The Surgical Treatment of Posttraumatic Skull Base Defects with Cerebrospinal Fluid Leak

Ashish Jung Thapa¹ Bing-Xi Lei¹ Mei-Guang Zheng¹ Zhong-Jun Li¹ Zheng-Hao Liu¹ Yue-Fei Deng¹

¹Department of Neurosurgery, Center of Cranio-Maxillofacial Surgery, Sun Yat-Sen Memorial Hospital, Sun Yat-Sen University, Guangzhou, Guangdong, China

Address for correspondence Dr. Yue-Fei Deng, MD, Department of Neurosurgery, Sun Yat-Sen Memorial Hospital, 107# Yanjiangxi Road, Guangzhou 510080, China (e-mail: dengyuefei@tom.com).

J Neurol Surg B 2018;79:205–216.

Abstract

Objectives The objective was to explore further the surgical treatment of posttraumatic skull base defects with cerebrospinal fluid (CSF) leak and to identify the most common factors affecting the surgical treatment of posttraumatic skull base defect with CSF leak retrospectively.

Materials and Methods This study included 144 patients with head trauma having skull base defect with CSF leak who had been surgically treated at Sun Yat-Sen Memorial Hospital of Sun Yat-Sen University from 1998 to June 2016. There were 113 (78.5%) males and 31 (21.5%) females, with age ranging from 1 to 78 years and mean age of 26.58 ± 14.95 years. We explored the surgical approaches for the treatment of the skull base defect and the graft materials used and also measured the association among surgical approaches; location, size, and type of skull base defects; presence or absence of associated intracranial pathologies; postoperative complications; outcome; age; Glasgow outcome score (GOS) at discharge; and days of hospital stay.

Results The location, size, and types of skull base defect and the presence of associated intracranial pathologies were the common factors identified not only for choosing the appropriate surgical approach but also for choosing the materials for defect repair, timing of the surgery, and the method used for the defect as well as leak repair. The statistically significant correlation with $p < 0.001$ was found in this study.

Conclusion From this study, we could conclude that size, location, and types of the defect and the presence of associated intracranial injuries were the common factors that affected the surgical treatment of posttraumatic skull base defect with CSF leak. Hence, the importance of careful evaluation of these factors is essential for proper selection of the surgical approach and for avoiding unnecessary hassles.

Keywords

- ▶ skull base defect
- ▶ factors
- ▶ head trauma
- ▶ cerebrospinal fluid
- ▶ Glasgow Coma Scale
- ▶ Glasgow outcome score
- ▶ surgical approach

Introduction

The skull base is the most inferior area composed of complex bony and soft tissue interface. It is divided into three parts the anterior, middle/central, and posterior skull base. The discontinuation or breakage of the skull base alignment is skull base defect. Such defects lead to cerebrospinal fluid (CSF) leak when there is an abnormal communication between the subarachnoid space and upper airway or digestive tracts.^{1–3}

These defects may be due to various etiologies, such as external trauma (80%), iatrogenic (16%), and spontaneous (3–4%).^{1–3} These occur at various sites or locations, anterior skull base being the most common; this may be due to the firm adherence of dura to the anterior skull base. The surgical treatment of skull base defect with CSF leak is controversial as many kinds of literature and studies advocate spontaneous closure of the leak within 48 hours although the CSF leak stops, but the risk of infection, pneumocephalus, and the

received

April 4, 2017

accepted

July 26, 2017

published online

September 11, 2017

© 2018 Georg Thieme Verlag KG
Stuttgart · New York

DOI <https://doi.org/10.1055/s-0037-1606555>.
ISSN 2193-6331.

skull base defect still remains. Therefore, the need of surgical repair to prevent these complications from happening is to be considered. In 1926, Dandy performed the first successful intracranial repair of the CSF leak followed by traumatic skull base defect.^{1,2,4} Thereafter, the repair of posttraumatic CSF leak has been rapidly advancing with the invention of new technologies, such as endoscope, microscope, etc. The first successful extracranial repair was performed by Dohlman. Since the introduction of endoscopic sinus surgery in 1981 by Wigand,^{2,5-7} it has been progressively replacing the intracranial approaches. Although transnasal endoscopic surgery has a higher success and is minimally invasive, a limitation exists, and in certain conditions, open craniotomy is mandatory. In recent studies, a lot has been discussed about the management and treatment of posttraumatic skull base defects with CSF leak, especially for anterior skull base defect. Still, if we summarize it, confusion exists in the following few points: First, how to choose between the conservative or surgical management? Second, how to choose an approach for surgery? Finally, there are no standard guidelines for choosing an appropriate surgical approach. The surgical treatment for posttraumatic skull base defect with CSF leak varies with various factors, and there have been no standard guidelines to follow. Therefore, clinicians often have a dilemma in choosing the best way. Further, the outcome, timing of repair, materials used for repair, and complications also vary with methods. Although there are many studies that have stated the surgical treatment for posttraumatic skull base defect with CSF leak, these studies lack a proper identification of factors that can help surgeons in the easy evaluation of surgical approach for the repair. Therefore, this study aims to perform a retrospective study to further explore the surgical treatment of posttraumatic skull base defects with CSF leak at a tertiary trauma center in China and to determine the most common factors that affect the surgical treatment of posttraumatic skull base defect with CSF leak, thus targeting to provide neurosurgeons, otorhinolaryngologists, and related clinicians with a simple and effective way to evaluate the surgical approach for the defect repair.

Materials and Methods

This study, conducted at Sun Yat-Sen Memorial Hospital of Sun Yat-Sen University, Guangzhou city, PR China, included 144 patients with posttraumatic skull base defects with CSF leak who underwent surgical repair between 1998 and June 2016 and fulfilled the following criteria.

Inclusion Criteria

- Patients with posttraumatic skull base defect with CSF leak.
- All age group and both the sexes.
- Patients with all types, size, and location of defects.
- Patients with associated intracranial pathologies.

Exclusion Criteria

- Patients with non-traumatic, iatrogenic, spontaneous, or congenital skull base defect with CSF leak.
- Patients with severe extracranial vital organ injuries.

There were 113 males and 31 females with mean age of 26.58 years (range: 1–78 years) included in this study. The study population was divided into two groups on the basis of the surgical approach—transnasal endoscopic 51/144 (35.41%) patients and open craniotomy 93/144 (64.59%) patients. The patients' demographics, mode of injury, clinical state/Glasgow Coma Scale (GCS) on admission, and hospital stay (days) distribution are illustrated in ►Table 1. β -Transferrin test was done to identify the CSF from other bodily fluids, and high-resolution computed tomography (CT) and/or magnetic resonance imaging (MRI) was done to identify the location of the defect and leak. CT scan alone was performed in 91/144 (63.2%) patients, MRI alone in 13/144 (9%) patients, and both CT and MRI in 40/144 (27.8%) patients. CT cisternography and MR cisternography were unavailable at our center; therefore, these investigations were excluded. High-resolution CT was the most frequently used imaging technique for trauma cases to identify and to locate the defects as well as postoperative evaluation (as shown in ►Figs. 1 and 2). For massive injuries, suspected adjacent structures injuries, MRI was done before and after surgery and at the time of follow-up. The most common mode of injury for both the groups was a road traffic accident 23/51 (45.1%) and 56/93 (60.2%), respectively (►Table 1). The outcome at the time of discharge recorded as the Glasgow Outcome Scale (GOS) in this study and the distribution are shown in ►Table 1. Post or pre-operative anosmia/hyposmia was not taken for the neurological deficit. The death of one patient occurred due to the severe brain injuries sustained during trauma and pulmonary infection, leading to multiple organ failures. There was no statistical correlation between surgical approaches and Glasgow outcome score with $p > 0.05$. Follow-up was maintained with records from outpatient visits and phone calls, and non-responsive patients and dead patients were considered lost to follow-up and were assigned with 0 as follow-up time. The mean follow-up time was 16.33 months (range: 0–72 months).

Defects Summary

The size of the defect was measured using the CT and MRI images, reports of the CT/MRI imaging, and the intraoperative notes written by the surgeons. The size was divided into defects of size small (≤ 1 cm) and large (> 1 cm) (►Fig. 3). The types of defect were divided according to the nature of the skull base fractures into simple, compound, comminuted, depressed, and complex (i.e., the combination of any two) with the help of CT and MRI imaging (►Fig. 4). The compound defects were the open type of defects with an open fracture of the skull base. The localization of the defect was also done using the CT and MRI imaging technique. The location of the defects was categorized according to Pusic et al⁸ as (1) central defects (I) cribriform plate, orbital roof medial $\frac{1}{2}$, the inner wall of orbit, and planum sphenoidale; (2) lateral defects (II) orbital roof lateral $\frac{1}{2}$, a lesser wing of a sphenoid and lateral aspect of the frontal bone; (3) both central and lateral (III) including the frontal sinus defects; and (4) middle skull base defects (IV) petrous and temporal bone defects. These locations are shown in ►Fig. 5.

Table 1 Patient's demographics distribution between two approaches

Characteristics		Surgical approach		p-Value
		Transnasal endoscopic (n = 51)	Open craniotomy (n = 93)	
Sex	Male	43 (84.3%)	70 (75.3%)	0.29
	Female	8 (15.7%)	23 (24.7%)	
Age (years)	Mean $\pm$ SD	26.65 $\pm$ 18.65 ^a	26.5 $\pm$ 12.58 ^a	0.96
	Range	1–78	1–69	
Mode of trauma	RTA	23 (45.1%)	56 (60.2%)	0.005 ^b
	Fall	19 (37.3%)	14 (15.1%)	
	Assault	2 (3.9%)	14 (15.1%)	
	Others (mechanical, firearm, etc.)	6 (11.8%)	5 (5.4%)	
	Unknown	1 (2%)	4 (4.3%)	
GCS on admission	Mild (13–15)	42 (82.4%)	50 (53.8%)	0.003 ^b
	Moderate (8–12)	7 (13.7%)	35 (37.6%)	
	Severe (<8)	2 (3.9%)	8 (8.6%)	
Glasgow Outcome Scale on discharge	Good recovery	37 (72.5%)	71 (76.3%)	0.42
	Moderate disability	14 (27.5%)	18 (19.4%)	
	Severe disability	0	3 (3.2%)	
	Vegetative state	0	0	
	Death	0	1 (1.1%)	
Hospital stay (days)	Mean $\pm$ SD	8.8 $\pm$ 3.29 ^a	19.9 $\pm$ 14.07 ^a	<0.001 ^b
	Range	4–19	5–75	
Follow-up (months)	Mean $\pm$ SD	22.08 $\pm$ 20.41 ^a	13.09 $\pm$ 11.7 ^a	0.005 ^b
	Range	0–72		

Abbreviations: GCS, Glasgow Coma Scale; RTA, road traffic accident.

^aMean $\pm$ standard deviation.^bThe test is statistically significant at $p < 0.05$.

Surgical Protocol

Open Craniotomy Group

Indications: Ninety-three patients with large defects, compound, comminuted, depressed, and complex type of defects; a location unreachable with transnasal endoscope; defects with associated intracranial pathologies; foreign body in situ; massive injuries; and brain herniation had undergone open craniotomy, either extracranial or intracranial, or both in some cases.

Incision and flap selection: For anterior skull base defect, patients were positioned supine with head 15° elevated; unilateral or bilateral standard coronal hairline incision was done. Depending upon the requirements of skull base repair, a skin flap was isolated from the superior or inferior galea aponeurotica to the supraorbital margin, and a pedicle flap of 12 to 14 cm $\times$ 6 to 8 cm in size was prepared for repair of the skull base defect. The flaps harvested were pedicle frontal periosteal grafts, pedicle flaps or pericranial and galea aponeurotica flaps, pedicled temporalis muscle flap, and pedicle galea aponeurotica superior periosteal flaps.

Surgical routes and defect repair: The surgeries were performed with the target of the defect repair, taking care of the intracranial pathologies, and sealing the CSF leak completely irrespective of types, location, and size of the defects. Therefore, according to the location classification, the craniotomy was chosen; for type (I), frontal bone was used as a base, and frontal, extended sub-frontal, or a fronto-orbital craniotomy was done. For type II, temporal bone was used as base, and frontotemporal craniotomy was done. For type (III), both frontal and temporal bones were used as a base, and craniotomy was done accordingly. For type (IV) or the middle or lateral skull base defects, the temporal bone and parts of parietal bone were used as a base for craniotomy, and extended pterional or question mark incision with extended temporal craniotomy toward base was done. For the patients with a skull base defects accompanied with intracranial injuries and foreign body, first these were taken care of. Then, with the defects >4 cm in diameter, an artificial dural patch, isolated temporalis fascia or periosteum, was used to repair the dura first. Subsequently, a previously prepared pedicle flap was inverted backward and was tiled on the skull

Fig. 1 (1) Axial brain and sinus, (2) axial bone window, and (3) coronal bone window with small arrow heads showing comminuted defect of anterior and middle skull base involving frontal, maxillary, ethmoid, and sphenoid sinus; frontal, ethmoid, nasal, sphenoid, and petrous bones; and pneumocephalus in a 37-year-old male following road traffic accident. (4) Axial, (5) sagittal, and (6) 3D bone image showing postoperative changes in the same patient.

base. The margin of the flap was sutured to the dura mater; biological glue was used in deep areas, which could not be sutured. The small free bone fragments were removed, large ones were realigned, and either titanium plating or an appropriately trimmed titanium mesh was placed between the external dura mater and the flap for the repair of the skull base bone defect. A previously prepared temporalis muscle flap was used to fill in the local residual cavity, which was >5 cm in diameter. For skull base defects with diameter <4 cm, an artificial dural patch, isolated temporalis fascia or periosteum, was used to repair the dural defect, and the pedicle flap was attached to the anterior skull base with sutures or biological glue.

Transnasal Endoscopic Group

Indications: Fifty-one patients with simple, small, location reachable with a transnasal endoscope and with no associated intracranial injuries had undergone transnasal endoscopic repair. A standard transnasal endoscope, Karl Storz endoscopic sinus surgical system (4 mm diameter and 18 cm length with 0°, 30°, and 70° wide-angle endoscope), was used to repair the defect. The side was chosen according to the location of the defect; the 0° endoscope was usually used. The repair was done by muscles and fat paste. The paste was made by mashing the retrieved muscle, which was then used

to fill the defect. The muscle graft was retrieved from either quadriceps femoris muscles, fascia lata graft, or fat graft from the thigh. The wound was covered with a gelatin sponge and was filled/supported by an iodoform strip; both of which were removed 1 week after surgery.

Decompressive craniectomy with a large bone flap to produce appropriate decompression was done whenever necessary in patients with severe brain injuries and raised intracranial pressure (ICP). Apart from these two surgical procedures, patients with low GCS score requiring critical care had tracheostomy done and were placed on ventilator support.

Postoperative Care

The lumbar drain had been placed postoperatively in patients with large defects from both groups for 7 to 10 days, draining 100 to 150 mL/day, while spinal tapping was routinely done postoperative, and routine CSF analysis was done for early diagnosis of infection and for measuring intracranial pressure. A Pan's drainage tube was placed deep in the surgical field and was removed 3 to 5 days after surgery. A broad-spectrum antibiotic, which easily passes through the blood-brain barrier (metronidazole combined with ceftriaxone or cefotaxime), had been administered to all patients for 1 week. Neurotrophic or antiepileptic medications were administered as required.

Fig. 2 (1) Sagittal, (2) coronal, and (3) axial bone window with white arrow showing huge defect in anterior skull base with tension pneumocephalus in a 31-year-old male following road traffic accident. (4) Axial brain image showing postoperative changes in the same patient.

Statistical Analysis

The data analysis was done with IBM SPSS version 23.0, SPSS Inc. A chi-square test or Fisher's exact test, whichever appropriate, was used for categorical variables, and independent samples *t*-test was used for quantitative variables for descriptive analysis; data were expressed in frequency, percentage, and mean $\pm$ standard deviation. Spearman's correlation was used to find the strength of the correlation with the level of significance at $p < 0.05$.

Results

Effect of Associated Intracranial Pathologies on Surgical Approach

The distribution of patients with associated intracranial pathologies according to surgical approaches is given in ►Table 2. There was a strong correlation (0.540) between associated intracranial pathologies and the two surgical approaches with $p < 0.001$. The presence of associated intracranial pathologies is an indication for open craniotomy approach to transnasal endoscopic approach.

Effects of Size, Types, and Location of Defects with a Leak on the Surgical Approach

Forty-five (88.2%) of 51 vs 5/93 (5.4%) patients with simple defect had undergone transnasal endoscopic repair to open craniotomy, which showed strong association (0.695) of simple defects to transnasal endoscopic approach compared with open craniotomy. On the other hand, compound, depressed, comminuted, and complex types of defects tend to undergo open craniotomy compared with transnasal endoscopic approach as these defects are hard to repair through endoscopic approach ($p < 0.001$) (►Table 2). Forty-two (82.4%) of 51 vs 15/93 (16.1%) patients with a small defect (≤ 1 cm) had undergone transnasal endoscopic approach compared with open craniotomy. Similarly, 9/51 (17.6%) vs 78/93 (83.9%) patients with large defects (> 1 cm) had undergone transnasal endoscopic approach to open craniotomy. The association was strong (0.648) and p -value < 0.001 (►Table 3). All 51 patients with defects located central type (I) had undergone transnasal endoscopic surgery, and 13/93 type I, 4/93 type II, 71/93 type III, and 5/93 type IV had undergone open craniotomy, which showed strong association (0.801) of the location to surgical approach p -value < 0.001 (►Table 3).

Fig. 3 Classification of defect size (white circle) using coronal CT images.

Fig. 5 Classification of defects according to location. (Adapted from Pusic et al⁷.)

Fig. 4 Classification of defect types (black and white circles) using CT images.

Table 2 Correlation between associated intracranial pathology, types of defects, and surgical approaches

Factors	Types	Surgical approach	
		Transnasal endoscopic (n = 51)	Open craniotomy (n = 93)
Associated intracranial pathologies	Absent	38 (74.5%)	3 (3.2%)
	Hemorrhagic contusion	2 (3.9%)	25 (26.9%)
	Traumatic SAH	2 (3.9%)	6 (6.5%)
	EDH	2 (3.9%)	12 (12.9%)
	SDH	0	15 (16.4%)
	Severe injuries (combination of any two)	0	8 (8.6%)
	ICH	0	16 (17.2%)
	Pneumocephalus	7 (13.7%)	8 (8.6%)
Types of defects	Simple	45 (88.2%)	5 (5.4%)
	Compound	1 (2.0%)	51 (54.8%)
	Depressed	0	3 (3.2%)
	Comminuted	5 (9.8%)	16 (17.2%)
	Complex (combination of any two)	0	18 (19.4%)

Abbreviations: EDH, epidural hematoma; ICH, intracerebral hematoma; SAH, subarachnoid hemorrhage; SDH, subdural hematoma.

Note: There is very strong evidence of correlation at p -value <0.001.

Complications

Among the 144 patients, the distribution of postoperative complications is shown in ►Table 4. The cases of hydrocephalus had ventricular-peritoneal shunting (V-P shunt) procedure done. Among the eight cases of hyposmia, two had severely damaged olfactory nerve on the primary trauma that could not be repaired, and two recovered their sense of

Table 3 Correlation between size, location of defects, and surgical approach

Factors	Types	Surgical approach	
		Transnasal endoscopic (n = 51)	Open craniotomy (n = 93)
Size of Defects	Small (≤ 1 cm)	42 (82.4%)	15 (16.1%)
	Large (>1 cm)	9 (17.6%)	78 (83.9%)
Location of Defects	Central (I)	51	13 (14%)
	Lateral (II)	0	4 (4.3%)
	Central and lateral (III)	0	71 (76.3%)
	Middle skull base (IV)	0	5 (5.4%)

Note: There is very strong evidence of correlation at p -value <0.001.

Table 4 Distribution of postoperative complications within surgical approach

Postoperative Complications	Surgical approach	
	Transnasal endoscopic (n = 51)	Open craniotomy (n = 93)
None	44 (86.3%)	67 (72%)
Recurrence of leak	3 (5.9%)	4 (4.3%)
Infection (meningitis, wound infection, etc.)	0	3 (3.2%)
Pneumocephalus	1 (2%)	4 (4.3%)
Seizures	0	6 (6.5%)
Visual disturbances	0	2 (2.2%)
Hematoma	0	2 (2.2%)
Hyposmia/Anosmia	3 (5.9%)	5 (5.4%)

Note: There was no evidence of significant correlation with $p > 0.05$.

smell during 2 years follow-up. There was no significant statistical correlation between surgical approaches and postoperative complications with $p > 0.05$. The correlation coefficients and the p -value are shown in ►Table 5.

Discussion

Identification of Factors

The presence of intracranial pathologies, such as a hemorrhagic contusion, epidural hematoma (EDH), subdural hematoma (SDH), intracerebral hematoma (ICH), etc., is the most important factor predisposing the surgical treatment of post-traumatic skull base defect with CSF leak.^{1–3,9–12} This study

Table 5 Correlation coefficients and p -value between surgical approaches

Factors	Correlation coefficients (ρ)	p -Values
Associated intracranial injuries	0.540	<0.001 ^a
Type of defects	0.695	<0.001 ^a
Size of defects	0.648	<0.001 ^a
Site/Location of defects	0.754	<0.001 ^a
GCS on admission	0.277	0.003 ^a
Hospital stay (days)	0.567	<0.001 ^a
Mode of Trauma	0.09	0.005 ^a
Postoperative complications	0.138	0.073
Outcome (Glasgow outcome score)	0.064	0.42
Age	0.011	0.96
Sex	0.105	0.29

^aCorrelation statistically significant.

supports previous studies stating that the presence of intracranial injuries is indicative of open craniotomy rather than a transnasal endoscopic method for the skull base repair.^{1-3,9-12} During an intracranial approach not only the osteodural defect repair can be done, but the associated intracranial pathology indicative of surgery can also be taken care of during the same surgery. In this study, two patients with a hemorrhagic contusion, two with SAH, and two with EDH underwent transnasal endoscopic repair as their associated lesions were small and not indicative of surgical evacuation. Therefore, this study still advocates open craniotomy for the repair of posttraumatic skull base defect with CSF leak associated with intracranial pathologies.

Simple skull base defect with CSF leak can be repaired by transnasal endoscopic approach, but compound, depressed, comminuted, and complex type of defect are to be repaired through an open craniotomy approach.^{1-3,10-15} In compound, comminuted, depressed, and complex or mixed type of defect, the realignment, removal, and or fixation of fracture is not possible through an endoscope; therefore, in such cases, open craniotomy is mandatory. Also in this study, the comminuted fractures with very small floating bone fragments were removed, and if the defect is large then trimmed, titanium mesh was used, else titanium plates were used to fix the free bone fragments. For depressed fracture, the fracture was first elevated then titanium plates were used to fix the defect. Complex defects were realigned and repaired with either titanium plates or mesh accordingly.¹⁶⁻¹⁸ In corresponding with previous studies, this study identifies types of defect as one of the factors that affect the surgical approach for skull base defect repair. In this study, one patient with compound and five patients with comminuted defects had small defects, which could be easily repaired by transnasal endoscopic repair and no other strong indications for open surgery. We found a strong association that the types of the defect are also an affecting factor in deciding the surgical approach for the repair of posttraumatic skull base defect with CSF leak. The types of the defect are not only an indication for skull base defect repair surgery but also an essential factor for choosing the surgical method as previously discussed in this study.

Small defects (≤ 1 cm) can be repaired easily by transnasal endoscopic approach, but larger defects (>1 cm) require an open approach.^{1-3,10,14,15,19} In this study there was a strong association between the size of the defects and the approach of

surgery that corresponds with the previous studies that larger defects need an open craniotomy approach for the repair meanwhile, the small defect can undergo endoscopic repair.^{1-3,10,14,15,19} In our study, nine patients with larger defect underwent transnasal endoscopic repair with the other factors being supportive of transnasal endoscopic repair. In argument to Manuel et al²⁰ who state that endoscopic surgery is a gold standard for any type and size of skull base defect, this study found the size of the defects as a factor not only for choosing a surgical approach but also for choosing the graft and flap for the defect repair. In this study, larger defects were repaired with an artificial dura patch, and isolated temporalis fascia or periosteum was used to repair the dura first. Then, a previously prepared pedicle flap was inverted backward and was tiled on the skull base. Whereas for smaller defects, just an artificial dura patch, isolated temporalis fascia, or periosteum graft was used for defect repair.¹⁶⁻¹⁸

Central defects or type I defects can easily be repaired by transnasal endoscopic approach, but lateral defects (II), both central and lateral (III) including frontal sinus defects and middle skull base defects (IV), can only be repaired by an open approach.^{1-3,9,11-14,19,21-23} In this study, a strong relation between the location and the surgical approach was achieved, which denies the fact stated by Manuel et al²⁰ that location is not a predisposing factor for a surgical approach. Also in this study, no other endoscopic approach apart from transnasal endoscopic approach was done. Therefore, even Bhavana et al²⁴ being suggestive of the minimally invasive endoscopic approach to frontal sinus posterior wall defects, this study still states that posterior wall of frontal sinus defect is to be repaired by an open craniotomy. The identification of these factors provides an easy way to evaluate the surgical treatment of posttraumatic skull base defects with CSF leak. Prior to this study, no studies, however, have identified factors aiming to facilitate the selection of a surgical method for posttraumatic skull base defects repair as discussed previously.

Outcome

The outcome in this study was measured by the Glasgow Outcome Score (GOS) classifying the patients into good recovery, moderate disability, severe disability, vegetative state, and death at the time of discharge. The death of 1 patient out of 93 patients, operated by intracranial approach, was due to the complications of primary brain injury and long-standing

Fig. 6 Pie chart showing distribution of postoperative complications between surgical approaches.

Fig. 7 Bar graph showing distribution of Glasgow Outcome Score between surgical approaches.

pulmonary infection, leading to multiple organ failures. There were three severe disable patients who were lost to follow-up eventually, and hyposmia/anosmia, either preoperative or postoperative, was not accounted for neurological deficit. There were two cases of visual disturbances in open craniotomy group, which were due to the injury to optic nerve as the result of trauma. The disturbances resolved in 3 years follow-up in both the cases. In contrast to previous studies, this study

found no significant correlation in the outcome and the two approaches although the transnasal endoscopic approach is minimally invasive.^{3,6,19,25–28} (►Fig. 6)

Postoperative Complications

No significant correlation with postoperative complications and the two approaches was found in this study. In contrast to previous studies,^{3,6,25–29} indicating that open intracranial approach tends to have more complications than endoscopic approach, this study shows no difference in the complications (►Fig. 7). Hyposmia was found in three cases of transnasal and five cases of open craniotomy. This was the consequence of primary injury to olfactory nerve and had no relation to the surgical approaches. There was recurrence in three cases of endoscopic repair and in four in open craniotomy group, hematoma in two patients, and seizure in six cases with open craniotomy; these were statistically insignificant. In the cases of recurrence, pneumocephalus, and hematoma, patients underwent open craniotomy as second surgery, and the complications resolved after the second surgery. The postoperative seizure cases were given anti-epileptics, and they were seizure free in 5 years' follow-up.

Patient's Clinical State

In this study, the clinical state or the GCS of patients on admission showed weak, but statistically significant association

Fig. 8 Algorithm for surgical treatment of posttraumatic skull base defects with CSF leak.

(0.28) with the surgical approach. Patients with moderate (8–12) and severe (<8) state tend to undergo open intracranial approach rather than transnasal endoscopic; on the other hand, those with mild (13–15) state have more tendency to undergo transnasal endoscopic. This may be due to the fact that the severe state of the patient is usually predefined by the other factors, such as associated intracranial pathology, large, compound, comminuted, depressed, complex defect, and unable to be repaired through the transnasal endoscope.

Others

Hospital stay had a correlation (0.57) with the two surgical approaches; a longer hospital stay for open approach than that for transnasal endoscopic approach was found in this study. This may be due to many small factors, such as transnasal being minimally invasive, no bigger incision, and no suture removal required. Most of the severe cases are operated by open approach; therefore, their recovery is longer. There are studies describing the success rates of transnasal endoscopic approach ranging from 96 to 100%,^{6,20,25,27,28,30} but this study found the success rate of 92.1% for transnasal endoscopic and of 92.5% for open craniotomy in the first surgery and 100% for open craniotomy at second time. Many studies describe the failure rates of transnasal endoscopic approach, 6 to 33%, and open craniotomy repair, 6 to 27%.^{1,3} In this study, the success or failure rates for both the approach were within the reference limits of previous studies. In this study, there were three patients with postoperative infection. Postoperative antibiotics prophylactics were used in all the patients. There are studies that describe the rate of risk of infection in correspondence to location, size, and types of defect in posttraumatic skull base defect with CSF leak.^{3,12,15,22,31} In this study, there was no such encounter. Moreover, infection is an indication for surgery, and this study focuses on the exploring the surgery and the affecting factors for a surgical approach in posttraumatic skull base defect with CSF leak.

On the basis of these factors and the surgical treatment at the center of this study, we have tried to make an algorithmic flow chart for the surgical treatment (► Fig. 8).

Conclusion

From this study, we could conclude that size, site/location, and types of the defect and the presence of associated intracranial injuries were the common factors that affected the surgical treatment of posttraumatic skull base defect with CSF leak. These factors were significant not only for choosing the surgical approach, but also for the timing of the surgery, materials used for the repair, and the methods used for the defect as well as leak repair. Hence, the importance of careful evaluation of these factors is essential for proper selection of the surgical approach and for avoiding unnecessary hassles.

Ethical Approval

The procedures of this study involving human participants were in accordance with the ethical criteria of the Human

Study Committee of Sun Yat-Sen Memorial Hospital, Sun Yat-Sen University, Guangzhou, China, and the study was approved by the same committee. For this type of study, formal consent is not required.

Conflict of Interests

The authors declare no conflict of interests.

Funding

No funding to be declared.

Acknowledgments

I would like to express my special gratitude to Dr. Nisha Adhikari for her support in the manuscript writing, both intellectually and emotionally.

References

- 1 Rocchi G, Caroli E, Belli E, Salvati M, Cimatti M, Delfini R. Severe craniofacial fractures with frontobasal involvement and cerebrospinal fluid fistula: indications for surgical repair. *Surg Neurol* 2005;63(06):559–563, discussion 563–564
- 2 Scholsem M, Scholtes F, Collignon F, et al. Surgical management of anterior cranial base fractures with cerebrospinal fluid fistulae: a single-institution experience. *Neurosurgery* 2008;62(02):463–469, discussion 469–471
- 3 Yilmazlar S, Arslan E, Kocaeli H, et al. Cerebrospinal fluid leakage complicating skull base fractures: analysis of 81 cases. *Neurosurg Rev* 2006;29(01):64–71
- 4 Dandy WE. Pneumocephalus (intracranial pneumatocele or aérocoele). *Arch Surg* 1926;12:949–982
- 5 Calcaterra TC. Diagnosis and management of ethmoid cerebrospinal rhinorrhea. *Otolaryngol Clin North Am* 1985;18(01):99–105
- 6 Moukharbel RV, Haddad GF, Kahwaji G, Hadi U. Endonasal endoscopic approach to the anterior skull base for reconstruction of CSF fistulas. *International Congress Series* 1240; 2003:931–933
- 7 Wigand ME. Transnasal ethmoidectomy under endoscopic control. *Rhinology* 1981;19(01):7–15
- 8 Pusic AL, Chen CM, Patel S, Cordeiro PG, Shah JP. Microvascular reconstruction of the skull base: a clinical approach to surgical defect classification and flap selection. *Skull Base* 2007;17(01):5–15
- 9 Deng YF, Lin JH, Zhong ZG, Zheng YQ, Liu AM. The surgical treatment of the traumatic anterior skull base defect. *China J Nerv Ment Dis* 2003;29(04):269
- 10 Deng YF, Zhang JX, Chen B, Qiu JF. The diagnosis and treatment of the post-traumatic tension pneumocephalus. *Lignan Emergency Medicine Journal* 2007;12(04):265–267
- 11 Fishman G, Fliss DM, Benjamin S, et al. Multidisciplinary surgical approach for cerebrospinal fluid leak in children with complex head trauma. *Childs Nerv Syst* 2009;25(08):915–923
- 12 Schoentgen C, Henaux PL, Godey B, Jegoux F. Management of post-traumatic cerebrospinal fluid (CSF) leak of anterior skull base: 10 years experience. *Acta Otolaryngol* 2013;133(09):944–950
- 13 Archer JB, Sun H, Bonney PA, et al. Extensive traumatic anterior skull base fractures with cerebrospinal fluid leak: classification and repair techniques using combined vascularized tissue flaps. *J Neurosurg* 2016;124(03):647–656
- 14 Fliss DM, Zucker G, Cohen JT, Gatot A. The subcranial approach for the treatment of cerebrospinal fluid rhinorrhea: a report of 10 cases. *J Oral Maxillofac Surg* 2001;59(10):1171–1175
- 15 Talamonti G, Fontana R, Villa F, et al. “High risk” anterior basal skull fractures. Surgical treatment of 64 consecutive cases. *J Neurosurg Sci* 1995;39(03):191–197

- 16 Deng YF, Lei BX, Zheng MG, Zheng YQ, Chen WL, Lan YQ. A simple classification of cranial-nasal-orbital communicating tumors that facilitate choice of surgical approaches: analysis of a series of 32 cases. *Eur Arch Otorhinolaryngol* 2016;273(08):2239–2248
- 17 Deng YF, Geng JF, Niu JT. The clinical study of anterior skull base defects repair with pedicled subgaleal and pericranial flap. *Chin J Neurosurg* 2010;26(09):811–815
- 18 Deng YF, Chen B, Zheng YQ, Geng JF, Huang XM. Endoscopic transnasal combined transcranial resection of anterior-middle skull base communicative tumors. *Chin J Neurosurg* 2009;25(05):408–410
- 19 Sherif C, Di Ieva A, Gibson D, et al. A management algorithm for cerebrospinal fluid leak associated with anterior skull base fractures: detailed clinical and radiological follow-up. *Neurosurg Rev* 2012;35(02):227–237, discussion 237–238
- 20 Bernal-Sprekelsen M, Rioja E, Enseñat J, et al. Management of anterior skull base defect depending on its size and location. *BioMed Res Int* 2014;2014:346873
- 21 Frodel JL. Management of skull base fractures. *Operative Techniques in Otolaryngology-Head and Neck Surgery* 2008;19:214–223
- 22 Mincy JE. Posttraumatic cerebrospinal fluid fistula of the frontal fossa. *J Trauma* 1966;6(05):618–622
- 23 Sun ZL, Jiang W, Feng XR, Liu YY. Cerebrospinal fluid leak after traumatic skull base fracture: the cause and treatment. *J Otolaryngol Ophthal Shandong Univ* 2006;1673–3770
- 24 Bhavana K, Kumar R, Keshri A, Aggarwal S. Minimally Invasive Technique for repairing CSF leaks due to a defect of the posterior table of the frontal sinus. *J Neurol Surg B Skull Base* 2014;75(03):183–186
- 25 Banks CA, Palmer JN, Chiu AG, O'Malley BW Jr, Woodworth BA, Kennedy DW. Endoscopic closure of CSF rhinorrhea: 193 cases over 21 years. *Otolaryngol Head Neck Surg* 2009;140(06):826–833
- 26 Briggs RJS, Wormald PJ. Endoscopic transnasal intradural repair of anterior skull base cerebrospinal fluid fistulae. *J Clin Neurosci* 2004;11(06):597–599
- 27 Liu BY. Application of minimally invasive surgery in traumatic brain injury. *Chin J Traumatol* 2014;17(06):313–316
- 28 White DR, Dubin MG, Senior BA. Endoscopic repair of cerebrospinal fluid leaks after neurosurgical procedures. *Am J Otolaryngol* 2003;24(04):213–216
- 29 Zheng WJ, Zhang XJ, Ji T, Huang GD. Neuroendoscopic endonasal management of cerebrospinal fluid rhinorrhea. *J Craniofac Surg* 2015;26(02):459–463
- 30 Kirtane MV, Gautham K, Upadhyaya SR. Endoscopic CSF rhinorrhea closure: our experience in 267 cases. *Otolaryngol Head Neck Surg* 2005;132(02):208–212
- 31 Eljamel MSM, Foy PM. Post-traumatic CSF fistulae, the case for surgical repair. *Br J Neurosurg* 1990;4(06):479–483