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The Spatial Relationship between Spinal Osteoarthritis and CSF Venous Fistulas in Patients with Spontaneous Intracranial Hypotension

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ABSTRACT

BACKGROUND AND PURPOSE: CSF venous fistula leads to spontaneous intracranial hypotension. The exact mechanisms underlying the development of CSF venous fistula remain unclear: Some researchers have postulated that underlying chronic intracranial hypertension may lead to damage to spinal arachnoid granulations, given that many patients with CSF venous fistulas have an elevated body mass index (BMI). However, individuals with higher BMIs are also more prone to spinal degenerative disease, and individuals with CSF venous fistulas also tend to be older. CSF venous fistula tends to occur in the lower thoracic spine, the most frequent location of thoracic degenerative changes. The current study aimed to examine whether CSF venous fistulas are more likely to occur at spinal levels with degenerative changes.

MATERIALS AND METHODS: Forty-four consecutive patients with CSF venous fistulas localized on dynamic CT myelography were included in analyses. Whole-spine CT was scrutinized for the presence of degenerative changes at each spinal level. The proportion of levels positive for CSF venous fistula containing any degenerative findings was compared to levels without CSF venous fistula using the Fisher exact test. The Pearson correlation coefficient was calculated to explore the association between the burden of degenerative disease and BMI and age and between BMI and opening pressure.

RESULTS: Forty-four patients with 49 total CSF venous fistulas were analyzed (5 patients had 2 CSF venous fistulas). Mean patient age was 62.3 (SD, 9.5) years. Forty-seven CSF venous fistulas were located in the thoracic spine; 1, in the cervical spine; and 1, in the lumbar spine. Within the thoracic spine, 39/49 (79.6%) fistulas were located between levels T7–8 and T12–L1. Forty-four of 49 (89.8%) CSF venous fistulas had degenerative changes at the same level. The levels without CSF venous fistulas demonstrated degenerative changes at 694/1007 (68.9%) total levels. CSF venous fistulas were significantly more likely to be present at spinal levels with associated degenerative changes (OR = 4.03; 95% CI, 1.58-10.27; $P = .001$). Age demonstrated a positive correlation with the overall burden of degenerative disease (correlation coefficient: 0.573, $P < .001$), whereas BMI did not (correlation coefficient: 0.076, $P = .625$). There was a statistically significant positive correlation between BMI and opening pressure (correlation coefficient: 0.321, $P = .03$).

CONCLUSIONS: Results suggest a potential association between spinal degenerative disease and development of CSF venous fistula.

ABBREVIATIONS: BMI = body mass index; CVF = CSF venous fistula; DCTM = dynamic CT myelography; SIH = spontaneous intracranial hypotension

CSF venous fistula (CVF) is increasingly recognized as a major cause of spontaneous intracranial hypotension (SIH), comprising a substantial number of SIH cases evaluated at quaternary referral centers.[1] While it is well-understood that CVF causes abnormal egress of CSF through the paraspinal veins and/or the epidural venous plexus, the exact pathogenesis of this phenomenon is unclear.

Prior studies have demonstrated that CVFs tend to occur in older individuals with an increased body mass index (BMI).[2,3] This finding has led previous authors to hypothesize that CVFs may result from pre-existing chronic intracranial hypertension causing damage to the spinal arachnoid granulations and dysregulation of physiologic CSF egress from the spinal subarachnoid space.[4] However, overweight/obese and older individuals are also more prone to spinal degenerative disease.[5,6] CVFs have repeatedly been shown to occur mostly in the thoracic spine, which may be explained, in part, by a predominance of arachnoid villi.[7] More specifically, prior studies indicate a predilection of CVF for the lower thoracic spine, with most CVFs clustered between T7 and T12.[2,8] Interestingly, this finding coincides with the distribution of osteoarthritis in the thoracic spine, which tends to occur

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in the lower thoracic levels with a reported prevalence ranging from 68% to 75%.[9-12] In this study, we hypothesized that there may be a spatial relationship between CVF incidence and the presence of spinal degenerative changes at a given spinal level.

MATERIALS AND METHODS

This was a retrospective, cross-sectional cohort study evaluating 44 consecutive patients who had CVFs localized on dynamic CT myelography (DCTM) at the University of Colorado Anschutz Medical Campus between February 1, 2021, and December 6, 2023. Approval from the institutional review board was obtained, and written informed consent was waived. Whole-spine CT obtained during dynamic CT myelography (DCTM) was scrutinized by a neuroradiology fellow and a board-certified subspecialty-trained neuroradiologist by consensus for the presence of spinal osteoarthritis at each of 24 spinal levels (C1–C2 through L5–S1). The presence of osteoarthritis was treated as a binary variable and not characterized on the basis of severity or laterality. Osteoarthritis was considered to be present if there was any disc pathology (bulge, protrusion, extrusion, or vacuum phenomenon), osteophytosis, and/or facet arthrosis; these specific types of degenerative findings were recorded for each level. Disagreements on the presence or absence of degenerative changes were resolved by consensus. The proportion of CVF levels containing any degenerative findings was compared with non-CVF levels using the Fisher exact test. The Pearson correlation coefficient was calculated to explore associations between the burden of degenerative disease and BMI and age and between BMI and opening pressure.

Patient, CVF, and spinal osteoarthritis characteristics

	Overall (n = 44)
Total fistulas	49
Age	
Mean (SD)	62.3 (9.5)
BMI	
Mean (SD)	28.0 (4.4)
Sex	
Female	26/44 (59.1%)
Male	18/44 (40.9%)
Fistula location	
Cervical	1/49 (2.0%)
Thoracic (T1–T2 through T6–T7)	8/49 (16.3%)
Thoracic (T7–T8 through T12–L1)	39/49 (79.6%)
Lumbar	1/49 (2.0%)
Osteoarthritis	
Nonfistula levels	694/1007 (68.9%)
Fistula levels	44/49 (89.8%)
Disc disease	29/44 (65.9%)
Osteophytes	43/44 (97.7%)
Facet arthrosis	31/44 (70.5%)

RESULTS

Forty-four total patients with 49 total CVFs were analyzed (5 patients had 2 CVFs). The mean patient age was 62.3 (SD, 9.5) years; 18/44 (40.9%) were men, and 26/44 (59.1%) were women. The mean BMI was 28.0 (SD, 4.4) (Table). Forty-seven CVFs were located in the thoracic spine; 1, in the cervical spine; and 1, in the lumbar spine. Within the thoracic spine, 39/49 (79.6%) fistulas were between the levels of T7–T8 and T12–L1, with 1/47 at T1–T2, 1/47 at T4–T5, 6/47 at T6–T7, 7/47 at T7–8, 5/47 at T8–T9, 8/47 at T9–T10, 9/47 at T10–T11, 6/47 at T11–T12 and 4/47 at T12–L1.

Forty-four of 49 (89.8%) CVFs had degenerative osteoarthritis changes present at the same level. The levels without CVFs had degenerative changes at 694/1007 (68.9%) total levels. CVFs were more significantly likely to be present at a level with spinal degenerative changes (OR = 4.03; 95% CI, 1.58–10.27; P = .001). The relationship and distribution of CVFs and spinal degenerative changes are illustrated in Fig 1.

In levels with degenerative disease and a CVF, there was disc degeneration at 29/44 (65.9%) levels, osteophyte formation at 43/44 (97.7%) levels, and facet arthrosis at 31/44 (70.5%) levels. Figure 2 demonstrates osteoarthritis findings at CVF levels.

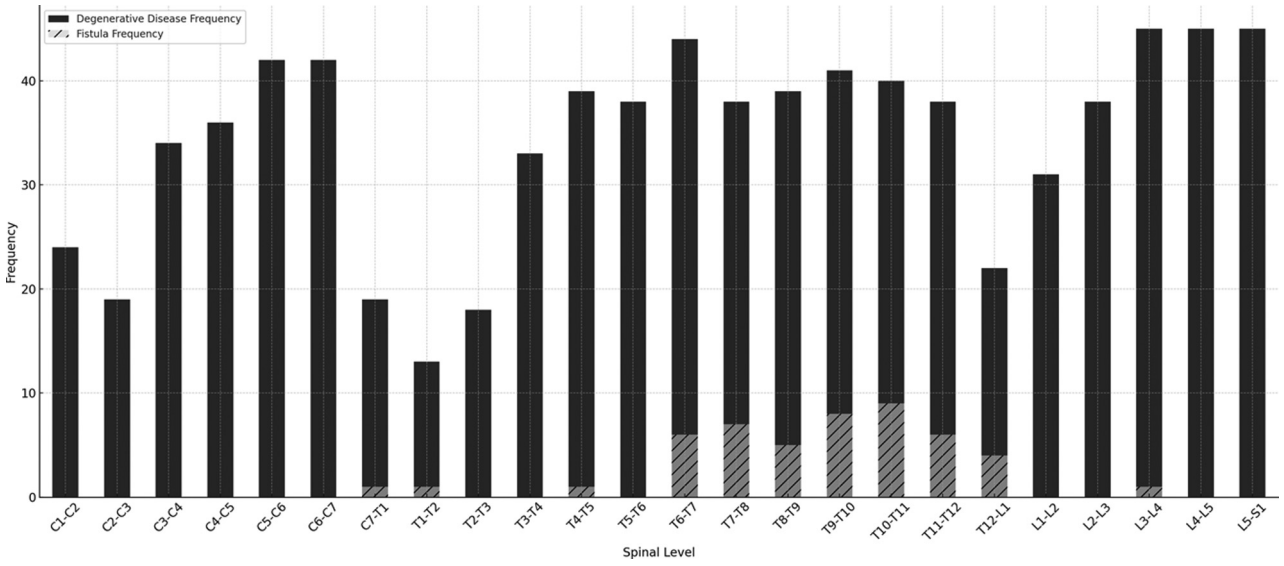

FIG 1. Distribution of spinal degenerative disease and CVFs.

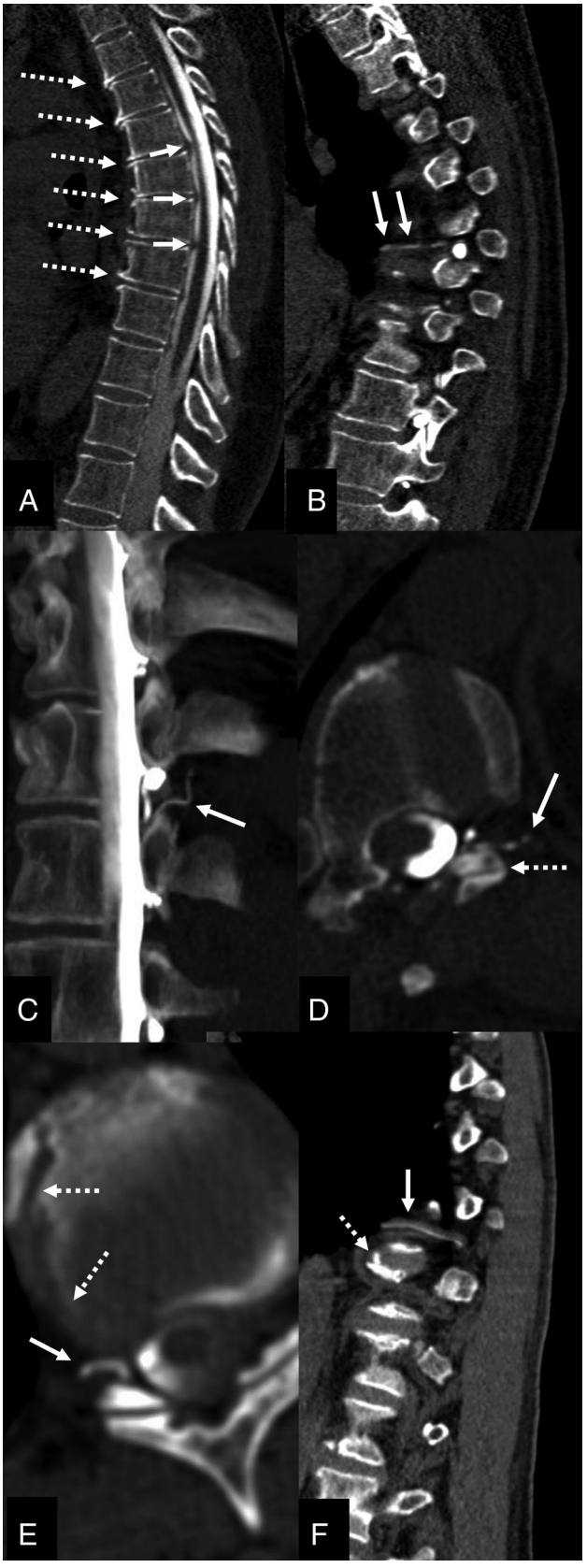

FIG 2. Three patients with osteoarthritis at the level of their CVFs. *Upper row*, A 66-year-old woman with intracranial hypotension and a right T7–T8 CVF. *A*, Midline sagittal CT image from dynamic myelography demonstrates anterior endplate osteophytes clustered from T4–T5 through T9–T10 (*dashed arrows*) and disc protrusions at T6–T7, T7–T8, and T8–T9. *B*, Paramidline sagittal CT image from dynamic myelography demonstrates a CVF arising from the right T7–T8 neural foramen (*solid arrows*). *Middle row*, A 61-year-old man with intracranial hypotension and a left T11–T12 CVF. *C*, Oblique coronal MIP CT image from dynamic myelography demonstrates a CVF arising from a meningeal diverticulum at T11–T12 on the left (*arrow*). *D*, Axial image from DCTM demonstrates left T11–T12 facet arthrosis (*dashed arrow*) and a corresponding CVF (*solid arrow*). *Lower row*. A 61-year-old man with intracranial hypotension and a right T10–T11 CVF, *E*, Axial CT image from dynamic myelography demonstrates a disc bulge and endplate osteophytes (*dashed arrows*) and a CVF (*solid arrow*) at the T10–T11 level. *F*, Sagittal paramidline CT image demonstrates disc bulging with lateral endplate osteophytes at T10–T11 (*dashed arrow*) and an adjacent CVF (*solid arrow*).

Age demonstrated a moderate yet-statistically significant positive correlation with the overall burden of degenerative disease (correlation coefficient: 0.573, $P < .001$), whereas BMI did not (correlation coefficient: 0.076, $P = .625$).

Opening pressures were recorded for all 44 patients. The opening mean (SD) pressure was 13.0 (4.7) cm H_2O. The median value was 12.0 cm H_2O. Two of 44 patients had an opening pressure of <6.0 cm H_2O.[13] One patient had an opening pressure of >20 cm H_2O (26 cm H_2O). BMI demonstrated a moderate-yet-statistically significant positive correlation with opening pressure (correlation coefficient: 0.321, $P = .03$).

DISCUSSION

In this retrospective cohort study of 44 consecutive patients with CVFs, most CVFs were present in the thoracic spine between T7–T8 and T12–L1, overlapping with the thoracic levels most prone to osteoarthritis.[14] Moreover, degenerative disease was statistically significantly more likely to be present at levels with CVF compared with non-CVF levels; 89.8% of CVFs in our cohort had degenerative changes at the same level, compared with 68.9% of non-CVF levels.

Several studies have observed that most thoracic osteoarthritis occurs in the lower thoracic levels.[14,15] This distribution can be explained, in part, by anatomic differences in the lower thoracic spine, resulting in increased motion. The ribs arising from the T7 vertebral body are the most inferior that individually fuse to the sternum. The eighth through 10th ribs indirectly articulate with the sternum through a collective costal cartilage, which articulates with the seventh costal cartilage, and the 11th and 12th ribs do not articulate with the sternum at all. This articulation permits increased flexibility, motion, and less weight-bearing ability in the lower spine, resulting in a higher likelihood of developing degenerative disease.[14]

In addition to both being caused by and resulting in increased biomechanical stress, spinal osteoarthritis and specifically osteophyte formation (the most prevalent osteoarthritic finding in our cohort) have been linked to an inflammatory milieu within the joint environment. Transforming growth factor β, bone morphogenic proteins, and insulin-like growth factor 1 play significant roles in osteophyte formation.[16] The nerve root, where CVFs tend to occur, straddles the environments of both the disc space and facet joints and is thus susceptible to both the mechanical and inflammatory stresses induced by spinal osteoarthritis. Given that most spinal levels with osteoarthritis in our cohort demonstrated osteophyte formation, a potential link among osteophytosis, inflammation, and

CVF pathogenesis should be the target of future study. Finally, patients with SIH may report thoracic radicular symptoms, the etiology of which is unclear.[17] Future work should continue to explore these associations and potential relationships.

If spinal osteoarthritis is linked to CVF formation, it begs the question why CVFs do not occur more frequently in the cervical or lumbar spine, which exhibit degenerative disease at much higher rates than the thoracic spine.[15] This discrepancy may be, in part, explained by the normal anatomic distribution of spinal arachnoid villi, the points of physiologic egress of CSF from the spinal subarachnoid space. Thus, CVF development may require a biomechanical or inflammatory insult at or near the nerve roots where physiologic CSF resorption occurs. Prior work examining the distribution of spinal arachnoid villi in postmortem specimens has had varied results: Kido et al[7] reported a predilection for the thoracic spine, which parallels CVF distribution; however, Tubbs et al[18] noted a predilection of spinal arachnoid villi in the lumbar spine. Thus, it is unclear whether the distribution of spinal arachnoid villi alone explains the distribution of CVF. CVF potentially arising in the lower lumbar spine presents a particularly interesting paradigm, because DCTM commonly interrogates spinal levels cephalad to the puncture level, raising the question of whether CVFs caudal to the lumbar puncture site are missed with any significant frequency.

Prior authors have hypothesized that underlying intracranial hypertension and subsequent damage to the spinal arachnoid villi may predispose patients to CVF development. While 1 patient (2.2%) in our cohort had an opening pressure of >20 cm H_2O, only 2/44 (4.5%) patients had an opening pressure of <6 cm H_2O, a finding that has been replicated in prior literature.[19] Thus, it could be the case that before CVF development, these patients had higher CSF pressures, and the CVF acted as a release valve so that opening pressures were within the normal range at the time of their DCTM. This possibility warrants further investigation, and a multifactorial model for CVF pathogenesis should be considered.

This study is limited by its retrospective design, single-institution experience, and modest sample size. The lack of a control group further limits the potential generalizability of these findings. Furthermore, we emphasize the critical difference between correlation and causation, particularly in explaining the observed overlap in the distribution of thoracic osteoarthritis and CVF. Thus, we recommend interpretation of the findings of this study with caution. We encourage other centers to investigate the replicability of these findings in their patient cohorts. In addition to providing potential insight into the pathogenesis of CVF, an association of CVF with degenerative changes may aid in cases where there is high suspicion of underlying CVF but DCTM findings are indeterminate.

CONCLUSIONS

This analysis of 44 consecutive patients with CVFs suggests a spatial relationship between spinal osteoarthritis and the incidence of CVF. Future work should continue to assess the factors influencing CVF pathogenesis.

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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