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Microsurgical Repair of Ventral Cerebrospinal Fluid Leaks in Spontaneous Intracranial Hypotension: Efficacy and Safety of Patch-Sealing Versus Suturing

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This work was presented in part at the annual joint meeting of the German Neurosurgical Society in Göttingen (GER) on June 11, 2024 and at the annual joint meeting of the Swiss Neurosurgical Society in Interlaken (CH) on June 20, 2024.

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Received, May 30, 2024; **Accepted,** June 25, 2024; **Published Online,** August 12, 2024.

Operative Neurosurgery 00:1–7, 2024 https://doi.org/10.1227/ons.0000000000001310

BACKGROUND AND OBJECTIVES: In patients with spontaneous intracranial hypotension (SIH), microsurgical repair is recommended in Type 1 (ventral) dural leaks, when conservative measures fail. However, there is lacking consensus on the optimal surgical technique for permanent and safe closure of ventral leaks.

METHODS: We performed a retrospective analysis of surgically treated SIH patients with Type 1 leaks at our institution between 2013 and 2023. Patients were analyzed according to the type of surgical technique: (1) Microsurgical suture vs (2) extradural and intradural patching (sealing technique). End points were resolution of spinal longitudinal epidural cerebrospinal fluid collection (SLEC), change in brain SIH-Score (Bern-Score), headache resolution after 3 months, surgery time, complications, and reoperation rates.

RESULTS: In total, 85 (66% women) patients with consecutive SIH (mean age 47 ± 11 years) underwent transdural microsurgical repair. The leak was sutured in 53 (62%) patients (suture group) and patch-sealed in 32 (38%) patients (sealing group). We found no significant difference in the rates of residual SLEC and resolution of headache between suture and sealing groups (13% vs 22%, $P = .238$ and 89% vs 94%, $P = .508$). No changes were found in the postoperative Bern-Score between suture and sealing groups (1.4 [±1.6] vs 1.7 [±2.1] $P = 1$). Mean surgery time was significantly shorter in the sealing group than in the suture group (139 ± 48 vs 169 ± 51 minutes; $P = .007$). Ten patients of the suture and 3 of the sealing group had a complication (23% vs 9%, $P = .212$), whereas 6 patients of the suture and 2 patients of the sealing group required reoperation (11% vs 6%, $P = .438$).

CONCLUSION: Microsurgical suturing and patch-sealing of ventral dural leaks in patients with SIH are equally effective. Sealing alone is a significantly faster technique, requiring less spinal cord manipulation and may therefore minimize the risk of surgical complications.

KEY WORDS: Spontaneous intracranial hypotension, Spinal cerebrospinal fluid leak, Dural leaks, Microsurgical techniques

Spontaneous intracranial hypotension (SIH) is caused by cerebrospinal fluid (CSF) leaks along the spinal axis that manifests primarily with orthostatic headache (HA) and accompanying symptoms.[1-6] The diagnostic workup typically demonstrates several intracranial findings reflected by a high brain MRI-based brain SIH-Score (Bern-Score)[7] and/or a spinal longitudinal epidural CSF collection (SLEC).[1] Recent studies emphasized the profound negative impact of SIH on the quality of life of affected patients.[6,8,9] Therefore, early diagnosis and treatment are paramount to reduce disease burden and enhance the chances of recovery.[10]

ABBREVIATIONS: Bern-Score, brain SIH-Score; **CSF,** cerebrospinal fluid; **CT,** computed tomography; **SIH,** spontaneous intracranial hypotension; **SLEC,** spinal longitudinal epidural CSF collection.

There are 3 types of spinal cerebrospinal fluid (CSF) leaks leading to SIH.[11] Type 1 leaks represent a particular challenge because of their location on the anterior aspect of the dura, making them difficult to access surgically. Type 2 leaks are situated laterally, whereas Type 3 leaks are caused by CSF venous fistulas.[11,12] If conservative management fails, surgery has been shown to be very successful for CSF leak repair.[5]

Different surgical techniques have been described in the literature.[13-17] A minimally invasive transdural approach was shown to be effective in visualizing and safely closing various types of CSF leaks.[18,19] This requires specialized neuroradiological noninvasive and invasive diagnostics. At our institution, patients with SIH undergo a standardized workup including dynamic myelography techniques, which are crucial for precise localization of spinal CSF leaks and successful microsurgical management.[20-22] For latter, intradural suturing or a suture-free, intradural, and extradural patch, the so-called "sandwich technique," has been proposed in the literature.[10,18,19] The aim of our study was to compare the efficacy and safety of both techniques for repairing ventral dural leaks in a cohort of patients with consecutive SIH treated at our hospital.

METHODS

Study Design

We conducted a retrospective single-center analysis of patients with consecutive SIH treated at our institution between 2013 and 2023. For the diagnosis of SIH, the criteria of the International Classification of HA Disorders, third edition (HA Classification 2013) were applied.[23] We only included patients with a confirmed ventral CSF leak (Type 1), according to Schievink et al.[11] Patients diagnosed with other types of CSF leaks were excluded from this study. Patient-specific data and data regarding the radiological findings, surgery, and postsurgical course were retrospectively collected. The study adhered to the guidelines outlined in the Strengthening the Reporting of Observational Studies in Epidemiology statement.[24]

Ethics

The local ethics committee gave ethical approval. All patients included in this study gave consent for the use of health-related data.

Standard Treatment

We adhered to a standardized and stepwise algorithm approach to investigate and localize the CSF leak in each patient. These techniques have been previously described in more detail elsewhere.[20-22] Initial conservative measures such as bed rest, caffeine tablets, or blood patches were unsuccessful in all patients. Surgery was then offered to all patients with confirmed SIH and a proven CSF leak.

Surgery was performed under general anesthesia, and in prone position. The index level was identified by intraoperative fluoroscopy. A tailored dorsal midline or slightly paramedian approach was then performed, with either a non-expandable tubular retractor or a 3-cm median skin incision, followed by an interlaminar unilateral laminotomy or hemilaminectomy. After extradural exploration and inspection of the ventro-lateral dura, a paramedian durotomy was performed followed by cutting of the ipsilateral dentate ligament. The spinal cord was then gently rotated contralaterally to create a safe surgical corridor to the ventral dural defect, as described previously (Figure 1A).[10,18,19] After transection of herniating arachnoid membranes through the ventral defect,[25] discogenic spurs, if present, were removed bluntly. The ventral dural defect was then repaired using 1 of 2 different techniques. The first technique (suture group) involved placing 1 or 2 sutures intradurally with a nonabsorbable 6-0 suture to close the dural defect, followed by placing an adhesive patch intradurally on the sutured defect. For patch augmentation DuraGen® (Integra) or TachoSil® (Takeda Pharmaceutical AG), DuraMatrix® (Stryker) was used depending on the surgeon's preference (Figure 1B). The second technique (sealing group) was a slight simplification of the first one by omitting intradural suturing. Here, the ventral dural defect was sealed solely with an intradural and extradural TachoSil®, DuraMatrix®, or DuraGen® patch ("sandwich-technique") (Figure 1C).[18]

In both techniques, the paramedian durotomy was closed identically using a nonabsorbable 6-0 watertight running suture with extradural augmentation using TachoSil® and fibrin glue. Nevertheless, our institution has seen a steady change from suturing to patch-sealing over the past few years. The surgeries over the entire timespan were exclusively performed by experienced board-certified neurosurgeons familiar with the required microsurgical techniques.

Radiological and Clinical End Points

All patients were routinely followed up to assess changes in preoperative and postoperative SLEC on spine MRI and the Bern-Score on brain MRI at 3 months. The Bern-Score is a 9-point scoring system and predictive tool for assessing the likelihood of an ongoing CSF leakage in patients with suspected SIH. The score is composed of 3 major and 3 minor criteria, resulting in classification into low (≤2), intermediate (3-4), and high (≥5) probability for SIH.[7] SLEC was studied using high-resolution sagittal T2 sequences and/or additional application-optimized contrasts by using different flip angle evolution sequence. Only experienced neuroradiologists interpreted all radiological examinations.

As the clinical end point, we assessed HA at 3-month follow-up. Here, the results were trichotomized into "better," "same," and "worse." To investigate the safety and feasibility of both surgical techniques, we analyzed rates of intraoperative and postoperative complications and reoperations until follow-up. Complications were defined as any deviation from the normal postoperative course. Furthermore, we compared the surgery time between the 2 techniques.

Statistical Analyses

The descriptive statistics involved calculating the mean and SD. To compare groups, the χ^2 test was used for categorical variables, and the Mann-Whitney *U*-test was applied for continuous variables. Group means were analyzed using either an independent or paired samples *t*-test. For matched samples with nonnormally distributed data, the Wilcoxon signed-rank test was employed. The Pearson product-moment correlation coefficient was calculated to assess the relationship between continuous variables and a continuous outcome. Missing values were first addressed through data reanalysis, and if they remained unretrievable, pairwise deletion was implemented. Statistical significance was defined by an alpha error of less than 0.05. All statistical tests were performed using SPSS (IBM, version 28).

RESULTS

Baseline Characteristics

Between 2013 and 2023, 85 patients with SIH (56 women and 29 men) with a Type 1 leak who underwent microsurgical treatment were included for final analysis. The mean patient age was 47 (±11) years. In 53 (62%) patients, the ventral leak was

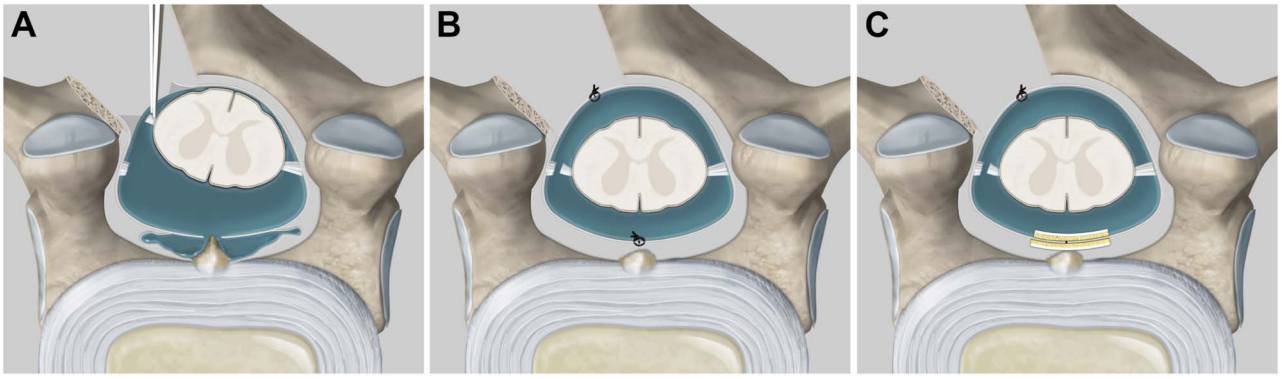

FIGURE 1. *Schematic drawings of the 2 techniques.* **A**, *Following a paramedian durotomy and spinal cord releasing maneuver and removal of the spur and any arachnoidal hernias, the ventral dura mater was either* **B**, *sutured or* **C**, *patch-sealed. © Inselspital, Bern University Hospital, Dept. of Neurosurgery, 2024.*

sutured and patch-sealed in 32 (38%) patients. In the suture group, there were 40 women (75%), compared with 16 (50%) in the sealing group. The mean overall preoperative Bern-Score was 6.1 (±2.9), signifying high probability for a spinal CSF leak. There was no significant difference in the preoperative Bern-Score between the suture and the sealing group (mean 6.3 [±2.7] vs 5.7 [±3.3], P = .754). All except 1 patient in the sealing group were SLEC-positive on preoperative spinal MRI. Although 78 (97%) leaks were localized in the thoracic spine, only 2 (2%) were localized in the cervical and 1 (1%) in the lumbar spine (Table 1).

Radiological Outcome

Seventy-five patients underwent follow-up with cranial MRI either at our institution or at an external hospital. Ten patients did not receive standard radiological follow-up because many patients lived abroad and were not able to obtain the recommended postoperative MRI. There was a significant decrease in the Bern-Score below the low probability threshold after surgery (from 6.1 [±2.9] to 1.6 [±1.8], Z = -6.9, P = .001). Sixty-three individuals (84%) were found to have a lower postoperative Bern-Score, 10 (13%) patients had no change in their Bern-Scores, and 3 (4%) had a higher Bern-Score after treatment. Mean postoperative Bern-Scores showed no statistically significant difference between both groups (1.4 [±1.6], the suture group vs 1.7 [±2.1], the sealing group, P = 1). There was also no significant difference in the mean absolute postoperative reduction of the Bern-Score (the suture group (−5 [±2.8]) and the sealing group (−4 [±3.2], P = .253) (Table 2).

A postoperative MRI of the spine was performed in 79 patients. Six patients were lost to radiological outcome regarding the spine for reasons stated above. Of them, 13 (17%) patients remained SLEC-positive (6 in the suture group [13%] and 7 in the sealing group [22%], P = .238).

Headache Resolution

A total of 77 patients were followed up clinically. Seventy (90%) reported improvement of headaches: 41 (89%) within the suture group and 29 (94%) of the sealing group (P = .508).

Complications and Reoperations

In total, adverse events occurred in 15 (18%) patients. Of them, 5 patients experienced temporary mild paresis of a lower extremity and 1 patient experienced nonradicular, diffuse hypesthesia. All of these symptoms had resolved within 3 months. A permanent neurological deficit occurred in 1 patient of the suture group (2%), who suffered from index dermatome neuralgia. In comparison, no permanent neurological deficits were recorded in patients of the sealing group. When compared by groups, there was no significant difference in complication rates between groups (23% suture group vs 9% sealing group, P = .212). Reoperations were performed for dural leak revisions in 5 patients (4 [8%] patients in the suture group vs 1 [3%] in the sealing group) and for early postoperative epidural hematomas in 2 patients (1 [2%] vs 1 [3%]). One patient of the suture group underwent a local wound revision because of a surgical site infection. There was no statistical significant difference in the reoperation rate between groups (11% vs 6%, P = .438) (Table 3).

Surgery Time

The average duration of the surgical procedure in the suture group was 169 (±51) minutes and 139 (±48) minutes in the sealing group (P = .007). Over the years, the surgery time has steadily decreased, shown as clear inverse correlation (r = −0.533, P = .001) (Figure 2).

DISCUSSION

Our data demonstrate that suturing and patch-sealing are equally efficient microsurgical techniques for successful closing of ventral dural leaks in patients with SIH. Regarding radiological and clinical end points, both techniques achieved comparable success rates. We observed complication rates of 9% in the sealing group and 23% in the suture group, with no statistically significant difference. However, patch-sealing was significantly faster.

TABLE 1. Baseline Characteristics of the Study Cohort, Presenting Age, Sex Distribution, Preoperative Bern-Score, Prevalence of SLEC, and Spinal Level of the Leak

Baseline characteristics	Total	Suture group	Sealing group	*P*
n	85	53	32	
Mean age, y (SD)	47 (11)	48 (11)	46 (11)	.298
Female (%)	56 (66)	40 (75)	16 (50)	**.016**
Mean preoperative Bern-Score (SD)	6 (2.9)	6 (2.7)	6 (3.2)	.754
SLEC-positive (%)	84 (99)	53 (100)	31 (97)	.195
Localization of leak (%)				
C 5/6	1 (1)	0 (0)	1 (3)	
C 6/7	1 (1)	0 (0)	1 (3)	
C 7/T 1	2 (2)	2 (4)	0 (0)	
T 1/2	16 (19)	9 (17)	7 (22)	
T 2/3	8 (9)	7 (13)	1 (3)	
T 3/4	4 (5)	3 (6)	1 (3)	
T 4/5	7 (8)	2 (4)	5 (16)	
T 5/6	7 (8)	6 (11)	1 (3)	
T 6/7	7 (8)	6 (11)	1 (3)	
T 7/8	5 (6)	2 (4)	3 (9)	
T 8/9	4 (5)	2 (4)	2 (6)	
T 9/10	2 (2)	2 (4)	0 (0)	
T 10/11	2 (2)	1 (2)	1 (3)	
T 11/12	14 (17)	6 (11)	8 (25)	
T 12/L1	4 (5)	4 (8)	0 (0)	
L 1/2	1 (1)	1 (2)	0 (0)	

n, number; Bern-Score, brain SIH-Score; SLEC, spinal longitudinal epidural CSF collection; C, cervical; T, thoracic; L, lumbar.
Bold represents statistically significant data.

In our department, we prefer a unilateral laminotomy to minimize bony resection and to spare the posterior ligamentous complex. The transdural approach was probably first described by Horwitz et al, initially adopted for the treatment of median thoracic disk herniations,[26] and was later refined and described for the management of ventral dural leaks in SIH.[18,19] However, this approach is not without risks, requiring exposure of the spinal cord followed by a releasing maneuver to slightly rotate the spinal cord contralaterally. Operating on the ventral dura through this narrow corridor, especially when using tubular retractors, is challenging and requires microsurgical expertise. Evidently, suturing of a ventral dural breach through this working channel is tedious because of limited space and often compromised visibility, and additional manipulations of the spinal cord are unavoidable. Here, the sealing technique offers an advantage by skipping the suturing part and simply inserting an intradural patch over the dural breach. As a result, this technique has shown to lead to a significantly shorter duration of surgery and a lower complication rate.

The total rate of permanent complications within our cohort was very low (1%), which is consistent with an earlier publication.[18] Considering additional transient symptoms and directly treatable complications, a complication rate of 18% was observed. This is comparable with findings in the literature (17%-28%).[18,19] Although the only permanent complication occurred in the suture group and was attributable to a deliberate nerve root transection, we nevertheless found a higher rate of transient radicular symptoms in the suture group. It is plausible that this is attributable to increased spinal cord manipulation during suturing.

To our knowledge, there are no other studies that have compared dural closure techniques exclusively in patients with

TABLE 2. Summary of Outcomes

Outcomes	Suture group	Sealing group	*P*	*P*
n	45	30		
Mean preoperative Bern-Score (SD)	6 (2.9)	6 (3.3)	.754	**.001**
Mean postoperative Bern-Score (SD)	1.4 (1.6)	1.7 (2.1)	1	
Mean difference Bern-Score (SD)	−5 (2.8)	−4 (3.2)	.253	
n	48	31		
SLEC-positive follow-up (%)	6 (13)	7 (22)	.238	
n	46	31		
HA postoperative improved (%)	41 (89)	29 (94)	.508	
HA postoperative no change (%)	5 (11)	2 (6)		
n	53	32		
Mean surgery duration (min) (SD)	169 (51)	139 (48)	**.007**	
Correlation analysis[a]				
Operation date vs surgery duration	*r* =	−0.533	**.001**	

n, number; HA, headache; Bern-Score, brain SIH-Score; SLEC, spinal longitudinal epidural CSF collection.
Bold represents statistically significant data.
[a]Pairwise deletion for missing values.

SIH with ventral Type 1 leaks. However, in the field of degenerative lumbar spine surgery, numerous studies on incidental durotomy have demonstrated that there is no relevant difference between primary suturing and patching.[27-29] Yet, these results cannot be simply extrapolated to the thoracic spine, where the hydrostatic pressure in an upright position is more forgiving compared with the lumbar spine. In addition, a transdural approach allows for both intradural and extradural patch placement, providing additional reinforcement and augmentation for reconstruction of a dural breach. Therefore, additional suturing hardly adds any relevant benefit, which is reflected in our results.

In 90% of our patients, we observed a subjective HA improvement, which is in concordance with previous studies.[8,10] While acknowledging this high rate of HA improvement, it must also be noted that because of the retrospective nature of this

TABLE 3. Overview of Complications, Reoperations, and Rates, Respectively, per Group

Complications and reoperations	Total	Suture group	Sealing group	*P*
N	85	53	32	
Transient mild paresis (%)	5 (6)	4 (8)	1 (3)	
Transient radicular hypesthesia (%)	1 (1)	1 (2)	0 (0)	
Wound infection (%)	1 (1)	1[a] (2)	0 (0)	
Neuralgia (%)	1 (1)	1 (2)	0 (0)	
Unsuccessful leak closure (%)	5 (6)	4[a] (8)	1[a] (3)	
Epidural bleeding (%)	2 (2)	1[a] (2)	1[a] (3)	
Total complications (%)	15 (18)	12 (23)	3 (9)	.212
Reoperations (%)	8 (9)	6 (11)	2 (6)	.438

n, number.
[a]Complications that required reoperation.

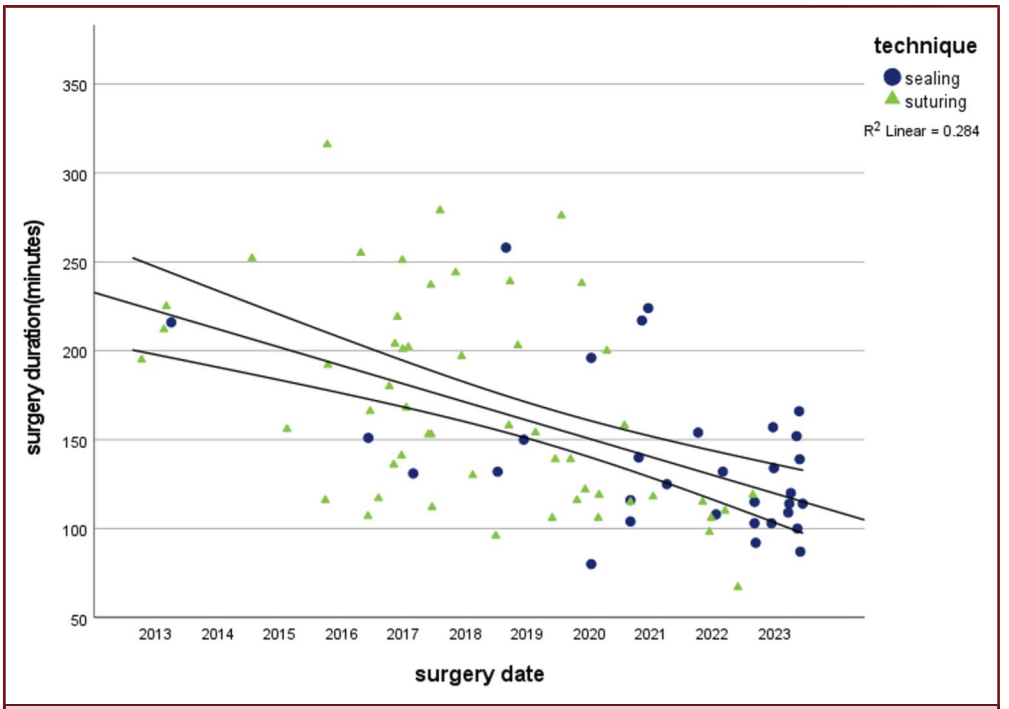

FIGURE 2. *Correlation between surgery duration and date, with linear regression line reporting a 95% CI.*

analysis, the precise residual symptoms and thus the complete therapy outcome from the patient's perspective are not adequately represented. These patients often suffer from concomitant complaints that are sometimes more debilitating than the HA itself,[1,6] with relevant negative impact on social and professional life.[6,8]

Although the brain MRI-based Bern-Score has been originally devised to assess the likelihood of underlying SIH,[7] it has been shown to serve as a valuable monitoring tool to objectively evaluate treatment success.[30] Representing a quantifiable value, both sealing techniques exhibited similar radiological success rates. Interestingly, 3 patients had a higher postoperative Bern-Score at follow-up. However, 2 of them still remained within the low probability group according to the Bern-Score.[7] Similarly, although 1 patient's Bern-Score worsened from 7 to 9 points, he reported a significant reduction of headaches nonetheless. This suggests that MRI findings may lag behind clinical improvement. In any case, prolonged MRI and clinical follow-ups seem warranted for patients with high postoperative Bern-Scores.

The relatively high postoperative rate of 17% SLEC-positivity was not reflected in the clinical outcome, where all but 1 SLEC-positive patient reported improvement of preexisting HA. Of note, the same patient was later diagnosed with analgesic-induced headaches, which is not uncommon in patients with chronic diseased SIH. Thus, an overall discrepancy is observed here, although it is also not discussed in the literature whether a postoperative positive SLEC serves as a surrogate for a residual leaking or should still be considered as residue. One might postulate that follow-up imaging was conducted too early. This needs to be further analyzed in long-term studies. In any case, SLEC-positive patients should be further followed up with serial MRIs to observe the dynamics of residual of recurrent extrathecal CSF collections. For patients with additional symptom recurrence, reintervention should be considered at a low threshold.

Successful management of patients with SIH relies on close interdisciplinary collaboration, usually in an academic setting. Therefore, the generalizability of our study results may be restricted to specialized neurosurgical services at dedicated SIH centers.

Limitations

First, comparing 2 surgical techniques in retrospect include the inherent risk of selection and recall bias because of the non-randomized nature of the study design. In addition, the retrospective data introduce the possibility of incomplete or inconsistent documentation, potentially compromising the accuracy and reliability of the findings. Because of the relatively small cohort size, potentially confounding factors could not be fully excluded. Furthermore, we lack the ability to control for confounding variables or assess causality, limiting the strength of the conclusions drawn. To address these limitations, a prospective randomized study is required.

CONCLUSION

Suturing and patch-sealing alone in the surgical management of ventral CSF leaks in patients with SIH are equally effective with

regard to radiological and clinical outcome. However, sealing alone is the significantly faster technique, requiring less spinal cord manipulation and less exposure and may therefore be advantageous by minimizing the risk of surgical complications.

Funding

This study did not receive any funding or financial support.

Disclosures

The authors have no personal, financial, or institutional interest in any of the drugs, materials, or devices described in this article.

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Acknowledgments

The authors would like to thank Anja Giger for providing the schematic drawings (Figure 1A-1C) for this article. Author Contributions: TP: project administration, conceptualization, methodology, data collection, data analysis, visualization, writing original draft, manuscript revision. LH: data collection, data analysis, manuscript review and editing. JG, TD, EIP: data analysis, manuscript review and editing. AR: supervision, manuscript review and editing. CJM, RTS: project administration, conceptualization, methodology, supervision, manuscript review and editing, manuscript revision.

COMMENTS

Spontaneous intracranial hypotension due to idiopathic cerebrospinal fluid leaks is an uncommon but challenging pathology to diagnose and treat. The authors present 85 consecutive patients, one of the largest series to date, who underwent CSF leak repair using 1 of 2 surgical techniques: Direct suture repair or an intra/extradural patch technique. With 90% follow-up, data indicate a 90% headache improvement rate, with an associated 18% complication rate (6% transient paresis) without statistically significant difference between the 2 techniques. The authors conclude that as both techniques appear to have similar outcomes, sealing may be the preferred method due to the lesser degree of spinal cord manipulation and exposure compared with the traditional suturing technique. The authors of this study have clear experience with pathology and provide a well-written manuscript and informative illustrations. I believe the conclusions of this study are of value to the surgical community, despite the limitations of single center, multiple surgeon study design, as well as possible selection bias associated with choice of technique. I commend the authors on their work.

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