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Management of incisional cerebrospinal fluid leak in open cranial surgeries and the "folding technique" in duraplasty

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OBJECTIVE The aim of this study was to review a series of patients who underwent open cranial surgeries to evaluate the incidence of iatrogenic incisional CSF leaks and discuss its prevention and management. The authors also discuss the utility of the "folding technique" used in duraplasty as an alternative to conventional dural reconstruction techniques.

METHODS All patients undergoing open cranial surgery were reviewed, and those with incisional CSF leak were included in this study. CSF leakage was managed using either conservative nonsurgical methods or surgical interventions. When the conservative nonsurgical methods failed to curb the leak, surgical procedures such as lumbar external drainage (LED) using lumbar subarachnoid drainage, external ventricular drainage (EVD), a lumboperitoneal or ventriculoperitoneal shunt (VPS), and reexploration of the surgical site were considered.

RESULTS Between 2019 and 2024, 2149 patients underwent open cranial surgeries at our hospital for any cranial pathology; 39 (1.8%) of these patients experienced postoperative incisional CSF leakage. The majority of the pathologies requiring surgeries were located in the supratentorial region (76.9%). Patients were classified according to the type of dural closure technique used. Primary stitching, the patient's fascia, or synthetic dura (resorbable, nonresorbable, or both) were used for dural reconstruction. The median interval between the surgery and the start of the leakage was 19 (IQR 1–79) days in patients with no history of radiotherapy; however, this duration was longer in patients who received radiotherapy (median 45 [IQR 10–540] days). The surgical interventions for CSF leakage were classified as wound resuturing (combined with other conservative approaches such as tightened dressing and elevating the head end of the bed), LED or EVD, or surgical reexploration. The folding technique in duraplasty is a simple way to achieve watertight duraplasty even with autograft or synthetic material.

CONCLUSIONS Incisional CSF leakage is a potentially preventable complication with high morbidity. Such cases could be managed via conservative approaches including wound resuturing, LED or EVD, and surgical reexploration. However, the management strategy is beyond any strict algorithm. This folding technique for duraplasty is a worthy replacement for conventional primary suturing for dural repair or reconstruction in cranial and even spinal defects. This study highlights the importance of regaining the watertight nature of the dura in the primary surgery to prevent any further intervention and lower the overall morbidity.

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KEYWORDS cranial; CSF leak; dura mater; duraplasty; incisional

Iatrogenic CSF leakage is a relatively common complication of neurosurgical procedures, with leakage rates as high as 16%.[1] Although such iatrogenic cases are reported more commonly with endoscopic skull base approaches used for rhinorrhea, incisional CSF leaks after open cranial surgeries require special attention given their high incidence and the associated burden of morbidity.

An iatrogenic CSF leak occurs due to a damaged dura or any closure defect that hampers the impermeable nature of the dura. It is most commonly found in procedures involving the posterior fossa, cerebellopontine angle (CPA) pathologies, and Chiari malformations and ventricular pathologies. Also, these leaks are known to be refractory to conservative treatment approaches and need additional

ABBREVIATIONS CPA = cerebellopontine angle; EVD = external ventricular drainage; LED = lumbar external drainage; VPS = ventriculoperitoneal shunt.

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TABLE 1. Summary of different cranial pathologies of the patients with incisional CSF leakage along with the total number of related operated pathologies in the same period

Pathology	No. of Pts (%)	No. of Pts w/ Op	Total CSF Leak Ratio, %
Glioma	7 (17.9)	415	1.7
Meningioma	6 (15.4)	245	2.4
Metastatic lesion	5 (12.8)	212	2.4
Parenchymal hemorrhage	3 (7.7)	140	2.1
Dermoid epidermoid cyst	2 (5.1)	17	11.8
Arachnoid cyst	2 (5.1)	12	16.7
Aneurysm	1 (2.6)	243	0.4
SDH	1 (2.6)	172	0.6
SAH	1 (2.6)	25	4.0
Colloid cyst	1 (2.6)	11	9.1
Schwannoma	1 (2.6)	35	2.9
Craniopharyngioma	1 (2.6)	21	4.8
Chordoma	1 (2.6)	10	10.0
Choroid plexus papilloma	1 (2.6)	8	12.5
Hemangiopericytoma	1 (2.6)	8	12.5
Epilepsy	1 (2.6)	21	4.8
Chiari malformation	1 (2.6)	49	2.0
Posterior fossa ependymoma	1 (2.6)	13	7.7
Hydrocephalus	1 (2.6)	484	0.2
Posterior fossa AVM	1 (2.6)	8	12.5

AVM = arteriovenous malformation; pt = patient; SAH = subarachnoid hemorrhage; SDH = subdural hematoma.

interventions;[2] however, there is no consensus regarding their management.

In this single-center study, we retrospectively reviewed a series of patients who underwent open cranial surgeries to evaluate the incidence of iatrogenic incisional CSF leaks and discuss their prevention and management. We also discuss the utility of the "folding technique" defined by us and used in duraplasty as an alternative to conventional dural reconstruction techniques.

Methods

We conducted a retrospective analysis of the clinical data of patients who underwent surgery for any cranial pathology that needed a durotomy at the Department of Neurosurgery, School of Medicine, Ankara University, Turkey. The study was approved by the institutional review board. All patients undergoing open cranial surgery with fully registered data were reviewed, and those with incisional CSF leakage were included in this study. Patients with rhinorrhea who had previously undergone surgery via a transnasal transsphenoidal approach and those with a previously placed ventricular shunt, multiple surgical cranial interventions, trauma, or missing data were excluded.

Incisional CSF leakage was defined as the presence of persistent clear fluid discharge through the skin and the surgical incision. CSF leakage was managed using either conservative nonsurgical methods or surgical interventions. Conservative approaches included resuturing (skin closure) the wound, aspirating the collected material (if presented), tightening the dressing, elevation of the head end of the bed, using stool softeners, and implementing strategies to avoid straining. Additionally, acetazolamide, a carbonic anhydrase inhibitor, was used (250 mg 3 times daily) to lower CSF pressure. When conservative nonsurgical methods failed to curb the leak, surgical procedures such as lumbar external drainage (LED) using lumbar subarachnoid drainage, external ventricular drainage (EVD), a lumboperitoneal or ventriculoperitoneal shunt (VPS), and reexploration (reopening all anatomical layers in order to reach the dura and try to solve the issue of CSF leak) of the surgical site, were considered.

Results

Between 2019 and 2024, 2149 patients underwent open cranial surgeries at our hospital due to any cranial pathology; 39 (1.8%) of these patients (18 females [46%] and 21 males [54%]; mean age 44.8 ± 16.2 years) experienced postoperative incisional CSF leakage. The final evaluation data of these 39 patients was used in this study.

The majority of the pathologies requiring surgeries were located in the supratentorial region (76.9%). Most of the leaks were noted in the frontotemporal area (23.1%) and the posterior fossa (17.9%) in the supratentorial and infratentorial regions, respectively. Table 1 provides a summary of the different pathologies for which the patients underwent surgery, with particular focus on those with incisional CSF leakage. Hydrocephalus was found in 20.5% of patients during the initial presentation. Factors such as diabetes and preoperative steroid usage that can influence wound healing were noted in 5.1% and 51.3% of

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patients, respectively. Table 2 presents detailed characteristics of the patients regarding their cranial pathologies, the primary operation, and follow-up data.

Intraoperative dural laceration or damage was noted in 23.1% of the patients, and patients were classified according to the type of dural closure technique used. Primary stitching (66.7%) was performed for patients with intact dura; otherwise, the patient's fascia (5.1%) or resorbable (25.6%) or nonresorbable (25.6%), or both (10.3%), were used for dural reconstruction. Fibrin glue was used in all patients regardless of the closure technique used. Table 3 provides details of the interventions for CSF leakage and dural reconstruction.

Incisional CSF leakage was graded as mild (51.3%) for cases with minimal dripping CSF, moderate (33.3%) for cases with significant wetting of the dressing, and severe (15.4%) for cases with excessive pulsatile CSF leakage. The median (interquartile range) interval between the surgery and the start of the leakage was 19 (IQR 1–79) days in patients with no history of radiotherapy; however, this duration was longer in patients who received radiotherapy (median 45 [IQR 10–540] days). Acetazolamide use was noted in 38.5% of the patients.

The surgical interventions for CSF leakage were classified as wound resuturing (combined with other conservative approaches such a tightened dressing and elevating the head end of the bed), LED or EVD placement, or surgical reexploration. The majority (76.9%) of patients received resuturing and other conservative approaches as the first line of management; the mean time to move on to the next step was 10.7 ± 15.4 days. LED and EVD were used in 23.1% and 15.4% of patients, respectively. Postoperative hydrocephalus was observed in 25.6% of patients, of whom 15.4% needed a VPS. The median time for leakage cessation was 18 days. Table 2 presents detailed characteristics of the study population regarding the leak and interventions.

All patients with incisional CSF leakage received prophylactic antibiotics after consulting with the infectious diseases department. However, 9 patients (23.1%) developed meningitis after a mean duration of 35.4 days postoperatively (median 12 days). Thromboembolism formation due to immobilization was noted in 2 patients (5.1%). The median total hospitalization time due to incisional CSF leakage was 26 (IQR 3–135) days.

Folding Technique in Duraplasty

The folding technique is a simple way to achieve watertight duraplasty even with autograft or synthetic material. In this technique, the region where the dural integrity is preserved is exposed all around the durotomy, ensuring that the healthy dural edges are free. Duraplasty is achieved using a 4-0 or 5-0 silk suture with round needles. The detailed technique was previously reported by Bayatlı et al.[3] for nonresorbable synthetic dura, but it can be similarly applied for autografts.

A suturable (nonresorbable) synthetic dura, approximately 20%–30% larger than the area of the dural defect, is cut and placed in the area. The nonresorbable synthetic dura is placed approximately 5–8 mm below the edges of the patient's dura. A free dural suture is placed on four sides of the defect to ensure that the patch is centered. Stop points, where the continuous stitch will be tied, are created by keeping these intermediate stitch threads long, and continuous stitching is started.

In the conventional primary suturing process, the needle is passed through the dura and the patch once, regardless of the side. In our folding technique, the nonresorbable synthetic dura is folded on itself, approximately 3 mm from the edge, and the needle is passed through the normal dura from bottom to top after passing through two layers of the synthetic patch. Thus, the two layers of the synthetic dura are folded under the normal dural tissue (Fig. 1).

Watertightness is tested using the Valsalva maneuver, and the final duraplasty is supported by fibrin glue (Fig. 2).

Discussion

Iatrogenic incisional CSF leakage, a significant complication of neurosurgical procedures, is associated with a significantly high morbidity/mortality burden and treatment costs.[4,5] Rhinorrhea is the most common condition in which a CSF fistula can develop postoperatively and can be regarded as an iatrogenic CSF leak.[1,6,7] However, regions such as the posterior fossa and CPA are more commonly subjected to such leaks, with reported incidences of 17%–26.7% and 14%, respectively.[8,9] The incidence of CSF leakage is six times more common in infratentorial procedures (17%) when compared with supratentorial ones.[4,10] In our study, the majority of the population had supratentorial pathologies, so an even comparison was not possible; however, we noted that patients undergoing radiotherapy seem to harbor a risk of delayed CSF leakage. Therefore, there is a need for multicenter studies with larger and more diverse patient samples for evaluating the real incidence of incisional CSF leakage.

While there is no rigid consensus on the best treatment option, the etiology and severity of the leak guide the surgeon toward the optimal management strategy. Posttraumatic CSF leakage reportedly resolves spontaneously in 85% of patients, and an additional 85% of such patients who start medical treatment tend to recover within a week after injury.[11,12] Selesnick et al.[13] reported very high success rates (up to 71%) for local treatments, including the conservative approach, for incisional CSF leakage after vestibular schwannoma surgery. However, iatrogenic leaks are known to be resistant to conservative strategies. Babuccu et al.[14] reported that contact between CSF and soft tissues caused muscle degeneration, dystrophic calcification, fat necrosis, and coagulation necrosis in animal models. In our study, only 3 patients (7.7%) recovered with the conservative approach (including resuturing), and all others required additional interventions.

Acetazolamide is known to lower CSF pressure by decreasing its production by 40%–90%, and is used in traumatic cases to reduce CSF pressure; however, it might not be effective as the first-line or single-treatment option for iatrogenic CSF leakage.[15–17] In a single-center study involving 32 patients with CSF leaks after a retrosigmoid surgery, 31.3% of patients responded well to acetazolamide as part of conservative treatment and needed no additional intervention.[17] In our department, acetazolamide

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TABLE 2. Detailed characteristics of the study population with incisional CSF leakage, including their cranial pathologies, the primary operation, and follow-up data

Pt No.	Primary Pathology	Cranial Region	Preop Hydrocephalus	Primary Op	RT Hx	Meningitis (postop day)	VPS Necessity	Thromboembolism due to Immobilization	Total Hospitalization, days
1	Glioma	Temporal	No	GTR	Yes	No	Yes	No	135
2	Glioma	Temporal	No	GTR	Yes	Yes (86)	No	Yes	105
3	Glioma	Occipital	Yes	GTR	No	Yes (11)	No	No	19
4	Glioma	Frontotemporal	No	GTR	Yes	No	No	No	21
5	Glioma	Parietal	No	GTR	Yes	No	No	No	14
6	Glioma	Frontal	No	GTR	No	Yes (35)	No	Yes	63
7	Glioma	Frontal	No	GTR	No	No	No	No	9
8	Meningioma	Parietal	No	GTR	Yes	No	No	No	48
9	Meningioma	Frontal	No	GTR	No	No	No	No	12
10	Meningioma	Frontotemporal	No	STR	Yes	No	No	No	42
11	Meningioma	Frontotemporal	No	GTR	No	No	No	No	8
12	Meningioma	CPA	Yes	GTR	Yes	No	Yes	No	42
13	Meningioma	Frontal	No	GTR	No	No	No	No	27
14	Metastatic lesion	Frontal	No	GTR	No	Yes (5)	No	No	15
15	Metastatic lesion	Posterior fossa	Yes	GTR	No	No	No	No	17
16	Metastatic lesion	Frontal	No	GTR	Yes	Yes (8)	No	No	64
17	Metastatic lesion	Posterior fossa	No	GTR	Yes	No	No	No	5
18	Metastatic lesion	Posterior fossa	No	GTR	Yes	Yes (5)	No	No	29
19	Parenchymal hemorrhage	Temporal	No	GTR	No	Yes (12)	No	No	22
20	Parenchymal hemorrhage	Frontal	Yes	Decompressive craniectomy	No	No	Yes	No	7
21	Parenchymal hemorrhage	Parietal	No	Decompressive craniectomy	No	No	No	No	107
22	Dermoid epidermoid cyst	Frontotemporal	Yes	STR	No	No	No	No	25
23	Dermoid epidermoid cyst	CPA	No	GTR	No	Yes (90)	Yes	No	118
24	Arachnoid cyst	Temporal	No	GTR	No	No	No	No	19
25	Arachnoid cyst	Frontotemporal	No	Endoscopic cyst fenestration	No	No	No	No	31
26	Aneurysm	Frontotemporal	No	Aneurysm clipping	No	No	Yes	No	76
27	SDH	Parietal	No	Hematoma evacuation	No	No	No	No	22
28	SAH	Frontotemporal	No	Aneurysm clipping	No	No	No	No	7
29	Colloid cyst	Ventricular	Yes	GTR	No	No	No	No	13
30	Schwannoma	Temporal	No	GTR	No	No	No	No	18
31	Craniopharyngioma	Frontotemporal	No	GTR	Yes	No	No	No	53
32	Chordoma	Posterior fossa	No	GTR	No	Yes (12)	No	No	41
33	Choroid plexus papilloma	Occipital	Yes	GTR	No	No	Yes	No	4
34	Hemangiopericytoma	Frontal	No	GTR	No	No	No	No	40
35	Epilepsy	Frontotemporal	No	GTR	No	No	No	No	33
36	Chiari malformation	Posterior fossa	No	Decompressive craniectomy	Yes	No	No	No	3

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TABLE 2. Detailed characteristics of the study population with incisional CSF leakage, including their cranial pathologies, the primary operation, and follow-up data

Pt No.	Primary Pathology	Cranial Region	Preop Hydrocephalus	Primary Op	RT Hx	Meningitis (postop day)	VPS Necessity	Thromboembolism due to Immobilization	Total Hospitalization, days
37	Posterior fossa ependymoma	Posterior fossa	No	GTR	No	No	No	No	45
38	Hydrocephalus	Parietal	Yes	VPS	No	No	Yes	No	26
39	Posterior fossa AVM	Posterior fossa	No	GTR	No	No	No	No	32

GTR = gross-total resection; Hx = history; RT = radiotherapy; STR = subtotal resection.

is not used routinely due to the associated risk of electrolyte imbalance and is rather prescribed as an adjunct in the case of failed conservative treatment or when the CSF pressure is significantly high.

CSF diversion is considered the next step when conservative ways fail; however, there is a lack of consensus about the optimum technique and means of CSF drainage.[7,13,18] LED is the most commonly used approach, with an associated 3%–5% complication risk,[6,7] which includes infections, meningitis, radiculopathy, and deep vein thrombosis secondary to immobility. Some authors recommend performing LED earlier in cases such as CPA lesions to facilitate healing.[18] Selesnick et al.[13] suggested 2–5 days for LED to be effective for CSF diversion and that other techniques of treatment be tried in case of failure. Bayazit et al.[17] described treatment failure as the absence of a response to conservative treatment after 3 days or drainage of > 30 cm^3 of CSF per day after 3 days. EVD is another technique preferred in patients with impaired consciousness and additional brain injury.[7] A VPS is used in cases of postoperative intractable hydrocephalus. All these techniques are reported to enhance the management of CSF leakage, and many surgeons prefer to use these approaches routinely in addition to standard repair or even simultaneously with conservative procedures.[11]

The timing for surgical exploration in patients with iatrogenic CSF leakage is another important aspect. Generally, failure of 3–7 days of medical treatment after trauma is considered an indication for surgical exploration.[2,19] Additionally, surgical exploration is indicated when LED fails to control the CSF leak (> 300 ml of CSF drainage/day for 7 days).[17] In clinical practice, we believe that many factors influence the choice of management modality in these patients. For example, patients who are supposed to undergo radiotherapy for malignant pathologies do not have additional time to deal with wound complications; thus, CSF leakage must be stopped as soon as possible. Accordingly, we prefer surgical reexploration in some patients as soon as a leak is detected and do not wait for conservative management.

A previous study reported a 19% incidence of meningitis in traumatic CSF leaks 2 weeks after the trauma.[20] In contrast, there is no clear reporting on the incidence of meningitis after iatrogenic CSF leaks for which prophylactic antibiotics have been used.[4,21] In the present study, all patients were administered third-generation cephalosporins as a part of the postsurgical medications.

Our prevention strategy is mainly based on maintaining a "watertight dura" in the first primary surgery as much as possible. This can be achieved by avoiding unwanted dural lacerations during craniotomy/craniectomy. We should emphasize the importance of preventing CSF leakage during the primary surgery by making the maximal effort to regain the watertight nature of the dura mater; meticulous primary dural closure or using autograft and/or synthetic materials when needed is essential. Previous reports have suggested many different techniques for this, which include plugging the dural closure with fat or muscle, using synthetic materials for dural augmentation, or performing epidural augmentation with sealants.[22–24] At our hospital, we prefer using mannitol-like antiedema agents during

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TABLE 3. Details of the interventions performed for the CSF leaks and dural reconstruction

Pt No.	Intraop Dural Laceration	Primary Duraplasty Technique	Adjunct Duraplasty Material	Incisional CSF Leak, Postop day	Incisional CSF Leak Severity	Intervention (postop days)			Acetazolamide	Time to CSF Leak Cessation, days
						1st	2nd	3rd		
1	No	Primary suturing	Fibrin glue	21	Mild	Resuturing (21)	Reexploration (89)	Reexploration (166)	Yes	180
2	No	Primary suturing	Fibrin glue	85	Mild	Resuturing (85)	Reexploration (86)	Reexploration (112)	Yes	112
3	No	Primary suturing	Fibrin glue	1	Severe	Resuturing (1)	EVD (15)	NA	Yes	15
4	No	Primary suturing	Fibrin glue	28	Mild	Resuturing (28)	NA	NA	No	29
5	No	Primary suturing	RSD, fibrin glue	60	Moderate	Resuturing (60)	Reexploration (61)	NA	No	28
6	No	Primary suturing	Fibrin glue	21	Mild	Resuturing (21)	LED (25)	NA	No	28
7	No	Primary suturing	Fibrin glue	21	Mild	Resuturing (21)	NA	NA	No	150
8	Yes	Synthetic duraplasty	NRSD, fibrin glue	119	Mild	Reexploration (135)	Free flap reconstruction (168)	NA	No	33
9	Yes	Synthetic duraplasty	NRSD, fibrin glue	79	Mild	Resuturing (79)	Reexploration (118)	NA	Yes	118
10	Yes	Primary suturing	RSD, fibrin glue	21	Mild	Resuturing (21)	Resuturing (41)	Reexploration (59)	Yes	38
11	Yes	Primary suturing	Fascia, fibrin glue	2	Severe	Reexploration (2)	NA	NA	No	2
12	No	Synthetic duraplasty	NRSD, fibrin glue	41	Moderate	Resuturing (41)	NA	NA	No	44
13	Yes	Synthetic duraplasty	NRSD, fibrin glue	6	Moderate	Resuturing (6)	Reexploration, LED (17)	NA	No	18
14	No	Primary suturing	RSD, fibrin glue	1	Moderate	Reexploration, LED (3)	NA	NA	Yes	5
15	No	Synthetic duraplasty	NRSD, fibrin glue	11	Moderate	Resuturing (11)	EVD (14)	NA	No	16
16	No	Primary suturing	RSD, fascia, fibrin glue	49	Mild	Resuturing (50)	Reexploration, EVD (52)	NA	No	NA
17	No	Primary suturing	RSD, fibrin glue	30	Mild	Resuturing (31)	Reexploration (32)	NA	No	NA
18	No	Synthetic duraplasty	NRSD, RSD, fibrin glue	10	Mild	Resuturing (10)	Reexploration, EVD (12)	NA	Yes	NA
19	No	Primary suturing	Fibrin glue	12	Mild	Resuturing (13)	Reexploration (18)	NA	No	18
20	Yes	Synthetic duraplasty	NRSD, RSD, fibrin glue	22	Severe	Reexploration (23)	NA	NA	No	5
21	Yes	Synthetic duraplasty	NRSD, fibrin glue	25	Mild	Resuturing (25)	Reexploration, LED (26)	NA	No	NA
22	No	Primary suturing	RSD, fibrin glue	19	Moderate	Resuturing (19)	NA	NA	No	21
23	No	Synthetic duraplasty	NRSD, fibrin glue	37	Moderate	Resuturing (37)	Reexploration (49)	EVD (53)	Yes	59
24	No	Primary suturing	Fibrin glue	21	Mild	Resuturing (21)	Reexploration (28)	NA	Yes	7
25	No	NA	NA	14	Mild	Resuturing (14)	NA	NA	No	17
26	No	Primary suturing	Fibrin glue	9	Severe	Resuturing (13)	Reexploration (18)	NA	Yes	49
27	No	Primary suturing	RSD, fibrin glue	16	Mild	Resuturing (16)	Reexploration (19)	NA	No	3
28	No	Primary suturing	Fibrin glue	2	Severe	Reexploration (3)	NA	NA	No	1
29	Yes	Synthetic duraplasty	NRSD, RSD, fibrin glue	21	Moderate	Resuturing (21)	Reexploration, LED (25)	NA	No	3
30	No	Synthetic duraplasty	NRSD, fibrin glue	28	Mild	Resuturing (29)	Reexploration, LED (31)	NA	No	5
31	No	Primary suturing	RSD, fibrin glue	65	Mild	Resuturing (65)	Reexploration (68)	NA	No	18
32	Yes	Autograft duraplasty	Fascia, fibrin glue	23	Mild	Reexploration (24)	NA	NA	Yes	75

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TABLE 3. Details of the interventions performed for the CSF leaks and dural reconstruction

Pt No.	Intraop Dural Laceration	Primary Duraplasty Technique	Adjunct Duraplasty Material	Incisional CSF Leak, Postop day	Incisional CSF Leak Severity	Intervention (postop days)				Time to CSF Leak Cessation, days
						1st	2nd	3rd	Acetazolamide	
33	No	Primary suturing	RSD, fibrin glue	69	Severe	Reexploration (70)	LED (72)	NA	Yes	2
34	No	Synthetic duraplasty	NRSD, RSD, fibrin glue	10	Moderate	Reexploration (12)	LED (15)	NA	No	25
35	No	Primary suturing	Fibrin glue	21	Moderate	Resuturing (21)	Reexploration (28)	NA	No	7
36	No	Synthetic duraplasty	NRSD, fibrin glue	540	Mild	Resuturing (540)	Reexploration (541)	NA	Yes	3
37	No	Primary suturing	RSD, fibrin glue	14	Moderate	Reexploration, EVD (17)	EVD change (27)	NA	Yes	1
38	No	NA	NA	34	Moderate	Resuturing (35)	Reexploration (77)	NA	Yes	77
39	No	Synthetic duraplasty	NRSD, fibrin glue	5	Moderate	Resuturing (5)	LED (8)	NA	No	10

NA = not applicable; NRSD = non-RSD; RSD = resorbable synthetic dura.

FIG. 1. Illustration representing the folding technique in duraplasty. **A:** The final appearance of the dural layer during suturing. **B:** The steps of the needle as it passes through the synthetic nonresorbable dura or the autograft and passes once again to create a folded layer; finally, it passes through the primary dura to create a three-layer duraplasty. **C and D:** The reconstruction acts as an extra barrier that prevents leakage (*arrows* in D) from the needle holes and maintains the integrity of the three-layer dura. *Light blue* represents the dura and *light yellow* represents the nonresorbable dura/autograft. © Gökhan Canaz, published with permission.

initial anesthesia to relax the brain and prevent persistent dural adherence to the calvaria, especially in patients with severe cerebral edema. Opening the burr holes as much as possible, particularly in elderly patients and in lesions with accompanying severe edema, could assist in dissecting the epidural space and prevent dural tears during craniotomy. Also, for posterior fossa or CPA lesions, we prefer per-

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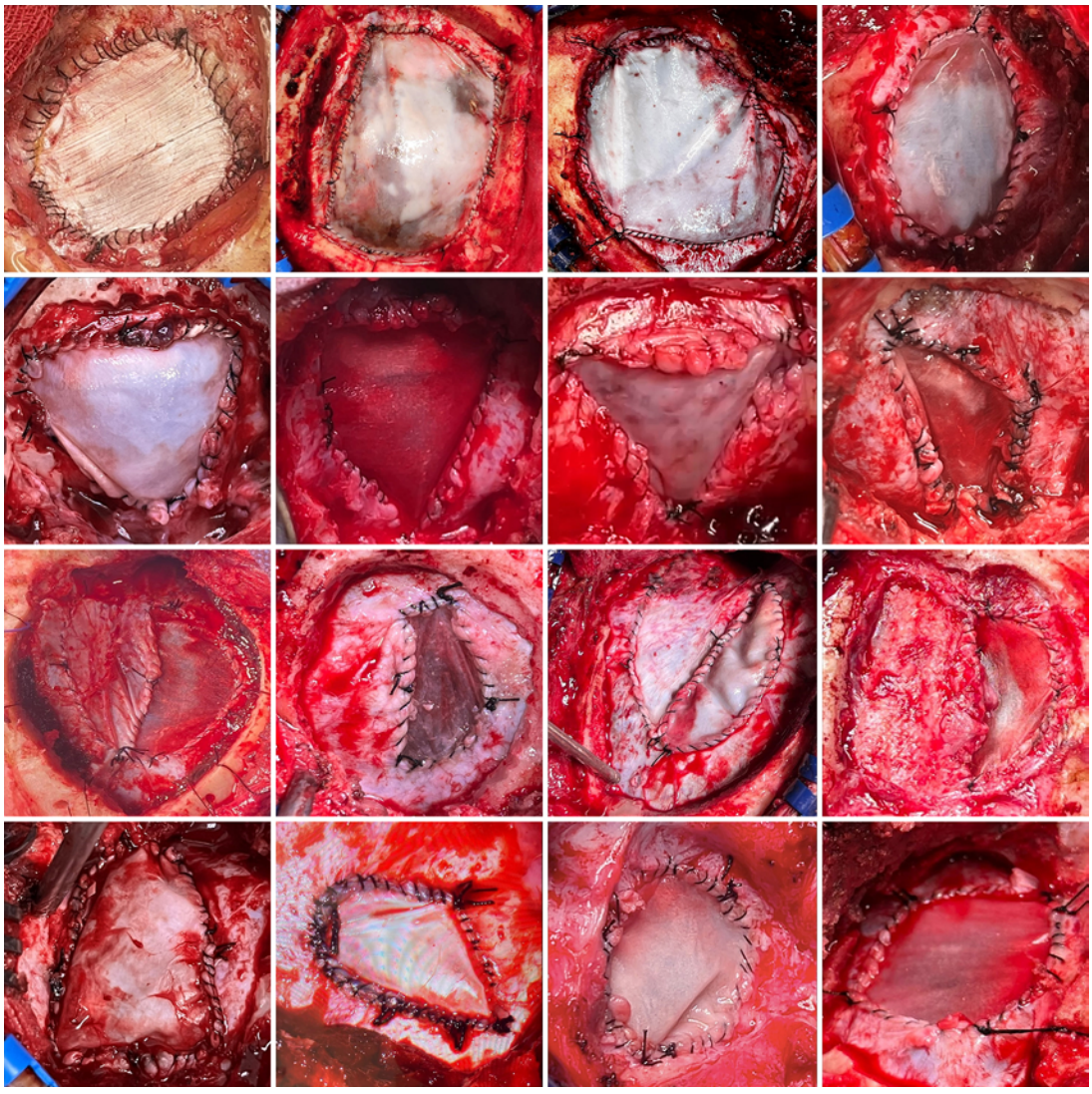


FIG. 2. Demonstration of the different stages of duraplasty in different patients performed during primary surgery with autografts or synthetic nonresorbable dura using the folding technique.

forming craniotomy instead of craniectomy, especially for benign lesions where the bone flap serves as a barrier to support the sutured dura and prevent CSF leakage.

Our innovative folding technique seems to help surgeons achieve watertight duraplasty. This technique was not used in the majority of the retrospectively reviewed and reported patients since it is a relatively newly defined technique. However, we now use the technique in almost all patients who need duraplasty during the primary surgery. A previous study compared this technique (n = 43, 55.8%) with the traditional technique (n = 34, 44.2%) of duraplasty.[3] The results represented significantly shorter hospitalization times with no CSF leakage in the group in which the folding technique was used ($p = 0.001$).[3] Also, craniotomy was found to dominate craniectomy in patients in whom the traditional technique was used ($p = 0.006$). In other words, although the craniectomy rate was higher in the folding technique group, no CSF leakage supports the success of the technique. Furthermore, the folding technique was found to be comparable to or even better than traditional primary stitching to achieve watertight duraplasty. We believe that fascia or periosteum as autografts are the best materials for duraplasty; other synthetic materials could be used when necessary. Whatever the materials, the folding technique can be used during duraplasty to overcome the possibility of CSF leaking through pinholes of dural sutures created by needles.[25] In our clinical experience, this technique is also useful in complex cases like recurrent Chiari malformations and spinal cases in which CSF leakage is a major concern.

This study has certain limitations. A retrospective review of the patient data from a single center can lead to data inaccuracies due to selection bias for the definition and treatment of leak, observer bias, missing data, and variations in patient follow-up. Moreover, the records can miss patients who were managed conservatively without additional surgical intervention. Also, other variables such as malnutrition that may influence wound healing were not

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studied. Any conclusion regarding the efficacy of treatments for incisional CSF leaks seems to need wide multicenter, randomized controlled and even prospective studies.

Conclusions

Incisional CSF leakage is a potentially preventable complication with high morbidity. To our knowledge, this is the first paper that has focused on cranial incisional CSF leaks generally excluding endoscopic transnasal approaches. Such cases could be managed via conservative approaches including wound resuturing, LED or VED, and surgical reexploration. However, the management strategy is beyond any strict algorithm. Our reported folding technique for duraplasty is a worthy replacement for conventional primary suturing for dural repair or reconstruction in cranial and even spinal defects. This study highlights the importance of regaining the watertight nature of the dura in the primary surgery to prevent any further intervention and lower the overall morbidity.

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Disclosures

The authors report no conflict of interest concerning the materials or methods used in this study or the findings specified in this paper.

Author Contributions

Conception and design: Ozgural, Bayatli, Kahilogullari, Caglar, Dogan. Acquisition of data: Ozgural, Bayatli, Erdin, Karadagoglu, Kahilogullari, Caglar, Dogan. Analysis and interpretation of data: Bayatli, Karadagoglu, Caglar. Drafting the article: Ozgural, Bayatli, Kahilogullari, Dogan. Critically revising the article: Bayatli, Kahilogullari, Tuna, Attar, Unlu, Caglar, Dogan. Reviewed submitted version of manuscript: Ozgural, Bayatli, Kahilogullari, Ugur, Tuna, Attar, Caglar, Dogan. Approved the final version of the manuscript on behalf of all authors: Ozgural. Statistical analysis: Bayatli, Caglar. Administrative/technical/material support: Ozgural, Bayatli, Karadagoglu, Ugur, Attar, Caglar. Study supervision: Ozgural, Bayatli, Ugur, Tuna, Attar, Caglar, Dogan.

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