependently in the lumbar spine.

KNOWLEDGE ADVANCEMENT: Our findings speak to the safety of transvenous CVF Onyx embolization from the perspective of Onyx migration into the CSF. Additionally, this suggests possible one-way physiology of CVF.

INTRODUCTION

Cerebrospinal fluid venous fistulas (CVFs) are abnormal connections between the spinal subarachnoid space and adjacent paraspinal veins, leading to CSF loss into the circulatory system.[1] These fistulas are a recently recognized source of spontaneous spinal CSF leakage that cause spontaneous intracranial hypotension (SIH).[2-4] Management strategies for CVFs include surgical ligation[5], percutaneous patch with or without administration of fibrin[6], and transvenous Onyx (Ethylene vinyl alcohol copolymer, Medtronic) embolization[7].

Onyx embolization is the standard treatment for many pathologic entities, such as arteriovenous malformations (AVMs), intracranial dural arteriovenous fistulas (DAVFs), and carotid-cavernous fistulas (CCFs).[8,9] Although Onyx has been shown to be an effective method of treating such conditions, it has known risks including the risk of migration of embolic material.[10-13] Studies evaluating the safety of Onyx embolization of spinal AVMs have identified embolic material in unexpected locations such as lung and spine vasculature, including the anterior spinal artery.[14]

To date, however, no studies have specifically examined for Onyx migration in the setting of CVF embolization. This study therefore set out to elucidate whether Onyx embolization used for CVF treatment resulted in migration into the subarachnoid space and the outcomes of any known migration events.

MATERIALS AND METHODS

Patient Cohort

Patients who underwent transvenous embolization of a CVF at a single institution from July 2020 – June 2022 were retrospectively reviewed. Patients were included if they had a post-embolization CT of the spine. Our institution was the first to perform CVF transvenous embolization. Post-procedural evaluation and management of patients has evolved, but we initially performed non-contrast CT, immediately or within several months following embolization, to further evaluate our embolization technique. Additionally, some patients with persistent or recurrent symptoms underwent CT myelography to evaluate for a CSF leak.

Imaging Review

CT of the spine was used to evaluate both for migration of Onyx into the CSF at the level of the CVF embolization as well as dependent migration into the lumbar spine. Images were from a non-contrast spine CT or a CT myelogram and were reviewed by a single reader (CM) for Onyx migration. Any equivocal cases were subsequently reviewed by an additional reviewer (IM). Basic demographic information including age and sex were recorded from the electronic medical record.

Embolization Technique

In general Onyx embolization was performed as previously described.[15] Femoral access with a 6 Fr sheath was obtained. The azygous or hemiazygous system was catheterized using a 6 Fr RIST catheter (Medtronic). Following this, a headway duo 167 was advanced into the foraminal vein and then into the internal epidural plexus. Initial injection with Onyx 34 was then followed with 1 cc-2 cc of Onyx 18 using a plug and push technique. Embolization was stopped when the epidural, paraspinal, foraminal, and intercostal veins were filled with Onyx. All Onyx injections were performed manually and somewhat forcefully with 0.1 cc every 5 seconds.

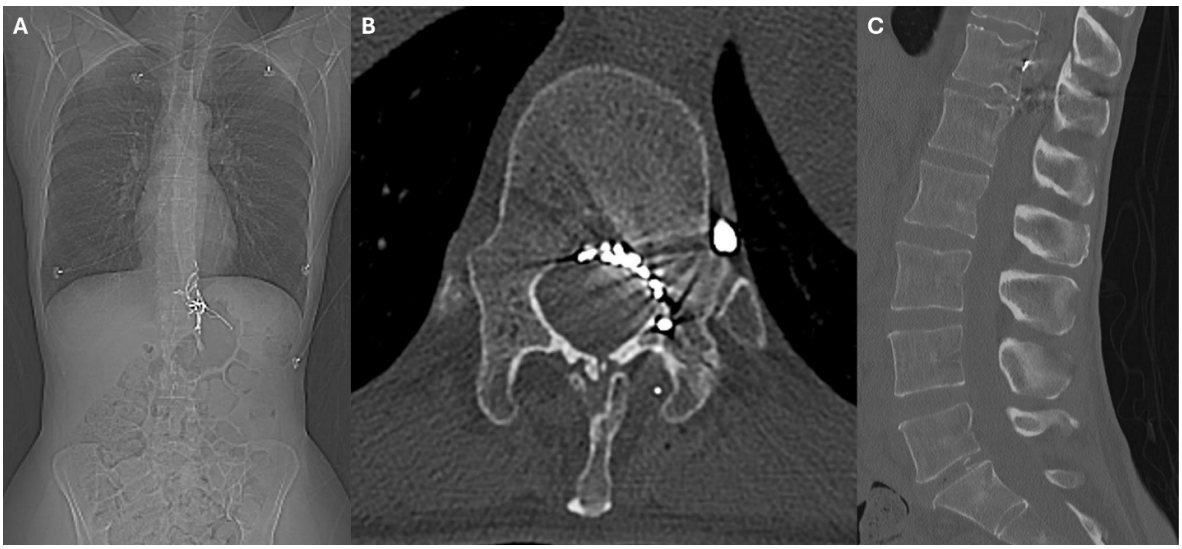

FIG 1. 66-year-old female with a left T12 CVF. Scout image (A) from a post-embolization CT of the thoracic and lumbar spine, (B) axial CT at the level of the embolization shows Onyx in the internal vertebral venous plexus and a paraspinal vein, and (C) sagittal CT of the lumbar spine do not show Onyx in the subarachnoid space.

RESULTS

100 patients who underwent CVF embolization were evaluated for this study. 68% of the patients were female. The mean age was 59.2

years (+/- 10.9, 28-88). 48 patients had imaging (28 had a CT myelogram and 20 had a non-contrast CT) covering the embolization site and were evaluated for local extravasation into the CSF (**Fig. 1**). Of these patients, none had local Onyx extravasation into the CSF/thecal sac.

34 patients had imaging of the lumbar spine to evaluate for dependent migration of extravasated Onyx into the CSF. 6 had a lumbar spine CT and 28 had a total spine CT myelogram. None of these patients had Onyx extravasation in their lumbar spine.

DISCUSSION

Our study evaluated patients that underwent transvenous CVF embolization and found no cases of Onyx migration into the subarachnoid space. These results speak to the safety profile of transvenous CVF Onyx embolization given the low likelihood of Onyx migration into the CSF. Additionally, the lack of central migration into the CSF infers that there is one-way physiology of CVF.

Our study builds on prior work that has previously evaluated the safety profile of transvenous CVF Onyx embolization. A systematic review and meta-analysis of 77 patients following CVF embolization found that rebound intracranial hypertension (28.6%) and transient pain at the treatment site (35.1%) were the two most common complications.[16] This meta-analysis included data from our group including 40 patients who underwent transvenous CVF embolization. The two most common complications were the same, with slightly lower rates: rebound intracranial hypertension (17.5%) and pain at the treatment site (30%).[15] 10 patients (10%) had minor complications that included Onyx pulmonary emboli and venous perforation. However, that study did not evaluate Onyx migration centrally into the CSF of the spinal canal.

The current study also gleans insight into the underlying pathophysiology of CVFs. The abnormal connection between the CSF and paraspinal vein that constitutes a CVF should have unregulated flow. If there were to be unimpeded bidirectional flow across CVF, one would expect at least occasional reflux of venous blood into the CSF, which could manifest as posterior fossa superficial siderosis. While superficial siderosis is a common finding more often associated with dural tears, only 2.6% of CVF cases had the same finding.[17] This predominantly one-way physiology from the CSF to the venous system could be explained by a pressure gradient. CSF pressure is most commonly normal in SIH and would therefore have a positive CSF-to-venous pressure gradient, although approximately 20% of cases can have very low CSF pressure.[18] If the one-way physiology was solely explained by the CSF-venous pressure gradient, then contrast should readily flow from the CSF to vein at the site of a CVF. This is not the case, as both digital subtraction myelogram (DSM)[19] and CT myelography[20] have shown that CVFs only transiently opacify with contrast, suggesting intermittent flow. The pressure gradient is also dynamic, as respiratory variations can change the gradient.[21,22]

Given the lack of intrathecal migration of Onyx, our study adds to the literature to serve as additional evidence of one-way flow in the majority of CVF. Not only did we not have Onyx migration into the CSF, but anecdotally, we did not see any cases of venous contrast traverse into the CSF at the time of embolization. This suggests that CVF are not simple open connections that will allow for passage of CSF at any time but are rather dependent on other factors that are largely unproven or unknown at this time.

It is not currently known why CVF occur, however, one theory could help to understand the one-way pathophysiology. Arachnoid granulations are microscopic structures that can hypertrophy due to increased CSF volume and pressure, typically ranging in size from 2 to 8 mm, allowing them to be viewed grossly when intracranial.[23] In the spine, arachnoid granulations are smaller and have been visualized with photomicrograph.[24] CVF have not been evaluated on a pathological basis, but they could potentially occur from a ruptured arachnoid granulation.[18] If ruptured arachnoid granulations lead to the formation of CVFs, it is possible that this rupture leads to one-way physiology by means of blockage or a pseudo valve (**Fig. 2**). In addition to the previously mentioned CSF > venous pressure gradient, other possible explanations of the one-way physiology could be related to the small and tortuous nature of the associated veins and their potential to coapt or collapse.

Our study has limitations, starting with the inclusion of single institution and single proceduralist's technique and data. While our data shows that transvenous CVF embolization is a safe procedure with low risk of onyx migration to the CSF, this is hard to generalize to other sites or providers who may use different techniques. Similar evaluations from other institutions would help to confirm the safety profile of this procedure. Additionally, we evaluated for Onyx migration into the CSF at the level of the embolization as well as dependently in the lumbar spine. We did not evaluate for superior migration into the cervical spine or posterior fossa. Finally, the heterogeneity of the post-embolization imaging reflected the novelty of CVF embolization at that time, and imaging was often performed out of an abundance of caution. Currently, our practice does not find it necessary to routinely perform non-contrast CT following embolization.

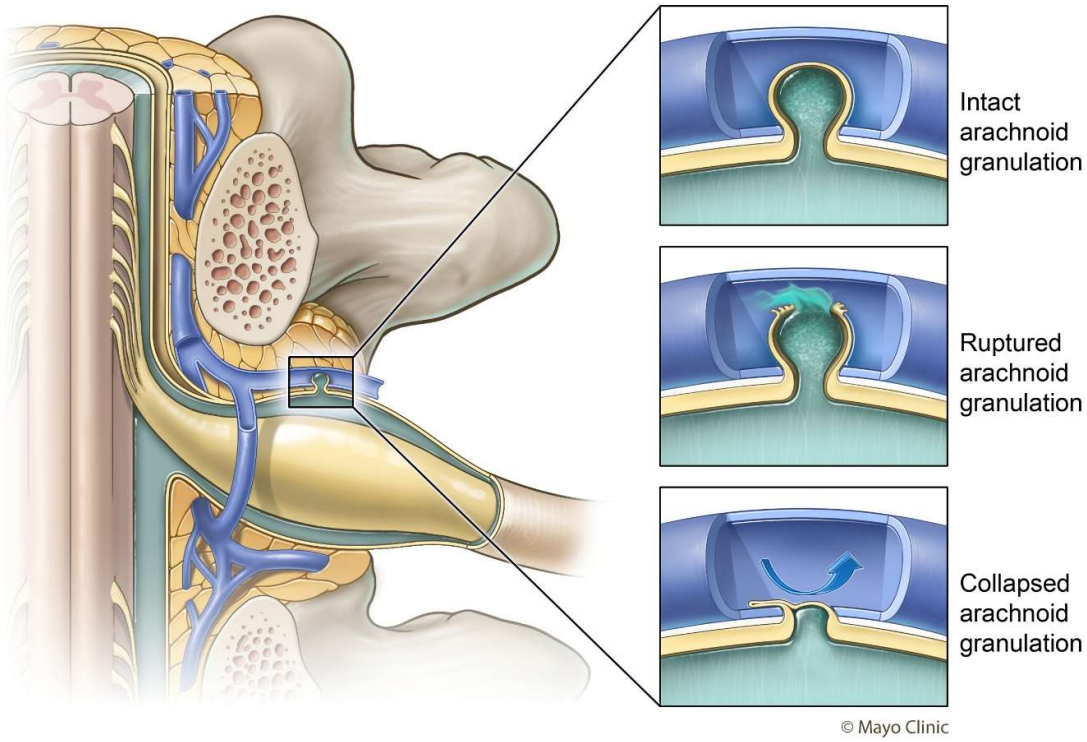

FIG 2. Ruptured spinal arachnoid granulations are a proposed mechanism of CSF-venous fistula formation. Given the lack of central Onyx embolization into the subarachnoid space, we theorize one-way physiology at the level of the CVF. This could be due to the ruptured arachnoid granulation.

CONCLUSIONS

Our study evaluated the rate of unintended Onyx migration into the subarachnoid space in patients who underwent transvenous embolization of CVFs. We did not find cases of Onyx in the CSF at the embolization site or distally in the lumbar spine. This speaks to the safety profile of transvenous CVF embolization and suggests possible one-way physiology of CVF.

Disclosure forms provided by the authors are available with the full text and PDF of this article at www.ajnr.org.

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