Diagnostic Yield of Decubitus CT Myelography for Detection of CSF-Venous Fistulas

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ORIGINAL RESEARCH

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ABSTRACT

BACKGROUND AND PURPOSE: Various imaging techniques have been described to detect CSF-Venous Fistulas (CVFs) in the setting of Spontaneous Intracranial Hypotension (SIH), including decubitus CT myelography (dCTM). The expected diagnostic yield of dCTM for CVF detection is not fully established. The purpose of this study was to assess the yield of dCTM among consecutive patients presenting for evaluation of possible SIH, and to examine what impact brain MRI findings of SIH had on diagnostic yield.

MATERIALS AND METHODS: Single-center, retrospective cohort of consecutive patients presenting over a one-year period who underwent CTM and had no CSF identified in the epidural space. Patients with epidural CSF leaks were included in a secondary cohort. Subjects were grouped according to positioning for the myelogram, either decubitus or prone, and the presence of imaging findings of SIH on pre-procedure brain MRI. Diagnostic yields for each subgroup were calculated, and the yield of dCTM was compared to prone CTM.

RESULTS: The study cohort included 302 subjects, including 247 patients with no epidural fluid. Diagnostic yield of dCTM for CVF detection among subjects with positive brain MRI and no epidural fluid was 73%. No CVFs were identified among subjects with negative brain imaging. Among subjects with epidural leak, brain MRI was negative for signs of SIH in 22%. Prone CTM identified a CVF less commonly than dCTM (43% vs. 73%, p=0.19), although the difference was not statistically significant in this small subgroup.

CONCLUSIONS: Conclusions: We found a diagnostic yield of dCTM to be similar to the yield previously reported for digital subtraction myelography among patients with positive brain imaging. No CVFs were identified in patients with negative brain imaging; epidural CSF leaks accounted for all cases of patients who had SIH with negative brain imaging. This study provides useful data for counseling patients and helps establish a general benchmark for dCTM yield for CVF detection.

ABBREVIATIONS: SIH = spontaneous intracranial hypotension; CVF = CSF-Venous Fistula; CTM = CT Myelography; dCTM = decubitus CT myelography; EBP = epidural blood patch

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SUMMARY SECTION

PREVIOUS LITERATURE:

CSF-venous fistulas (CVFs) are the presumptive etiology of SIH when no leaked epidural fluid is identified on spinal imaging. A previous investigation of digital subtraction myelography (DSM) found a diagnostic yield of 74%. Data on the diagnostic yield of decubitus CTM (dCTM) are sparse, consisting predominantly of studies with selected patient populations or smaller case series. Studies of diagnostic yield of dCTM for CVF detection investigating larger cohorts of consecutive, unselected patients are limited.

KEY FINDINGS:

In a retrospective study of 247 consecutive patients with no epidural fluid on spinal imaging, dCTM identified a CVF in 73% of patients who had brain imaging signs of SIH. No CVFs were identified in patients with negative brain imaging in this investigation.

KNOWLEDGE ADVANCEMENT:

Decubitus CTM is effective for the detection of CVFs, with a similar diagnostic yield to that previously reported for DSM, among patients with brain imaging signs of SIH. The absence of brain imaging signs of SIH was associated with a very low diagnostic yield for CVF detection.

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INTRODUCTION

CSF-venous fistulas (CVFs) are an important cause of Spontaneous Intracranial Hypotension (SIH), and are the presumptive etiology of SIH when no leaked epidural fluid is identified on spine imaging.[1, 2] Despite accelerating research into improving diagnosis and treatment of CVFs, detection of CVFs on imaging continues to be challenging. There remains substantial uncertainty regarding what spinal imaging methods are best for CVF diagnosis, and which patients should undergo these procedures.

Modifications to fluoroscopy- and CT-based myelographic techniques have been described in the literature that are intended to improve diagnostic performance for the detection of CVFs, most notably the use of decubitus positioning during myelography.[3, 4] Despite numerous publications on variations in decubitus myelographic technique, baseline data describing the actual diagnostic yield of decubitus myelography remains sparse. A previous publication reported a 74% yield for CVF detection with digital subtraction myelography (DSM), but comparable reports addressing decubitus CT myelography (dCTM) are limited.[3]

The purpose of this investigation was to report the diagnostic yield for dCTM among consecutive patients referred for evaluation of possible SIH who had no epidural fluid on initial spinal imaging. In particular, we were interested in the diagnostic yield of dCTM in the subgroups of patients with brain MR imaging signs of SIH and those without such signs. Secondarily, we sought to determine whether there were differences in detection rates of CVF between patients assessed with dCTM and patients evaluated with prone CTM performed prior to our routine implementation of dCTM.

MATERIALS AND METHODS

This investigation is a single-center retrospective cohort study examining the diagnostic yield of dCTM for CVF in all consecutive patients presenting for workup of possible SIH. The study was approved by the local institutional review board and is complaint with Health Insurance Portability and Accountability Act regulations.

Subjects & Myelogram Technique

All patients who underwent CTM after referral to our center for clinical suspicion of SIH between May 2021 and May 2022 were identified by screening procedure logs of a single CT scanner (Discovery 750HD; GE Healthcare; Milwaukee, Wisconsin), used as the primary interventional scanner for CSF leak workup at our institution, with scan parameters as previously reported.[5]

Standard decubitus CTM technique for all patients referred for suspected SIH and without epidural fluid at our institution currently involves obtaining bilateral decubitus scans of the thoracic spine (with coverage from C6-7 to L1-2) after a single lumbar puncture for injection of intrathecal contrast administration (10mL of myelographic contrast containing 300mg/mL iodine, injected as a single bolus), with the patient turned to the contralateral side immediately after the first decubitus scan. A foam wedge is used to elevate the hips and the head is elevated on pillows to promote contrast pooling in the thoracic spine (Fig. 1). In some cases, a prone scan of the total spine is obtained after decubitus scanning in order to ensure the absence of a subtle epidural leak that may have been missed on spinal MRI, at the discretion of the performing radiologist. Only a single phase of scanning is used per side and is obtained during maximum inspiration; dynamic myelogram technique involving multiple rapidly acquired phases of imaging per decubitus position is not used.

FIG 1. Illustration of patient positioning for decubitus CTM. Patient is placed in the lateral decubitus position. Hips are elevated with the assistance of a foam wedge, and head is elevated on pillows, allowing contrast to pool in the thoracic spine.

We currently perform dCTM on all patients being evaluated for SIH, but this practice has changed over recent years. Previously, when the prevalence of CVFs was thought to be lower and the importance of dCTM was still under initial investigation, decubitus scanning was not performed in every case and was frequently (but not exclusively) reserved for patients with positive brain imaging in order to avoid excessive radiation exposure. As a result, some of the early patients in our cohort were only scanned in the prone position, thereby providing a comparator group for subjects who underwent dCTM.

All consecutive patients who underwent CTM for suspected SIH were included. Exclusion criteria were subjects with incomplete data (such as absence of contrast-enhanced brain MR or missing CTM images) and non-standard CTM techniques (defined as any scan technique other than standard decubitus or prone imaging, such as prone imaging performed followed by decubitus imaging). Subjects with epidural fluid seen on preprocedural MRI or on the study CTM were included in a secondary study cohort, and analyzed separately from those with no epidural fluid because the presence of epidural fluid implicates a ventral or lateral dural tear (i.e. a Type 1 or Type 2 leak) rather than a CVF as the etiology of SIH; these subjects with epidural leaks were often scanned using Ultrafast CTM or prone CTM technique rather than dCTM.[6, 7] If a subject presenting during the study time period had >1 myelogram performed at our institution, such as in the case where a myelogram was repeated to confirm a finding or re-assess after treatment, the first myelogram performed at our institution regardless of date was designated as the index scan for analysis in order to represent the initial workup. Myelograms were then grouped according to the positioning of the patient for the myelogram: prone position only or decubitus positioning.

Imaging Assessment

Contrast-enhanced brain MRI is always obtained as a standard part of the pre-myelogram work-up at our institution. These scans were reviewed for all subjects and classified as either positive or negative for signs of SIH. Brain MRI was considered to be positive if it showed evidence of one or more of three previously described signs: diffuse dural enhancement, the venous distention sign, or brain sagging.[8-10] The presence of brain sagging was judged using previously reported criteria: downward sloping of the third ventricular floor resulting in descent of the mammillary bodies to the level of the dorsum sella present on either sagittal T1- or T2-weighted images.[10] Classification was based on assessment documented in a structured clinical note in the medical record at the time of initial patient assessment, entered after review by one of 4 attending radiologists with 6-16 years' experience in treatment of SIH. In the case of missing data or ambiguous assessment, the brain imaging was adjudicated by a study neuroradiologist with 15 years' experience in evaluating patients with SIH.

CT myelograms were reviewed to determine the presence of a CVF. Assessment was based on the presence of a "hyperdense paraspinal vein" sign, and was performed by one of two study neuroradiologists with 12-15 years' experience evaluating CTM done for SIH (Fig. 2).[11] In equivocal cases, the imaging was jointly reviewed by both neuroradiologists to reach consensus. (Fig. 3)

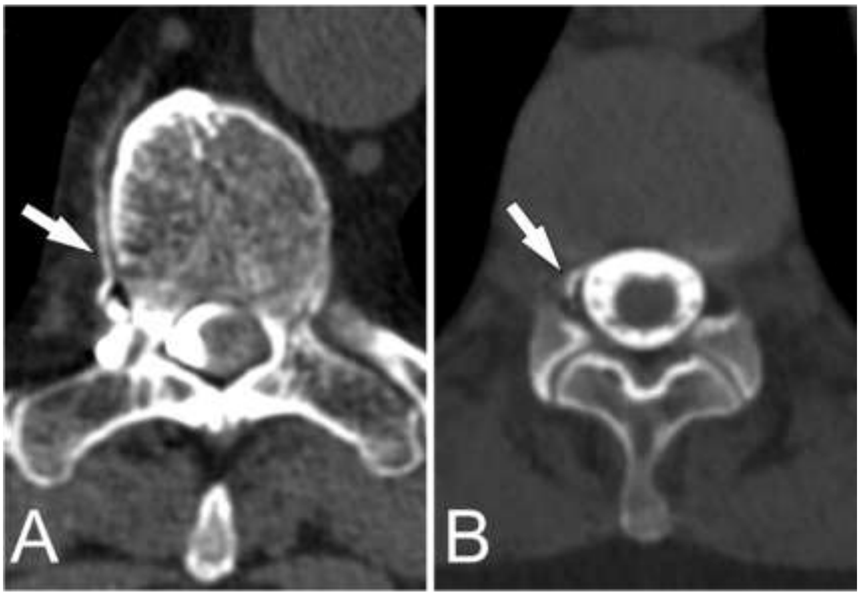

FIG 2. Examples of CVFs seen on CTM. Axial image from CTM performed in the right lateral decubitus position (A) shows venous contrast opacification indicating the presence of a CVF in a segmental spinal vein (white arrow). Axial image from CTM performed in the prone position (B) shows contrast opacification of the internal epidural venous plexus within the spinal canal (white arrow), also diagnostic of a CVF.

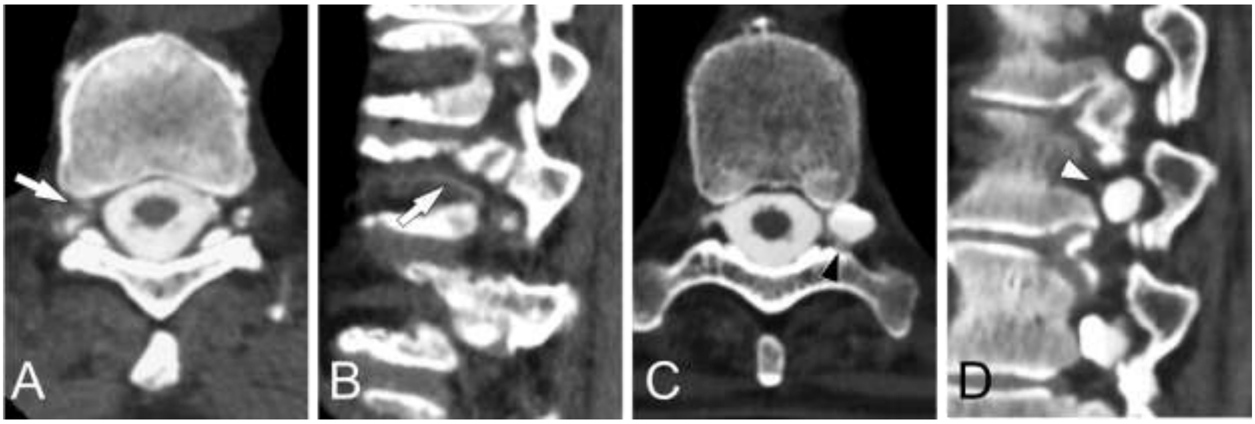

FIG 3. Examples of equivocal CVFs requiring adjudication. Axial (A) and sagittal (B) images from CTM in a single subject shows subtle increased attenuation of a foraminal vein and adjacent segmental spinal vein (white arrows); this was judged to represent a CVF after consensus read. Axial (C) and sagittal (D) images from CTM in a second subject whose faint increased attenuation posterior to perineural diverticulum (black arrowhead) and anterior to the same diverticulum (white arrowhead); this was judged to be not definitive enough to diagnose as a CVF following consensus read.

Statistical analysis

The primary outcomes of interest were the proportion of subjects who had a CVF diagnosed on dCTM. Subgroups of this larger cohort were also analyzed according to whether their brain MRI showed or did not show signs of SIH. A secondary outcome of interest was the proportion of subjects with epidural fluid on spinal imaging whose brain imaging was negative for signs of SIH. These proportions were reported using descriptive statistics.

Additionally, the proportion of studies showing evidence of CVF among subjects who underwent dCTM versus prone CTM imaging was compared using Fisher's Exact test. This analysis was performed using commercially available software (Prism 10, version 10.1.1, GraphPad Software). A p-value <0.05 was considered statistically significant.

RESULTS

Study Cohort

We identified 340 consecutive patients during the study period. A total of 38 subjects were excluded due to missing data (n=16) or non-standard myelogram technique (n=22). 55 subjects demonstrated epidural leak on imaging. The final primary study cohort of subjects without epidural fluid was thus 247 subjects (Fig. 4). Mean subject age in the primary cohort was 50.1 years (SD 15.8, range 16-82). Sixty-two percent of subjects (n=153) were female. The secondary study cohort included 55 subjects found to have epidural fluid on spine imaging. Mean subject age in the secondary cohort was 45.2 years (SD 11.3, range 15-75). Sixty-four percent of subjects in the secondary cohort (n=35) were female.

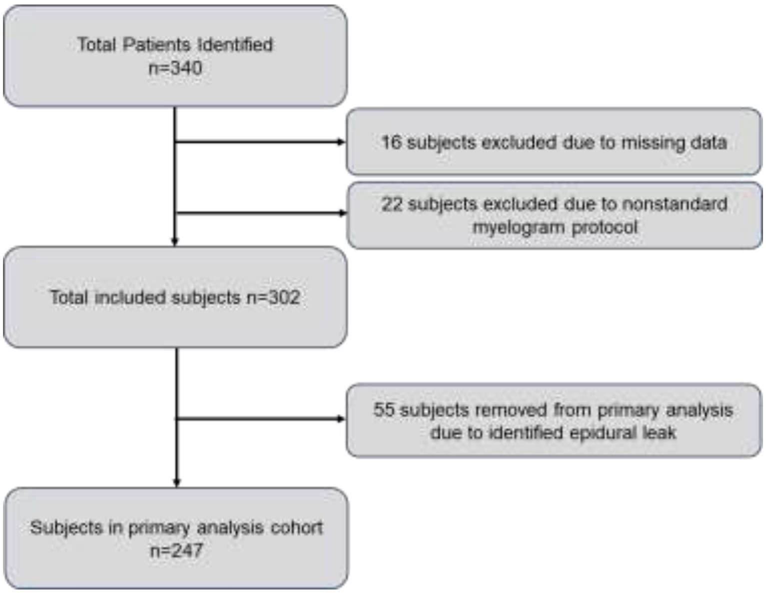

FIG 4. Flowchart of patient selection.

CT Myelography

The first available myelogram was performed using decubitus positioning (dCTM) in 57% of cases (n=141), and prone only positioning in 43% (n=106) cases. Results of diagnostic yield analysis are shown in Fig. 5.

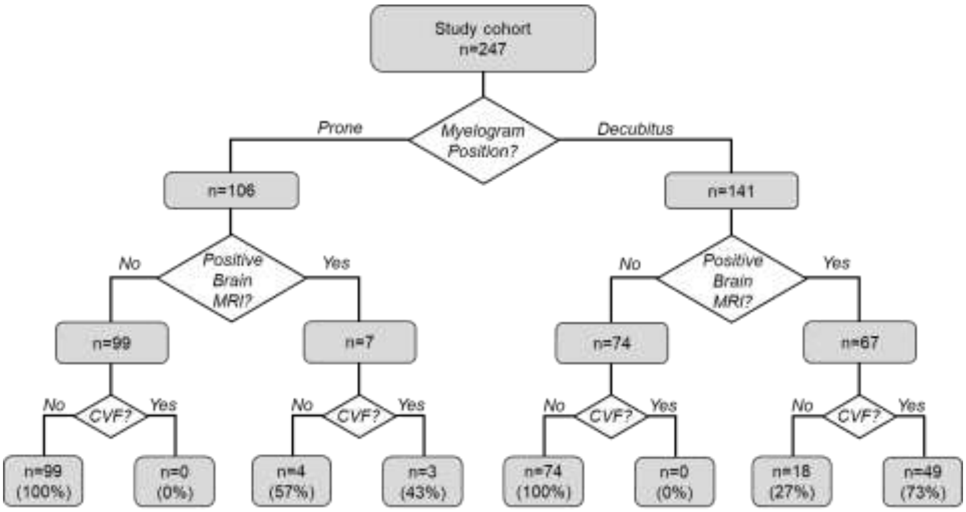

FIG 5. Results of diagnostic yield of prone and decubitus myelography for CVF detection.

For subjects with a CVF detected, the first decubitus scan was performed with the subject positioned in left lateral decubitus position in 77.4% (n=41), in right lateral decubitus position in 17.0% (n=9), and in prone position in 5.7% (n=3) of patients. Excluding cases where the CVF was identified on a prone scan, the CVF was identified on this first lateral decubitus scan (i.e. the side originally positioned down after contrast injection) in 65% (n=32/49) of cases, and was seen after turning to the contralateral side in 35% (n=17/49) of cases. Fistulas were identified between T1-2 and L1-2, with the most common levels being T6-7 (17.0%) and T10-11 (17.0%).

Of subjects who underwent dCTM, 48% (67/141) of subjects had brain MR imaging that was positive for one or more major signs of SIH (dural enhancement n=56, brain sagging n=42, venous distension sign n=46, and subdural collections n=3, missing data n=0). The remaining 52% of subjects (n=74) had a negative brain MR. For subjects with positive brain imaging who underwent dCTM, a CVF was identified in 73% (49/67) of subjects. A CVF was identified in 0% (0/74) of subjects who underwent dCTM where brain imaging was negative.

Of subjects who underwent prone CTM, 7% (7/106) had brain imaging positive for signs of SIH, and 93% (99/106) had negative brain imaging. Among this subgroup of patients undergoing prone CTM, a CVF was detected in 43% (3/7) of cases where brain imaging was positive, and 0% (0/99) of cases where brain imaging was negative.

Considering all pooled subjects with positive brain imaging, the subgroup who had CTM performed in the decubitus position showed a 70% increase in the rate of CVF detection compared to those who underwent prone CTM (73% vs. 43%, p=0.19), although the total number of cases of CVFs assessed with prone myelography was small and the difference was not statistically significant. No subjects with negative brain imaging in this study had a CVF detected, regardless of CTM positioning.

Of patients with epidural leak seen on spinal imaging (n=55), 78% (43/55) had positive brain imaging (dural enhancement n=32, brain sagging n=26, venous distension sign n=32, and subdural collections n=5; missing brain MRI n=1, missing post contrast imaging n=3); the remaining 22% (12/55) had no signs of SIH on brain imaging.

DISCUSSION

Our investigation sought to determine the diagnostic yield of dCTM for detecting CVFs in patients without epidural fluid on spine imaging who were undergoing evaluation for possible SIH. We found that in our cohort of 247 consecutive patients, a CVF was diagnosed in 73% of subjects with positive brain imaging, suggesting that dCTM is capable of identifying CVFs in a substantial majority of patients. This rate reflects the detection rate from the first CTM performed at our institution and does not account for diagnoses made on subsequent repeat examinations if the first CTM was negative, in order to best represent the diagnostic performance of a single imaging examination. Although direct comparison cannot be made with prior investigations because of potential differences in the composition of patient cohorts, these results are generally comparable to a previously study of the diagnostic yield for CVF detection using digital subtraction myelography (DSM), where a CVF was identified in 74% of subjects with SIH who had no leak seen on conventional spine imaging.[3] This suggests that dCTM is an effective first line imaging tool for evaluating patients with SIH who do not have epidural fluid on initial spine MRI. Of note, one recent study of 20 patients with SIH who underwent both DSM and decubitus DSM on the same day reported a yield of CVF detection of 35% (7/20) with DSM compared to 95% (19/20) for dCTM.[12] Although a small study with diagnostic yields that are more widely divergent than those reported in other centers, it generally supports our conclusion that dCTM is effective as a first-line diagnostic study for suspected CVF.

We also found that among patients with negative brain imaging (i.e. no signs of SIH) who were being evaluated for possible SIH with myelography, no CVFs were detected using either decubitus or prone positioning. The fact that the diagnostic yield among subjects with positive brain imaging was 73% using the same myelogram technique suggests that the low yield among subjects with negative brain imaging reflects a true lower prevalence of CVFs in this population, rather than reflecting a limitation of the imaging technology. Despite the fact that we found no CVFs among subjects with negative brain imaging in this study from May 2021 to May 2022, we have anecdotally found CVFs using dCTM in this subgroup of patients with negative brain imaging in clinical practice on rare occasions. We do not, therefore, assert that the prevalence of CVFs is zero when brain imaging in negative, however we can conclude based on this study that the prevalence is expected to be very low. This information can be useful when counseling patients on what to expect when undergoing myelography for possible SIH.

Our findings regarding patients with negative brain imaging differ from a previous investigation that used DSM to evaluate patients with orthostatic headache who had no brain imaging signs of SIH.[13] In that investigation, the authors identified a CVF in 10% (6/60) of subjects with normal brain and spine MRI. Importantly, however, all subjects in that study first underwent epidural blood patch (EBP) prior to DSM, and a positive response to EBP was reported in 82% of their cohort. It is possible that this additional selection step produced a different population of subjects than we enrolled in our study, and this difference in population accounts for the difference in the prevalence of CVFs between our investigation and this previous investigation. Our study enrolled a total of 173 subjects with negative brain imaging, including 74 who underwent dCTM, a larger population than in the prior study, suggesting that the low yield in our study is not likely attributable to a Type II statistical error produced as the result of a small sample size. Additionally, in their investigation, Schievink et al. found a higher rate of CVFs among the subgroup of patients with spinal meningeal diverticula. However, in our investigation, the absence of any CVFs among patients with negative brain imaging would suggest that spinal meningeal diverticula are of lesser diagnostic importance than brain MRI findings. Future investigation into the yield of dCTM and DSM in both selected and unselected populations of patients with orthostatic headache is warranted to better determine who is likely to benefit from myelography when brain imaging is negative.

Among those subjects with epidural fluid seen on spinal imaging, brain imaging was positive for signs of SIH in 78% of cases. The remaining 22% showed no evidence of SIH on brain imaging, despite confirmed spinal epidural fluid leak on spinal imaging. In comparison, all subjects found to have CVFs in this study had positive brain imaging. Neo-membranes have been directly observed at surgery to develop around chronic epidural fluid collections.[14] We hypothesize that these neo-membranes may partially contained the leak, resulting in a decreased rate of fluid loss leading to reversal of brain imaging changes of SIH, even though patients may remain clinically symptomatic. This hypothesis is supported by the observation that brain imaging changes of SIH have been shown become less prevalent with time after symptom onset, which suggests some physiologic compensation that develops over time.[15] Practically, this means that among patients referred for evaluation of possible SIH who have negative brain imaging, spinal MRI is likely to identify the large majority of patients who will ultimately satisfy ICHD-3 criteria for a diagnosis of SIH.

We also found that the rate of CVF detection was higher when CTM was performed in the decubitus position compared to prone position (73% vs. 43%), although the difference was not statistically significant, perhaps due to the small sample size of patients evaluated with prone CTM. The importance of decubitus positioning in CVF detection has been reported before,[4, 16] but this investigation provides additional information regarding the magnitude of the increase in yield with dCTM compared to prone imaging when comparing similar patient populations.

Our investigation was carried out using a single CT scanner with a conventional energy-integrating detector (EID) design. More recently, the use of photon-counting detector CT scanner design has shown promise in further increasing the diagnostic yield for detecting CVFs.[17-20] Additionally, respiratory maneuvers including the use of resisted inspiration have been shown to decrease venous pressure in the vena cava and facilitate the detection of some CVFs during myelography.[5, 21, 22] Application of these technologies and respiratory techniques while performing dCTM would be expected to further raise the diagnostic yield above the 73% we found in this study.

The technique we employ at our institution for decubitus CTM involves a single acquisition per side when scanning in the decubitus position, after careful patient positioning to maximize contrast density over the thoracic spine, where CVFs are most prevalent.[2] Some authors have recently described "dynamic" techniques for decubitus CTM in which multiple acquisitions are obtained per side immediately after injection while contrast is still migrating in the thecal sac.[23-25] Other authors have described a myelographic technique involving separate contrast injections for each decubitus scan in order to increase the density of dependently layering contrast.[26] It remains to be seen whether these techniques increase diagnostic yield compared to static dCTM technique as we describe in this study, since direct comparisons have not yet been performed. However, this study provides a useful benchmark for an approximate yield of static dCTM against which future studies can be generally compared.

At least one investigation of dCTM employed Bern scores[27] to examine diagnostic performance of dCTM, stratified according to Bern score probability categories.[18] This investigation utilized photon-counting detector CT, which is not currently widely available, and found a CVF in 56%, 73%, and 77% of patients with low-, intermediate- and high-probability scores, respectively. The study did not distinguish, however, between subjects with low Bern scores (i.e. 1-2) and those with entirely negative brain imaging (i.e. score 0). We intentionally decided against the use of the Bern score as a tool for describing the stratification of diagnostic yield in our study. The Bern score was initially described as a predictive score of the likelihood of an epidural leak being detected on spinal imaging in patients who had SIH, and was derived from a cohort of patients with established dural leaks.[27] The probability categories (i.e. low, intermediate, and high) do not provide a basis for dichotomization of showing vs. not showing brain imaging evidence of SIH, and therefore do not lend themselves to a straightforward diagnostic classification of SIH under the International Classification of Headache Disorders (ICHD-3) criteria, the most widely used diagnostic standard for this condition, which requires a binary assessment of whether brain imaging signs of intracranial hypotension are present.[28] For example, a hypothetical patient with diffuse, smooth dural enhancement pathognomonic for intracranial hypotension but no other features of

SIH on brain imaging would be assigned a Bern score of 2, falling into the low probability category. Such a patient, in our opinion, should still undergo decubitus myelography if no epidural fluid is seen on spine MRI, regardless of Bern score probability category, to assess for CVF. For the purposes of our investigation, then, a Bern score would not have clearly discriminated patients with or without brain imaging evidence of SIH, which was a primary question of interest.

Our study has several limitations. First, this study reflects a protocol for dCTM in use at the time of the study, but refinements for dCTM protocols are ongoing. Factors such as scanner hardware, timing of scanning, respiratory phase, intrathecal contrast volume, and other factors have been studied very recently, and these may influence yields with current dCTM protocols. Second, the study population reflects referral patterns to a quaternary referral center for SIH. As more centers engage in the evaluation of patients with suspected SIH, there is the potential for referral centers to see higher numbers of patients who have failed initial workup locally, thereby enriching the study population with SIH patients who have CVFs that are more difficult to detect. Simultaneously, with the growing awareness of SIH, referrals for evaluations of patients with refractory headaches and negative brain imaging has anecdotally increased, some of whom have headache phenotypes less stereotypical of those commonly seen with SIH. This has the potential to negatively skew the prevalence of CVFs among patients with negative brain imaging. An additional limitation is that our classification of imaging is based on expert reader interpretation, which necessitates some level of subjective judgment, as there is no current objective methodology for classification of CVFs in widespread use. However, the readers in our study were highly experienced in both spinal and brain imaging interpretation in SIH and were careful to submit all questionable cases for consensus reads, where a high standard of diagnostic certainty was applied when adjudicating cases. Finally, our cohort included only a small number of subjects with positive brain imaging who underwent prone imaging. Although decubitus imaging is now considered the standard for CVF investigation, and these subjects represent an older imaging protocol, the small subject numbers may affect the accuracy of the estimated diagnostic yield for prone-only imaging.

CONCLUSIONS

In conclusion, dCTM identified a CVF in 73% of patients who had brain imaging signs of SIH and no epidural fluid on spinal imaging. No patients with confirmed CVFs had negative brain imaging in this investigation. By comparison, patients with epidural fluid found on spinal imaging exhibited negative brain MRI in 22% of cases, suggesting that epidural leaks account for the majority of cases of SIH with negative brain imaging. This study provides useful data for counseling patients on expected yield of dCTM and establishes a general benchmark for assessing the impact on diagnostic yield of future modifications to dCTM technique.

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