



## Original Article

## Treatment of traumatic cerebrospinal fluid rhinorrhea via extended extradural anterior skull base approach

Feng Zhang<sup>a,1</sup>, Tao Zeng<sup>b,1</sup>, Liang Gao<sup>b,\*</sup>, Da-Ming Cui<sup>b</sup>, Ke Wang<sup>b</sup>, Zi-Jun Xu<sup>c</sup>, Xiang-Yuan Cao<sup>b</sup><sup>a</sup> The Second Hospital of Zhang Jiagang, Suzhou, 215600, Jiangsu Province, China<sup>b</sup> Department of Neurosurgery, Shanghai Tenth People's Hospital, Tongji University School of Medicine, Shanghai, 200072, China<sup>c</sup> Department of Radiology, Shanghai Tenth People's Hospital, Tongji University School of Medicine, Shanghai, 200072, China

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## ABSTRACT

**Objective:** To describe and assess the repair technique and perioperative management for cerebrospinal fluid (CSF) leak resulting from extensive anterior skull base fracture via extradural anterior skull base approach.

**Methods:** This was a retrospective review conducted at the Department of Neurosurgery of the Shanghai Tenth People's Hospital from January 2015 to April 2020. Patients with traumatic CSF rhinorrhea resulting from extensive anterior skull base fracture treated surgically via extended extradural anterior skull base approach were included in this study. The data of medical and radiological records, surgical approaches, repair techniques, peritoperative management, surgical outcome and postoperative follow-up were analyzed. Surgical repair techniques were tailored to the condition of associated injuries of the scalp, bony and dura injuries and associated intracranial lesions. Patients were followed up for the outcome of CSF leak and surgical complications. Data were presented as frequency and percent.

**Results:** Thirty-five patients were included in this series. The patients' mean age was 33 years (range 11–71 years). Eight patients were treated surgically within 2 weeks; while the other 27 patients, with prolonged or recurrent CSF rhinorrhea, received the repair surgery at 17 days to 10 years after the initial trauma. The mean overall length of follow-up was 23 months (range 3–65 months). All the patients suffered from frontobasal multiple fractures. The basic repair tenet was to achieve watertight seal of the dura. The frontal pericranial flap alone was used in 20 patients, combined with temporalis muscle and/or its fascia in 10 patients. Free fascia lata graft was used instead in the rest 5 patients. No CSF leak was found in all the patients at discharge. There was no surgical mortality in this series. Bilateral anosmia was the most common complication. At follow-up, no recurrent CSF leak or meningitis occurred. No patients developed mucocoeles, epidural abscess or osteomyelitis. One patient ultimately required ventriculoperitoneal shunt because of progressive hydrocephalus.

**Conclusion:** Traumatic CSF rhinorrhea associated with extensive anterior skull base fractures often requires aggressive treatment via extended intracranial extradural approach. Vascularized tissue flaps are ideal grafts for cranial base reconstruction, either alone or in combination with temporalis muscle and its fascia—fascia lata sometimes can be opted as free autologous graft. The approach is usually reserved for patients with traumatic CSF rhinorrhea in complex frontobasal injuries.

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## Introduction

The estimated incidence of basilar skull fracture from non-penetrating cranial trauma varies between 7% and 15% of all skull fractures. Because of the firm adherence of the dura to the skull

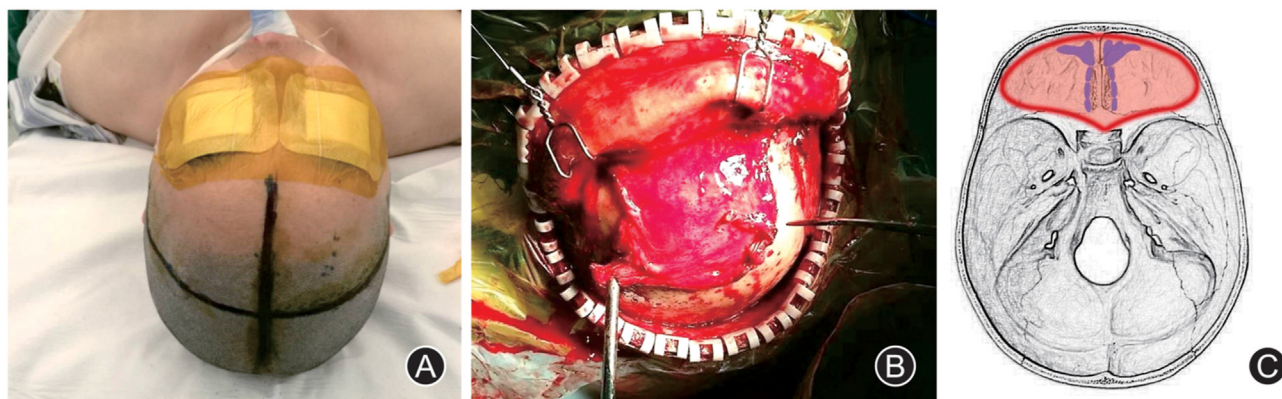
base, dura tears and subsequent cerebrospinal fluid (CSF) leak are common with the incidence identified as 10%–30% in cranial base fractures. The incidence in anterior skull base fractures is about 5–6 times more frequent than that in middle or posterior cranial fossa fractures.<sup>1,2</sup> Besides clear nasal discharge, patients with CSF

\* Corresponding author.

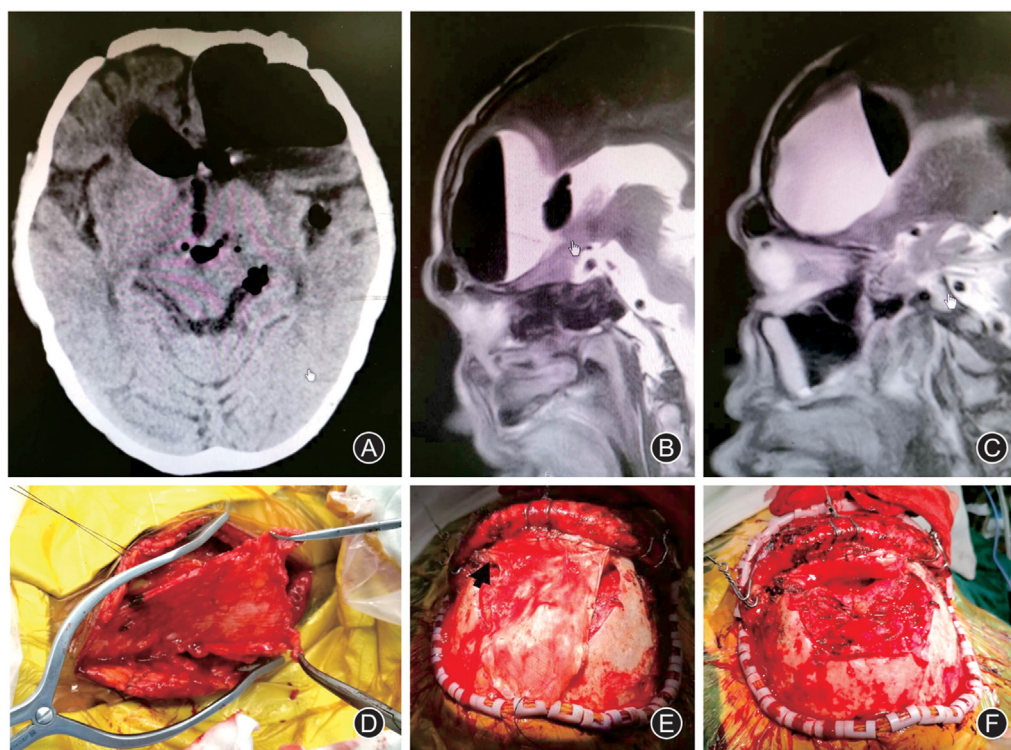
E-mail address: [lianggaoh@126.com](mailto:lianggaoh@126.com) (L. Gao).

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<sup>1</sup> Authors contribute equally to the paper.



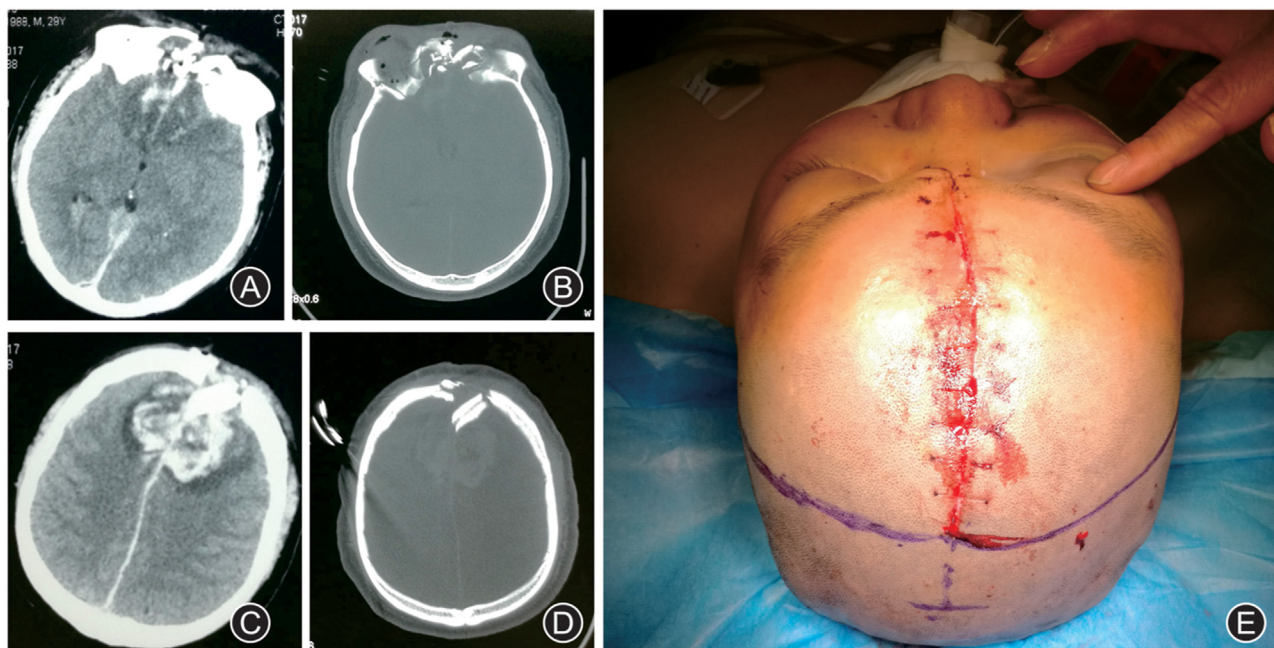
**Fig. 1.** Incision, preparation of pericranial membrane and range of exploration of the anterior skull base in a typical extradural anterior skull base approach. (A) A typical extended bifrontal coronal incision arises from the zygomatic level to the contralateral zygomatic level. (B) Extended subgaleal dissection of the pericranial membrane to the rim of the orbital edge was employed to harvest a large anteriorly based vascularized graft. (C) The area circumscribed by the red line illustrates the range of exploration for dura and skull base injuries.



**Fig. 2.** A 69-year-old male who had a history of previous surgery through a bifrontal craniotomy 6 years ago. The patients suffered from intermittent low-flow nasal discharge and repeated meningitis from 4 months before admission. (A) Head CT scan at admission showed signs of porencephaly accompanied by severe pneumocephalus in bilateral frontal horn of ventricle. (B, C) Heavily T<sub>2</sub>-weighted images and a fast spin-echo sequence with fat saturation were utilized in both supine and head-flexing position but failed to localize the fistula. During surgical exploration, multiple fractures in the bilateral anterior skull base with dura tear were detected. There was no pericranial membrane available. (D) A free autologous fascia lata graft was procured from the additional incision on the lateral side of thigh as repair graft. (E) A rotated lateral pedicled temporalis muscle graft (black arrow) was used as muscular plug for the repairment of skull base defect; the fascia lata was sutured to the pericranial membrane at the rim of orbital edge. (F) The fascia lata graft was laid extradurally along the floor of the frontal fossa, covering the entire anterior skull base and was held in place with fibrin glue, and then was folded over the subfrontal dura, which means dual or multilayer techniques.

rhinorrhea can present with other manifestations, including pneumocephalus and complications of intracranial infection such as meningitis or brain abscess.<sup>3–5</sup> For patient with CSF fistula unable to be cured by nonsurgical management, or those with recurrent CSF leakage after initial spontaneous cessation, surgical repair is usually mandatory because of a high risk of potentially fatal intracranial infection secondary to CSF rhinorrhea. The most important goals of surgical repair are to achieve leakproof dura seal and reconstruction of bony and soft tissue defects.

Many types of surgical repair techniques are utilized which provide multiple choices for surgeons across diverse clinical scenarios. However, to choose the most proper surgical approach when confronted with a patient with CSF rhinorrhea resulting from extensive frontobasal injuries, which means to achieve a reliable closure with minimal invasion, sometimes remains challenging for neurosurgeons. Although transnasal endoscopic techniques in anterior skull base trauma have grown, transcranial open surgery approach, especially extradural approach allowing exposure of the entire anterior cranial bone, are still needed in some challenging



**Fig. 3.** A case of traumatic cerebrospinal fluid rhinorrhea treated surgically in acute phase via extended extradural anterior skull base approach. (A–D) High-resolution CT scan images obtained in an acute injured 24 years-old female patient who presented with coma and cerebrospinal fluid rhinorrhea after a motorcycle-truck rear-end collision accident, revealing a complex frontobasal multiple comminuted fractures involved the cribriform-ethmoid and frontal sinus, concomitant with bilateral cerebral laceration and intraparenchymal hematoma. The patient underwent emergent surgical intervention 2 days after trauma for evacuation of the hematoma, reduction of nasofrontal fractures, and dura repair extradurally with autologous pericranium graft in combination with temporalis muscle and its fascia. No CSF leak was noted at the 6-month follow-up. (E) An extended bifrontal coronal incision was designed according to the concomitant frontal scalp laceration.

situation.<sup>6,7</sup> In this paper, a retrospective review was conducted at patients who underwent reconstruction of the anterior skull base for CSF rhinorrhea via extended extradural anterior skull base approach, to investigate the treatment effects.

## Methods

### Inclusion and exclusion criteria

Our study was in accordance with the ethical standards formulated in the Helsinki Declaration. Patients with traumatic CSF rhinorrhea treated surgically via extended extradural anterior skull base approach at the Department of Neurosurgery, Shanghai Tenth People's Hospital, Tongji University School of Medicine between January 2015 and April 2020 were the object of this study. Those with CSF rhinorrhea not resulting from extended anterior skull base injuries were excluded. Clinical and radiological records of the included patients, generally clinical status and findings on admission, initial imaging data including assembled fracture location, fracture characteristics and associated intracranial lesions, surgical techniques, and treatment outcomes were retrospectively reviewed.

### Image diagnostic procedures

All the included patients underwent high-resolution and thin-slice (1 mm) CT scan upon admission. Postprocessing with coronal and sagittal reconstructions was utilized to identify the skull base fracture or defects. MR exam was performed in patients who were tolerable for the procedure. Besides enhancement MR image to rule out possibility of cerebral abscess, heavily T<sub>2</sub>-weighted images and a fast spin-echo sequence with fat saturation were utilized to localize the fistula. The “reservoir sign,” which was the ability of a patient to leak CSF by flexing the head, was taken to add

the opportunity for detecting an occult fistula. Pretherapeutic CT scan allowed topographical diagnosis by visualization of the anterior cranial bone fracture. Criteria for MRI diagnosis of a CSF fistula included (1) continuous T<sub>2</sub> high signal from the subarachnoid space to the paranasal sinuses or (2) brain herniation into the paranasal sinuses.

### Indications for extradural anterior skull base approach

Extradural anterior skull base approach is commonly reserved for CSF rhinorrhea resulting from complex frontobasal injuries or refractory rhinorrhea. The existence of multiple comminuting bony fractures or defects at the anterior skull base, uncertain fistular localization, evidence of multiple fistulae, concomitant cerebrocranial injuries, and failure of previous surgical attempt are major concerns incorporating into the considerations of extradural approach.

### Standard surgical procedures

Typically, a bifrontal coronal incision from the zygomatic level to the contralateral counterpart allows harvest of sufficient pericranium. Following an extended bifrontal coronal incision and subgaleal dissection, the pericranial flap can be designed and a standard pedicled pericranial flap may be developed (Fig. 1A and B). If the patients had a history of prior operation, or the traumatic injury damaged the pericranium in this area, in which the pericranial flap was unavailable or insufficient, a vascular-pedicled flap, usually from the temporalis muscle with or without the overlying fascia was mostly opted for the repair. If there was no sufficient pedicled graft, a free autologous fascia lata graft could be harvested from the lateral side of the thigh.

After the tissue flaps had been dissected, a bifrontal craniotomy similar to the modified Derome's approach was performed. But

**Table 1**  
General demographic and preoperative data of the 35 patients with traumatic CSF rhinorrhea, n (%).

Parameters	Acute group (n = 8)	Non-acute group (n = 27)
<b>Symptoms</b>		
Cerebrospinal fluid rhinorrhea	8 (22.9)	27 (77.1)
Meningitis	2 (5.7)	9 (25.7)
<b>Flow of leakage</b>		
High-flow or persistent	7 (20.0)	6 (17.1)
Low flow or intermittent	1 (2.9)	21 (60.0)
<b>Preoperative GCS score</b>		
9–15	4 (11.4)	20 (57.1)
6–8	3 (8.6)	6 (17.1)
3–5	1 (2.9)	1 (2.9)
Duration from trauma to this surgery	0–13 days	17 days to 10 years
<b>Preoperative CSF drainage</b>		
Lumbar drainage	4 (11.4)	3 (8.6)
EVD/ICP monitor	3 (8.6)	/
Previous craniotomy for TBI	1 (2.9)	14 (40.0)
Prior surgical attempt to repair	/	6 (17.1)

GCS: Glasgow coma scale; CSF: cerebrospinal fluid; EVD: external ventricular drainage; ICP: intracranial pressure; TBI: traumatic brain injury.

**Table 2**  
Information of the preoperative diagnostic procedures of the 35 patients with cerebrospinal fluid, n (%).

Parameters	Acute group (n = 8)	Non-acute group (n = 27)
<b>Preoperative CT finding</b>		
Pneumocephalus	6 (17.1)	14 (40.0)
Comminute cranial base fracture	8 (22.9)	26 (71.4)
Other craniofacial fracture	7 (20.0)	22 (62.9)
<b>Preoperative MR findings</b>		
Localization of the fistula	1 (2.9)	14 (40.0)
Herniation of cerebral tissue	1 (2.9)	8 (22.9)
<b>Concomitant nerve or intracranial injuries</b>		
Injuries of optic nerve	4 (11.4)	1 (2.9)
Brain contusion and laceration	7 (20.0)	10 (28.6)
Intracranial hematoma	6 (17.1)	6 (17.1)

frontal-orbital osteotomies were usually unnecessary. The inferior border of bone window should be made as close as possible to the rim of the orbital to improve the working angles. With the assistance of the operative microscope, the dura of the anterior cranial base was dissected free from the underlying bone. Via a bilateral extradural subfrontal approach, the entire anterior cranial base (anteriorly to the posterior wall of the frontal sinus, laterally to the sphenoid wing, and medially and posteriorly to the sphenoidal planum (Fig. 1C) was inspected to visualize possible dura tears and do necessary repair, either directly by suturing whenever possible or indirectly by packing the pericranium or other graft with the aid of fibrin glue.

As for bony defects found in the process of dissecting, pedicled temporalis muscle flap or overlying temporalis fascia and sometimes fat or fascia lata were utilized to reconstruct the cranial base. A pedicled flap of pericranial tissue is spread to cover the entire anterior cranial base and then folded over to cover the repaired subfrontal dura (Fig. 2). Following graft pavement, fibrin glue was used to reinforce the graft in place. The anterior skull base and dura were reconstituted extradurally, while intradural maneuvers were not mandatory. We usually open the dura when there is concurrent intradural lesion needing evacuation or release of the CSF to relax brain tissue and facilitate retraction, or to test watertight suture of the repaired dura.

**Table 3**  
Types of flaps as dura graft in intraoperative repair and subdural maneuvers.

Dura repair and subdural maneuvers	Frequency
<b>Types of flaps in dura repair</b>	
Pedicled pericranial flap only	21
Pedicled pericranial flap + temporalis facial or muscle	9
Pedicled Pericranial flap + temporalis facial or muscle + free fascia lata	3
Free fascial lata + temporalis fascia and muscle	2
<b>Intraoperative dura opening</b>	
Evacuation of subdural lesions	7
Release subarachnoid CSF for brain relaxation	7
Test watertight dura repair	21

CSF: cerebrospinal fluid.

**Table 4**  
Postoperative management, complications and outcome of the 35 patients with cerebrospinal fluid, n (%).

	Number
Postoperative lumbar CSF drainage	5
For intracranial infection	3
For trace nasal discharge	1
For reinforcement of dura repair	1
Postoperative intracranial infection	
Clinical definite evacuation of subdural lesions	1
Clinical suspected	3
Wound dehiscence	2
Bilateral anosmia	23
Death	0

CSF: cerebrospinal fluid..

In patients with acute cerebrocranial injuries, the design of incision, bone window and intradural maneuvers should be modified according to the concomitant scalp and cerebrocranial injuries, as shown in Fig. 3.

*Postoperative management*

Postoperatively the patients were admitted to the neuro-intensive care unit to monitor for possible complications. The patients were kept in a supine position for about 1 week. Care was taken not to disrupt the graft by avoiding strenuous activity or straining or nose blowing for approximately 6 weeks following the repair surgery. As dissection occurs through a contaminated operative field, we chose to use postoperative prophylactic intravenous antibiotics. For patients with preoperative definite meningitis, the duration of postoperative antibiotics administration was prolonged. Postoperative lumbar CSF draining catheter was not routinely indwelled. CSF drainage was utilized for those with definite intracranial infection or those intraoperative watertight dura seal not reliably achieved. CSF was sampled repeatedly for laboratory test either from lumbar draining or serial lumbar puncture to monitor the occurrence of postoperative meningitis.

*Follow-up*

The patients were followed up through outpatient or telephone interview with patients themselves or their families. The contents of the follow-up included nasal discharge, manifestation of meningitis, healing of wound or incision and condition of anosmia. Enhanced MRI scan was performed at 6 and 12 months after discharge. The overall prognosis assessment was evaluated by Glasgow outcome score.

## Results

The study population was composed of 27 men and 8 women, with a mean age of  $(39.05 \pm 15.76)$  years. Eight patients who were treated surgically within 2 weeks (ranging from 0–14 days) were categorized into acute group, whereas the remaining 27 patients, with prolonged or recurrent CSF rhinorrhea after nonsurgical treatment or recurrent CSF leaks requiring subsequent conclusive reoperation and repair, were categorized into non-acute group. The patients' presentation as well as demographic and clinical characteristics is summarized in [Table 1](#).

### Image diagnosis

By thin-cut cranial base CT scan, extensive multiple fracture was confirmed in 32 patients, 4 of whom had optic nerve canal fractures. CSF fistula were confirmed in 15 of 30 patients underwent MRI scan, and cerebral herniation was found in 9 of these 30 patients. CT cisternography were performed in 1 patient, without detection of a fistulous tract. Preoperative topographical diagnosis was made in 62.9% patients (22/35). The information of image diagnostic, including CT and MRI is summarized in [Table 2](#).

### Surgical outcome

According to the classification by Madhusudan et al.,<sup>8</sup> the traumatic frontobasal fractures were classified as frontal, basal, and combined. Areas were separated as central (designated as type I) and lateral (designated as type II). Combined fractures involving both central and lateral areas were designated as type III. During exploration of anterior skull base, multiple frontobasal fractures were found in all the 35 patients: 8 classified as type I, 4 as type II, and 23 as type III. Multiple dura laceration was detected in 32 patients. Herniation of cerebral tissue was confirmed in 8 patients. In acute injury group, open surgery was required for associated lesions in 8 patients: 3 for evacuation of intracranial hematoma, 1 for cerebral contusion and laceration, and 4 for decompression of injured optic nerve. Dura laceration was repaired mainly extradurally. In this series, pedicled pericranial flap, adjacent temporalis muscle and its fascia, and free fascia lata were used alone or in combination as graft for dura repair. The details of types of flaps in intraoperative repair and subdural maneuvers are summarized in [Table 3](#).

There was no postoperative incidence of mortality. The major postoperative management, surgical outcome and complications are summarized in [Table 4](#).

### Follow-up

At discharge, CSF rhinorrhea was cured in all the 35 patients. The mean follow-up time was 19 months (range 3–65 months). At follow-up, no recurrent CSF leak or meningitis occurred. No patients developed mucoceles, epidural abscess or osteomyelitis. One patient ultimately required ventriculoperitoneal shunt because of progressive hydrocephalus. The mean Glasgow outcome score at 3 months after discharge was 4.3 (range 1–5). Most of these patients ( $n = 21$ ) had a score of 5, followed by score of 4 ( $n = 5$ ). For the other patients, one achieved a Glasgow outcome score of 1, one had a score of 2 and two had a score of 4.

## Discussion

Management of CSF leak associated with extensive frontobasal injuries is sometimes intricate. The anterior endocranial fossa, formed by the frontal, ethmoid and sphenoid bones, covers the

upper nasal cavity medially and the orbit and the optic canal laterally.<sup>9</sup> In severe injuries, traumatic force may transmit through the frontal, ethmoid, and sphenoid sinuses lying below the anterior endocranial fossa and lead to complex compound injuries including bony fractures and associated paranasal, dura and brain injuries, thus posing unique management challenges.<sup>10</sup>

There are several types of surgical approaches for repair. Regardless of the types of surgical approaches, the basic tenet is to reconstruct the anatomy of the cranial base to prevent CSF leak, meningitis and mucocele formation while optimizing cosmetic outcomes.<sup>10</sup> Thus, a watertight seal of dura repair is the key in reconstruction of anterior cranial base injuries. Although the endoscopic transnasal approach has become a very important part of the armamentarium for repair of CSF rhinorrhea, it is limited to specific indications, such as precisely located small tears without associated brain injuries requiring surgical intervention.<sup>11–13</sup> There are many particularly challenging scenarios to which craniotomy was indicated such as the presence of a large bone defect associated with brain herniation, open cranial trauma, association with intracranial hematomas or cranial nerve injuries necessitating surgical management. In addition, failure of prior surgical repair attempts, either by endoscopic or transcranial approach, can also be an indication for intracranial exploration and repair as a salvage treatment. In some patients, the occurrence of rhinorrhea and pneumocephalus or meningitis has been described as the first presentation years after the anterior cranial base injury, and moreover precise localization of the leak can present major challenges due to the intermittent slow or occult leak. The absence of preoperative topographical diagnosis is correlated with failed surgical repair.<sup>6</sup> Due to the complex nature of such circumstances, an intracranial approach, especially extradural approach, is warranted to allow for adequate exploration and repair.

In our series, we favored the intracranial extradural approach because it can provide wide exposure of the dura defect and visualization of the adjacent tissue damage, enabling the surgeons to perform all necessary extradural and intradural dissections to precisely identify the dura injuries and subsequently do proper repair work. The sphenoid sinus can be accessed through the extended craniotomy and skull base dissection. Bilateral craniotomy was preferred even if radiological studies show unilateral dura defects, because dura tears on the contralateral side are not rare. In our series, all the patients had multiple fractures and dura lacerations. Multiple reconstructive options have been described including free grafts (e.g., fascia lata, fat grafts, muscle plugs) and vascularized grafts (e.g. pericranial flap). By extended bifrontal incision and flap, both anterior based pericranial flap and laterally pedicled temporalis muscle or overlying fascial can be easily procured, which can extend far enough to span large defects across the frontal, ethmoid, and sphenoid sinuses. Watertight seal of the dura was emphasized. If primary repair of the dura is not feasible, in our series, autologous tissue, rather than artificial dura substitute, was used because autologous tissue offers the best compatibility and facilitates optimal wound healing. Regarding graft for dura repair, the choice depends on the location and size of the dura and bone defect, and availability of graft such as pericranial graft, fascia lata, temporalis muscle fascia, all of which can be used, either alone or in combination. If available, vascularized repair grafts is preferred, as it provides a more effective closure and healing. If the pericranium in this area was damaged in traumatic injury or prior surgery, a free fascia lata can be an alternative. Typically, a graft is laid below the subfrontal dura and folded over to cover fully the anterior cranial base with the aid of fibrin glue forming a multilayer barrier which can resist pressure gradients in both directions. Failure of one layer may be salvaged by another layer. It appears that even in relatively large defects, rigid skull base reconstruction is not always required

to prevent subsequent cerebral herniation through the defect.<sup>14–16</sup> In addition, we did not routinely cranialize the frontal sinus as mentioned in some literatures.<sup>10,17</sup> We also abandoned the utilization of bone wax to close the sinus; while autologous fat and muscle were most commonly opted instead.

CSF diversion, commonly with a lumbar drain, is advocated by many authors and is used as an adjunctive perioperative treatment to facilitate surgical manipulation and increase the success rate following surgical repair, because it reduces intracranial pressure and mitigate the flow of leakage, thereby preserving the position of the graft and facilitating the process of adhesion.<sup>18,19</sup> In our procedure, lumbar drain, placed either at the time of initial operation or during the time of postoperative management, is not always necessary. Considering the potential catastrophic consequences of intracranial infection and tension pneumocephalus associated with CSF rhinorrhea, in patients with acute associated brain contusion or elevated intracranial pressure, which increase the difficulty and mortality of early craniotomy, surgical repair should be still conducted at the early stage whenever possible. In these patients, the increased intracranial pressure can be relieved by obliterating intracranial lesion, external-ventricular drainage of CSF or by releasing CSF from dissecting basal cisterns subarachnoid membrane, which may make repair of CSF rhinorrhea in some patients with acute severe traumatic brain injuries possible. Furthermore, the microscope allows thorough exploration and meticulous repair with minimal retraction of the already injured frontal lobes, also minimizes the need for postoperative lumbar drains. Postoperative CSF drainage by lumbar catheterization was employed when assessment of the reliability of the dura repair dictates an additional maneuver to improve the chances of fistula closure.

As dissection occurs through a contaminated operative field, in our series, we elected to prescribe intravenous prophylactic antibiotics, usually antibiotics with good CSF penetration. The use of prophylactic antibiotics in the treatment of rhinorrhea is controversial. Some authors oppose the use of prophylactic antibiotics because they believe prophylactic antibiotics may increase the chance of serious infections caused by opportunistic pathogens.<sup>20–22</sup> The results in this series seems not supporting the proposal. There were no cases of serious infection in our cohort of patients, who were treated with prophylactic antibiotics.

In conclusion, each patient with CSF leak resulting from anterior skull base fracture is unique, and thus the therapy for repair the leak and perioperative managements should depend on the specific situation. Large extensive cranial base fractures necessitate surgical treatment via a bifrontal intracranial extradural approach, because they are almost always accompanied by extensive dura tears and cerebral injuries. The techniques described in this paper allow thorough inspect and meticulous repair of skull base and dura injuries, and are usually reserved for patients with complex trauma in frontobasal injuries presenting CSF leakage associated with intracranial hematomas, cranial nerve involvement. Besides, the techniques reported here might also serve as a salvage therapy for CSF leak patients failed in prior surgical repair attempts.

## Funding

Nil.

## Ethics statement

Our study is in accordance with the ethical standards formulated in the Helsinki Declaration.

## Declaration of competing interest

The authors declare that they have no conflicts of interest.

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