

Original Research

Outcomes and Complications of Endoscopic Endonasal Repair for Spontaneous CSF Rhinorrhea: A Four-Year Experience of 85 Cases

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ABSTRACT

Objective: This study evaluated outcomes of an endoscopic endonasal multilayer repair protocol for spontaneous CSF rhinorrhea at two major tertiary centers in Khyber Pakhtunkhwa, Pakistan.

Materials & Methods: This retrospective descriptive case series included 85 patients with spontaneous CSF rhinorrhea who underwent endoscopic endonasal multilayer repair over four years at two tertiary hospitals in KP, Pakistan. Diagnosis was confirmed by clinical evaluation, CSF analysis, and prone-position contrast MRI, supplemented by CT. Repair was defect-size-based: nasoseptal flap for 1-2 cm/high-flow defects (31.8%), middle turbinate flap for 7-10 mm/moderate-flow defects (35.3%), and fascia lata/fat graft for 3-6 mm/low-flow defects (32.9%). Fibrin glue was used selectively in high-risk cases; lumbar drains were used for high-flow leaks.

Results: Among 85 patients (mean age 39 ± 14.3 years; 68.2% female; mean BMI 28 ± 3.6 kg/m²), the cribriform plate was the commonest site (64.7%). Fibrin glue was used in 64.7%, and lumbar drains in 27.1%. Primary success at 3 months was 97.6% (83/85). Complications included nasal crusting (15.3%) and sinusitis (11.8%), with no meningitis, flap necrosis, or neurological deficit. Two patients (2.4%) required secondary repair, achieving 100% overall success; 2-year success was 95.3%, with late recurrence linked to elevated BMI, high-flow leaks, and radiologic IIH.

Conclusion: This defect-size-based repair protocol achieves excellent primary and overall success rates; long-term surveillance is warranted in IIH or elevated BMI.

Keywords: Anterior Skull base Surgery, Endoscopic endonasal Approach to Anterior skull base, Spontaneous cerebrospinal rhinorrhea, Naso-septal flap, Multilayer reconstruction, Surgical outcomes, Lumbar Drain.

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Date of Submission: 21-06-2026
Date of Revision: 20-08-2026
Date of Acceptance: 10-09-2026
Date of Online Publishing: 30-9-2026
Date of Print: 30-9-2026

DOI: 10.36552/pjns.v30i3.1303

INTRODUCTION

Spontaneous cerebrospinal fluid (CSF) rhinorrhea is rare but potentially life-threatening and increasingly linked to idiopathic intracranial hypertension (IIH) and obesity. Endoscopic endonasal repair is the gold standard, yet a defect-size-based algorithm with selective adjunct use remains under-validated in South Asia. Cerebrospinal fluid (CSF) rhinorrhea is the leakage of cerebrospinal fluid (CSF) through the nasal cavity as part of faulty communication between the nasal mucosa and arachnoid membrane of the meninges.¹ There are broadly two categories of CSF rhinorrhea: traumatic and non-traumatic. Traumatic causes account for the large majority of CSF rhinorrhea (approximately 80–90%), whereas non-traumatic (spontaneous) leaks are considerably less common; reported prevalence ranges from approximately 3–4% of all CSF fistulas in older series to as high as 28% in more recent reports, reflecting differing case definitions, referral patterns, and diagnostic sensitivity across studies.^{2,3,4} The most common cause of traumatic CSF rhinorrhea is head trauma, with the most vulnerable skull base sites being the cribriform plate and posterior wall of the frontal sinus due to their anatomical thinness.^{3,4} Risk factors include basal skull fractures, high-velocity craniofacial trauma, and prior neurosurgical or endoscopic sinus procedures.^{2,5} Within the non-traumatic category, the CSF leaks without an initiating event were referred to as "spontaneous."⁶ While each type of CSF leak is associated with a definite and documented cause, the spontaneous leak etiology was a mystery to the scientific community; later modern studies attributed it to long-term pressure dynamics. Certain factors, like idiopathic intracranial hypertension and obesity, are closely linked to such spontaneous leaks. For instance, Nelson et al, (2015) state that the obesity epidemic

in the United States began in the 1980s and that, after a 2-decade delay, a corresponding increase in patients with CSF leaks was observed.⁶ Another study documents factors like female gender and middle age (fourth to fifth decade), while further supporting obesity (body mass index [BMI] > 40) as contributing to the cause of sCSF.⁷ The pathophysiology suggests that obesity leads to increased pressure on venous return from the cranial cavity, which impairs the drainage of the cerebrospinal fluid, hence raising the intracranial pressure. This sustained pressure, if not resolved, eventually erodes the bone underneath and subsequently leads to a spontaneous leak. All types of CSF rhinorrhea present with mild symptoms of clear, watery discharge that gets worse with bending or the Valsalva maneuver. Moreover, headache, a metallic or salty taste in the mouth, confusion and impaired vision, anosmia, nasal congestion, or a history of meningitis are other symptoms presented. Encephaloceles, or deformities of the skull base, can also result in brain herniation.⁸

There are two types of spontaneous CSF leaks: "low-flow" and "high-flow" that affect the course of surgical approach, selection of repair material, use of prophylactic pressure-lowering drugs, and decision of drain placement for CSF diversion. A "low-flow" CSF leak is defined as a few drops of CSF leaking as a result of briefly elevated intracranial pressure while standing, straining, or coughing, whereas a "high-flow" leak is defined as a consistent CSF flow observed intraoperatively in the setting of a connection with cisterns or a ventricular system opening.⁹ Although one study describes a 70 to 80% patient cure rate with traditional neurosurgical cerebral repair by craniotomy.¹⁰ Yet, a study by Ray and Bergland shows 10% of individuals still have leakage following several intracranial treatments, with literature documenting a failure rate reaching 40%.^{4,5} Also, anosmia, memory impairments, bleeding, cerebral edema, and osteomyelitis of the bone flap are among the morbidities associated

with intracranial procedures, posing many risks to patients' overall outcome.^{11,12} Due to high success rates and fewer complications, the surgical approach to its treatment has greatly transitioned over the years from risk-prone intracranial approaches to more efficient ones. With Dohlman et al, reporting the first extracranial access in 1948 and Wiegand describing the first endoscopic repair for lateral skull base CSF repair in 1981, minimally invasive endoscopic techniques have mostly replaced open repair procedures for skull base CSF leaks over the past 30 years.^{13,14}

Numerous invasive and non-invasive techniques can be used to precisely locate the CSF leak. With an accuracy of roughly 90 to 100%, recent studies have employed combined CT and MRI imaging to identify the location of CSF leaks.^{15,16} To close the defect site, the literature has reported a wide range of surgical approaches, including the bathtub-plug technique, sandwich-graft technique, and three-layer closure, none of which are obviously better than the others.¹⁷ Another study employed a combination repair strategy that included covering the defect site with a fascia lata graft adhered to tissue glue and sealing it with a fat graft. Additionally, where there was high-flow leakage or a defect larger than 1 cm (16.67%), a middle turbinate flap was positioned as a cover.¹⁸

Treatment for the spontaneous leak ranges from non-invasive to various surgical procedures. The conservative strategy is first-line management. The patient is instructed to stay in bed, elevate their head, take drugs like diuretics, and limit their fluid consumption.² When such conservative therapy is ineffective, surgical correction is necessary.¹ Craniotomy and nasal approaches (external and endonasal ethmoidectomy) using an endoscope are the surgical repair methods.^{3,11}

The benefits of using an endoscope, such as improved lighting, image magnification, and optimal angle visualization, allow the surgeon to diagnose nasal CSF fistulas more accurately and treat them less invasively, making endoscopic

surgery a preferred treatment option.¹⁹ A precise preoperative assessment of the fistula's location, size, and surrounding anatomy is essential for endoscopic surgical correction of CSF rhinorrhea.¹⁹

A meta-analysis of 47 published studies, including 2586 patients, with a pooled primary success rate of 93.7% and an overall repair rate after revision surgery of 99.7%, demonstrates that endoscopic repair is a very effective treatment for spontaneous anterior skull base CSF leaks.²⁰ Despite the growing body of evidence in support of endoscopic endonasal repair of spontaneous CSF rhinorrhea, several important gaps exist in the literature. Firstly, most published studies originate from Western populations with higher body mass index (BMI) profiles, and data from South Asia remain limited. Secondly, there is substantial variation in surgical techniques regarding flap selection, particularly in determining the optimal use of the middle turbinate flap versus the nasoseptal flap for the repair of medium-sized defects. Thirdly, although commonly employed, the routine use of fibrin glue as an adjunctive sealant remains controversial, with recent meta-analyses showing no statistically significant benefit. Lastly, the adoption and validation of a standardized, defect size-based algorithm for flap selection across diverse populations remain limited.

Given these gaps, this study was designed to evaluate a standardized, defect size-based endoscopic endonasal multilayer repair strategy for spontaneous CSF rhinorrhea in a South Asian population treated at two tertiary care hospitals in Khyber Pakhtunkhwa, Pakistan. Rather than routine use of fibrin glue in all patients, our study incorporated selective use only in high-risk cases (defects >7 mm or high-flow leaks). This study provides real-world evidence on the outcomes of this tailored surgical protocol, including success rates, complications, and the safety of selective fibrin glue use.

MATERIALS & METHODS

Study Design and Setting

A descriptive, retrospective study design was used to conduct the study at two major tertiary care hospitals of KP, Pakistan (Department of Otorhinolaryngology and Head-Neck Surgery (ENT), Khyber Teaching Hospital, Peshawar; and Departments of Otorhinolaryngology and Neurosurgery, Swat Medical Complex and Teaching Hospital, Swat, KPK, Pakistan). The target population was patients diagnosed with spontaneous cerebrospinal fluid (CSF) rhinorrhea who underwent endoscopic endonasal multilayer repair between 15th February 2022 and 15th February 2026. Consultant surgeons with fellowship training in endoscopic skull base surgery performed all the procedures in collaboration with ENT and Neurosurgery departments, ensuring a multidisciplinary approach.

Ethical approval for the study was obtained from the Institutional Research and Ethical Review Board (IREB) of Khyber Medical College, Peshawar (Reference No. 887/DME/KMC) and Swat Medical College and Swat Medical Complex and Teaching Hospital, Saidu Sharif, Swat (Reference No.: RAC/SMC/112-19/DME). Due to the retrospective nature of the study, Informed consent was waived. All procedures were performed in accordance with the Declaration of Helsinki (1964) and its subsequent amendments. This study includes patients from a previously published case series conducted at one of the participating institutions (Khan et al., JMS 2025; n=34). All patients from that earlier case series were re-evaluated and included, along with additional patients from both institutions, incorporating more objectives and variables in the present larger cohort (N=85) after extending the follow-up period to 2 years.

Operational Definitions

Spontaneous CSF Rhinorrhea: Spontaneous cerebrospinal fluid (CSF) rhinorrhea was defined as

leakage of CSF occurring in the absence of any identifiable precipitating factor, prior sinonasal or skull base surgery, head trauma, or intracranial neoplasm. Exclusion of traumatic, iatrogenic, and neoplastic etiologies under this definition ensures a homogeneous cohort of truly spontaneous leaks.

Intraoperative CSF Flow Characteristics:

Intraoperative CSF flow was categorized as **low-flow** (slow, intermittent leakage visualized only with a Valsalva maneuver) or **high-flow** (continuous, pulsatile, or copious efflux seen spontaneously or after Valsalva, typically with larger dural defects or meningoencephalocele).

Multilayer Repair (Inlay and Onlay): Multilayer repair combines an inlay graft (placed deep to the bone, against the dura) with an onlay graft (placed superficially on the nasal side of the defect) to achieve a watertight seal (Figure 1). This inlay/onlay sandwich technique was used in all patients in this series.

Middle Turbinate Flap (MTF): The middle turbinate flap (MTF) is a vascularized mucosal flap pedicled on the sphenopalatine artery, harvested from the middle turbinate. It is used for small-to-medium defects (7-10 mm) of the cribriform plate or ethmoid roof, preserving the nasal septum and avoiding septal donor-site morbidity.

Nasoseptal Flap (NSF): The nasoseptal flap (NSF, Hadad-Bassagasteguy flap) is a vascularized septal mucosal flap pedicled on the posterior septal artery. Its larger surface area (up to 8-10 cm²) makes it the gold standard for medium-to-large defects ($\geq 1-2$ cm) of the anterior, central, or posterior skull base.

Prone Position MRI: MRI was performed with the patient in the **prone position** to increase gravity-dependent fluid accumulation at the defect site, improving detection of small or intermittent leaks. T2-weighted CISS sequences provided high-resolution visualization of the CSF tract, meningocele, or encephalocele.

Lumbar Drain: A **lumbar drain** is a catheter inserted at the L3-L4 or L4-L5 interspace for temporary CSF diversion, reducing pressure on the

repair site. Drains were placed intraoperatively for high-flow leaks (n=23, 27.1%) at 5-10 mL/hour for **3-5 days**, and removed once endoscopy showed no further leak, the patient was asymptomatic, and output was <10-15 mL/hour for 24 consecutive hours.

Two-Component Fibrin Sealant: The **two-component fibrin sealant** (e.g., Tisseel; Baxter Healthcare) combines fibrinogen/aprotinin with thrombin/calcium chloride to form a biodegradable fibrin clot, providing adjunctive tissue adhesion over the completed multilayer repair. Its use was restricted to high-risk cases (n=55, 64.7%): defects >7 mm or high-flow leaks.

Surgical Success (Primary and Long-Term): **Primary surgical success** was defined as complete clinical and radiological absence of CSF leak at 3 months after a single procedure. **Long-term success** was defined as continued absence of leak at 1 and 2 years, confirming durability of the repair.

Recurrent CSF Leak: A **recurrent CSF leak** was defined as reappearance of clear, watery nasal fluid after initial successful closure, confirmed by CSF analysis or characteristic MRI findings. Recurrence

was classified as early (≤ 3 months) or late (> 3 months), the latter often associated with IIH or elevated BMI.

Three graft placement techniques are used depending on defect size and flow (Figure 1): the **inlay (underlay)** technique places a fat graft intracranially for small-to-medium defects (≤ 5 mm); the **onlay (overlay)** technique places a mucosal graft over the nasal surface for small single-layer traumatic defects; and the **combined (sandwich)** technique pairs an intracranial fat inlay with a nasal-surface onlay for large defects (> 5 mm), high-flow leaks, or encephaloceles.

Multilayer reconstruction (Figure 2) proceeds from deep to superficial: Layer 1 (fat graft inlay), Layer 2 (fascia lata/temporalis fascia), Layer 3 (acellular dermis, optional), Layer 4 (mucosal graft/middle turbinate flap), Layer 5 (fibrin glue), and Layer 6 (absorbable packing, removed on postoperative days 5-7). Small, low-flow defects (≤ 3 mm) may be managed with layers 4-5 alone, while complex or high-flow leaks (> 5 mm) require all six layers with a vascularized flap and adjunct lumbar drain.

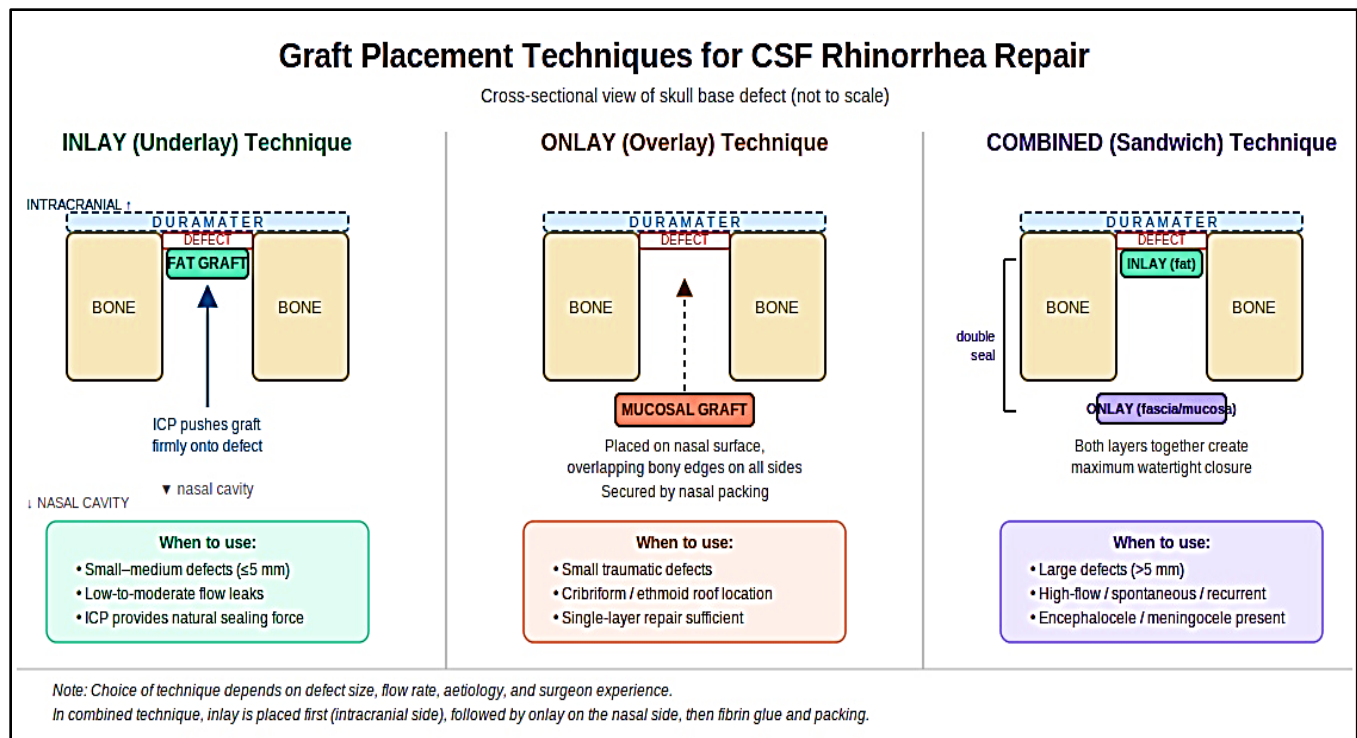


Figure-1: Graft placement techniques for repair of skull base defect in CSF rhinorrhea.

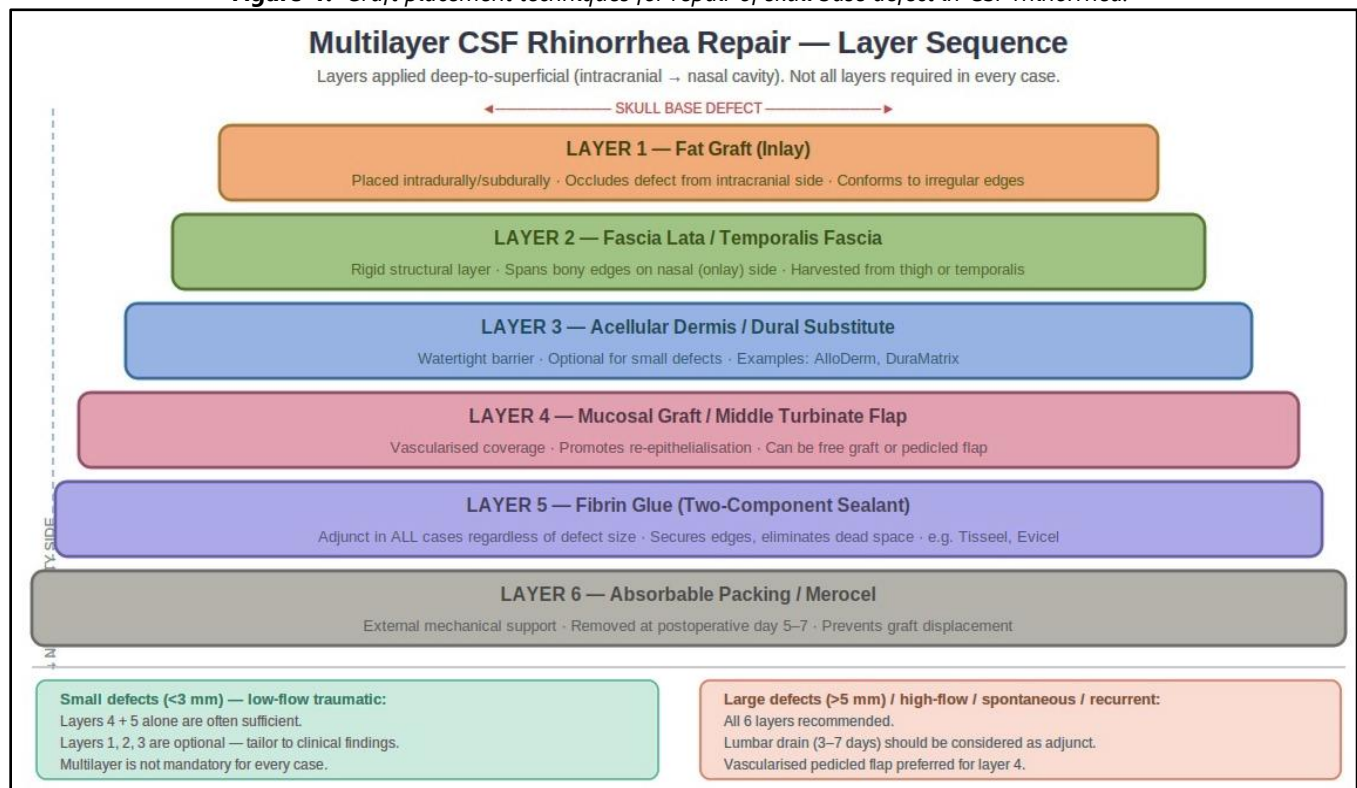


Figure-2: Multilayer Repair of the skull base.

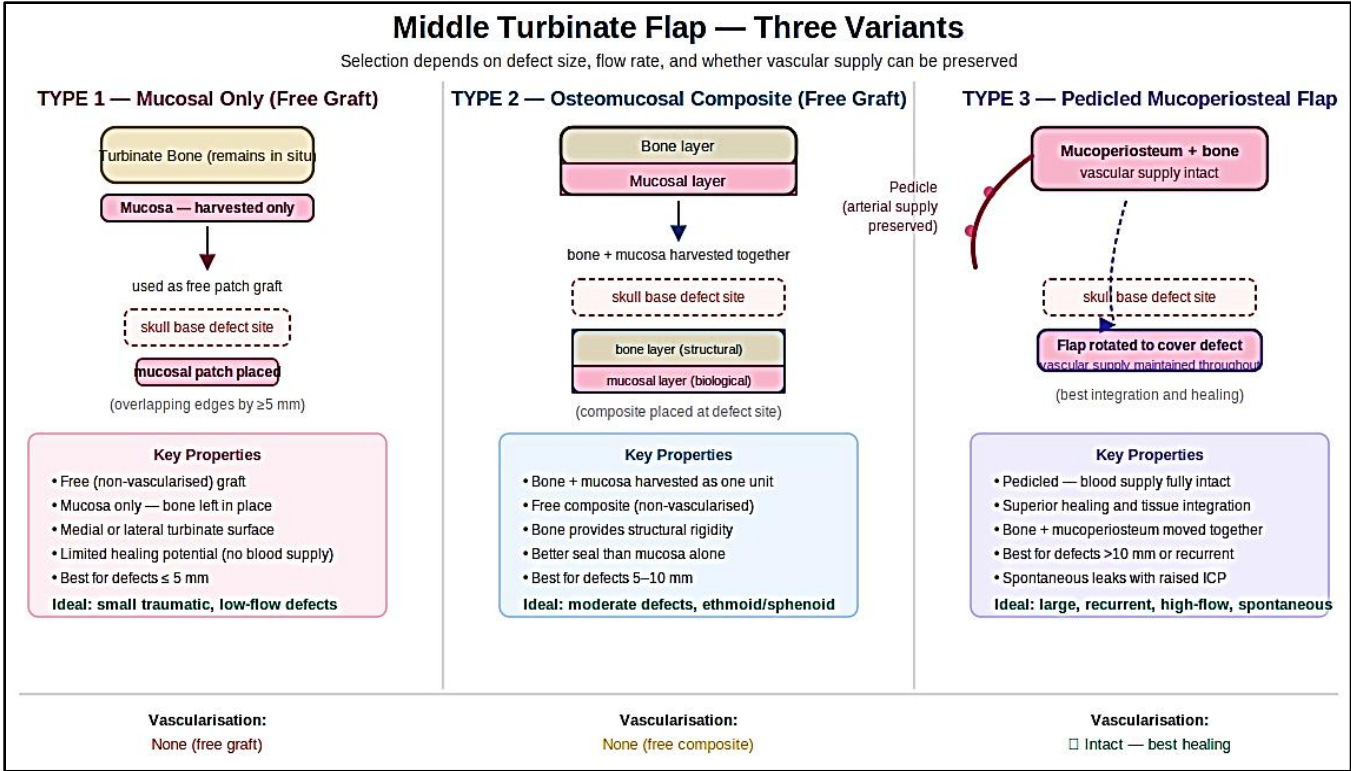


Figure-3: Variants of middle turbinate Flap.

Three middle turbinate flap variants are used according to defect size and vascularization needs (Figure. 3): **Type 1 (mucosal-only free graft)** for small, low-flow defects (≤ 5 mm); **Type 2 (osteomucosal composite free graft)** for moderate defects (5-10 mm), where the bone adds structural rigidity; and **Type 3 (pedicled mucoperiosteal flap)**, which preserves the arterial pedicle for superior vascularized healing and is preferred for large (> 10 mm), recurrent, high-flow, or spontaneous leaks with raised intracranial pressure.

Inclusion and Exclusion Criteria

Inclusion criteria were: (1) age ≥ 18 years (2) confirmed spontaneous CSF rhinorrhea through clinical evaluation and MRI with contrast in the prone position, supplemented by CT imaging or a combination of both modalities; (3) skull base defect on CT or MRI; (4) underwent endoscopic endonasal multilayer repair; (5) complete medical records; and (6) completed 3 months, 1 year, and 2 years follow-up. One additional pediatric patient (age 8 years) with spontaneous CSF rhinorrhea and preoperative meningitis is presented separately as an illustrative case (Illustrative Case 3) for its instructive clinical and radiological features; this patient fell outside the age-based inclusion criterion above and was therefore not counted within the N=85 outcome cohort or Tables 1-6.

Exclusion criteria were: (1) age less than 18 years; (2) traumatic etiology (history of head trauma, facial trauma, or skull base fracture); (3) iatrogenic etiology (prior sinonasal, skull base, or intracranial surgery including endoscopic sinus surgery, transsphenoidal surgery, or craniotomy); (4) neoplastic etiology (presence of benign or malignant intracranial or skull base tumors); (5) congenital skull base anomalies (e.g., congenital encephalocele or meningocele); (6) history of prior surgical repair of CSF leak (endoscopic or open); (7) active sinonasal or intracranial infection at the time of surgery; (8) incomplete medical records or

loss to follow-up before three months; (9) managed conservatively (observation, bed rest only, or lumbar drain alone without surgical repair); or (10) history of cranial or sinonasal radiotherapy.

Data Collection

The electronic health record system and paper-based medical records of the hospital were used to extract data. The collected variables comprised demographic information (age, sex, BMI), presenting symptoms, comorbid conditions, preoperative imaging findings, intraoperative details (defect site, defect size, CSF flow characteristics, reconstructive technique used), postoperative complications, and follow-up outcomes. All data were anonymized before analysis.

Preoperative Evaluation

A comprehensive preoperative assessment was performed for all patients. CSF rhinorrhea was diagnosed through clinical evaluation and confirmed on MRI with contrast in the prone position. To provide a high-resolution visualization of the CSF tract, meningocele, or encephalocele, T2-weighted CISS (constructive interference in steady state) sequences were used. This was supplemented by CT imaging or a combination of both modalities. High-resolution CT (HRCT) with bone window settings was used to map the precise size and location of the bony skull base defect. Imaging was used to precisely identify the location and size of the skull base defect, as well as to detect associated abnormalities such as meningocele, meningoencephalocele, or signs of idiopathic intracranial hypertension (IIH) (e.g., empty sella, optic nerve tortuosity). As a prophylactic measure, all patients received oral cefpodoxime (200 mg every 12 hours), acetazolamide (250 mg every 6 hours), and potassium chloride syrup (5–10 mL every 24 hours) before surgery.

Surgical Technique

All procedures were performed under general anesthesia. The endoscopic endonasal approach was used in all cases. Intraoperatively, the location of the CSF leak was confirmed by performing a Valsalva maneuver (the anesthesiologist applied gentle positive pressure to the endotracheal tube or increased peak airway pressure to 30-40 cm H₂O for 10-15 seconds) to observe active leakage (Shiny Appearance). The surgical field was exposed by endoscopic resection of adjacent turbinates and sinuses. Any associated meningocele or meningoencephalocele was reduced in standard fashion. **The choice of reconstructive technique was based on defect size and intraoperative CSF flow characteristics:** For defects measuring 3–6 mm (n=28, 32.9%) or with low-flow leakage, reconstruction was performed using autologous fascia lata graft or adipose tissue, placed as an inlay/onlay multilayer repair. For defects measuring 7–10 mm (n=30, 35.3%) or with moderate-flow leakage, a vascularized middle turbinate flap was harvested and used for multilayer closure. For defects measuring 1–2 cm (n=27, 31.8%) or with high-flow leakage, a vascularized nasoseptal flap (NSF; Hadad-Bassagasteguy flap) was raised and rotated to cover the defect. A two-component fibrin sealant was applied as tissue glue to secure the graft in selected high-risk cases only (n=55, 64.7%), including defects larger than 7 mm and high-flow intraoperative leaks. (composition detailed in Operational Definitions above). In the remaining 30 patients (35.3%) with small defects (3–6 mm) or low-flow leaks, multilayer repair was performed without fibrin glue, consistent with literature showing no statistically significant difference in outcomes with or without fibrin glue use. For patients with high-flow intraoperative leaks (n=23, 27.1%), a lumbar drain was inserted intraoperatively for CSF diversion. (drain protocol as defined above). Multilayer (inlay/onlay) repair, as defined above, was employed in all 85 patients. While some studies suggest single-layer repair

may suffice for very small defects, we opted for multilayer reconstruction in all cases to ensure a watertight seal, particularly given the potential for undiagnosed IIH in spontaneous CSF leak patients.

Postoperative Care

All patients were advised to complete bed rest with the head elevated at a 30-degree angle for five days postoperatively. Intravenous ceftriaxone (2 grams every 12 hours) was administered for five days, followed by oral cefpodoxime (200 mg every 12 hours) for ten days. Acetazolamide (250 mg every 6 hours) and potassium chloride syrup (5–10 mL every 24 hours) were continued postoperatively. Acetazolamide was tapered gradually over six to eighteen weeks following discharge.

Follow-up

Postoperatively, patients were followed up at one month, three months, one year, and two years for recurrence of CSF leak. A recurrent leak was defined as the presence of clear fluid confirmed by positive clinical examination and CSF analysis or characteristic imaging findings, irrespective of endoscopic appearance. Recurrence of CSF leak was assessed using a combination of: (1) clinical history (any new or persistent clear nasal discharge, especially with head-down bending or Valsalva), (2) contrast-enhanced MRI (T2-weighted imaging to detect any intracranial or sinus fluid collection suggestive of recurrence) and (3) nasal endoscopy (direct visualization of the repair site for active leakage, fluid pooling, or graft failure). Surgical success was defined as complete closure of the defect with no clinical or radiological evidence of CSF leak recurrence at the three-month follow-up.

Outcomes

Primary Outcome (measured at 3 months): The primary outcome was the success rate of the

endoscopic endonasal multilayer repair technique, defined as the absence of clinical and radiological evidence of CSF leak at three-month follow-up after a single procedure.

Secondary Outcomes (measured at 3 months, 1 year, and 2 years):

The secondary outcomes included postoperative complications such as nasal crusting, sinusitis, meningitis, flap necrosis, nasal bleeding, and neurological deficits; the rate of spontaneous resolution of postoperative CSF leak; the need for secondary repair (reoperation); overall success after reoperation; long-term durability at 1 and 2 years; demographic and clinical characteristics including age, sex, BMI, comorbidities, defect site and size, and intraoperative flow characteristics; and the safety and efficacy of selective fibrin glue use, assessed by comparing outcomes between patients who received fibrin glue versus those who did not.

Statistical Analysis

This study was designed a priori as a single-arm descriptive case series without a comparator group; no comparative or inferential analysis was planned at the design stage. Data were analyzed using SPSS software version 24. Continuous variables are presented as mean $\pm$ standard deviation (SD), median, and range. Categorical variables are presented as frequency (n) and percentage (%). Due to the retrospective, descriptive design of this case series with a single patient group and no comparator arm, no inferential statistical tests (e.g., chi-square, t-test, logistic regression, or survival analysis) were performed. Subgroup comparisons by sex are presented for descriptive purposes only and should be interpreted as hypothesis-generating rather than confirmatory.

Algorithm for Management of Cases

Figure 4 illustrates the standardized management protocol followed for all 85 patients with

spontaneous CSF rhinorrhea in this study. All patients underwent endoscopic endonasal multilayer repair. The reconstructive technique was selected based on defect size: fascia lata or fat graft for 3–6 mm defects (32.9%), middle turbinate flap for 7–10 mm defects (35.3%), and nasoseptal flap for 1–2 cm defects (31.8%). Fibrin glue was used selectively in high-risk cases (64.7%). A lumbar drain was placed for high-flow leaks (27.1%). The primary success rate was 97.6%, with 2.4% requiring reoperation, achieving 100% overall success.

RESULTS

Illustrative Case 1: A representative case among the 85 operated cases included a 63-year-old male who presented with a history of persistent, spontaneous clear fluid discharge from the right nasal cavity. In accordance with the study protocol, the diagnosis was established clinically and confirmed via 3D T2-weighted MRI in the prone position, which localized the site of the leak. Complementary high-resolution CT (HRCT) was utilized to map the specific osseous anatomy of the skull base. Radiological Findings: Imaging identified an 11 mm bony defect situated in the lateral wall of the right sphenoid sinus (Sternberg's Canal area). MRI sequences demonstrated a meningo-encephalocele, characterized by the herniation of the inferomedial temporal lobe into the sinus cavity. Notably, the presence of an "empty sella" and mildly dilated perioptic CSF sheaths provided strong radiographic evidence of underlying Idiopathic Intracranial Hypertension (IIH), a common driver in spontaneous etiologies (**Figure 5-7**). The patient underwent an endoscopic multilayer repair, featuring encephalocele reduction and reconstruction with a vascularized Middle Turbinate Flap (MTF). This vascularized approach was chosen over free grafts to provide a more robust seal against suspected elevated intracranial pressure. Postoperative care included five days of bed rest and a tapered course

of Acetazolamide to manage underlying intracranial hypertension. At the three-month, one- and two-year follow-up, endoscopy and MRI confirmed a successful repair with no recurrence.

Note: Written informed consent was obtained from the patient for publication of this case and any

accompanying images/Scans (Figures 5- 7). The patient has permitted the use of anonymized radiological scans and clinical images in this article. A copy of the written consent is available for review by the Editor-in-Chief of this journal upon request.

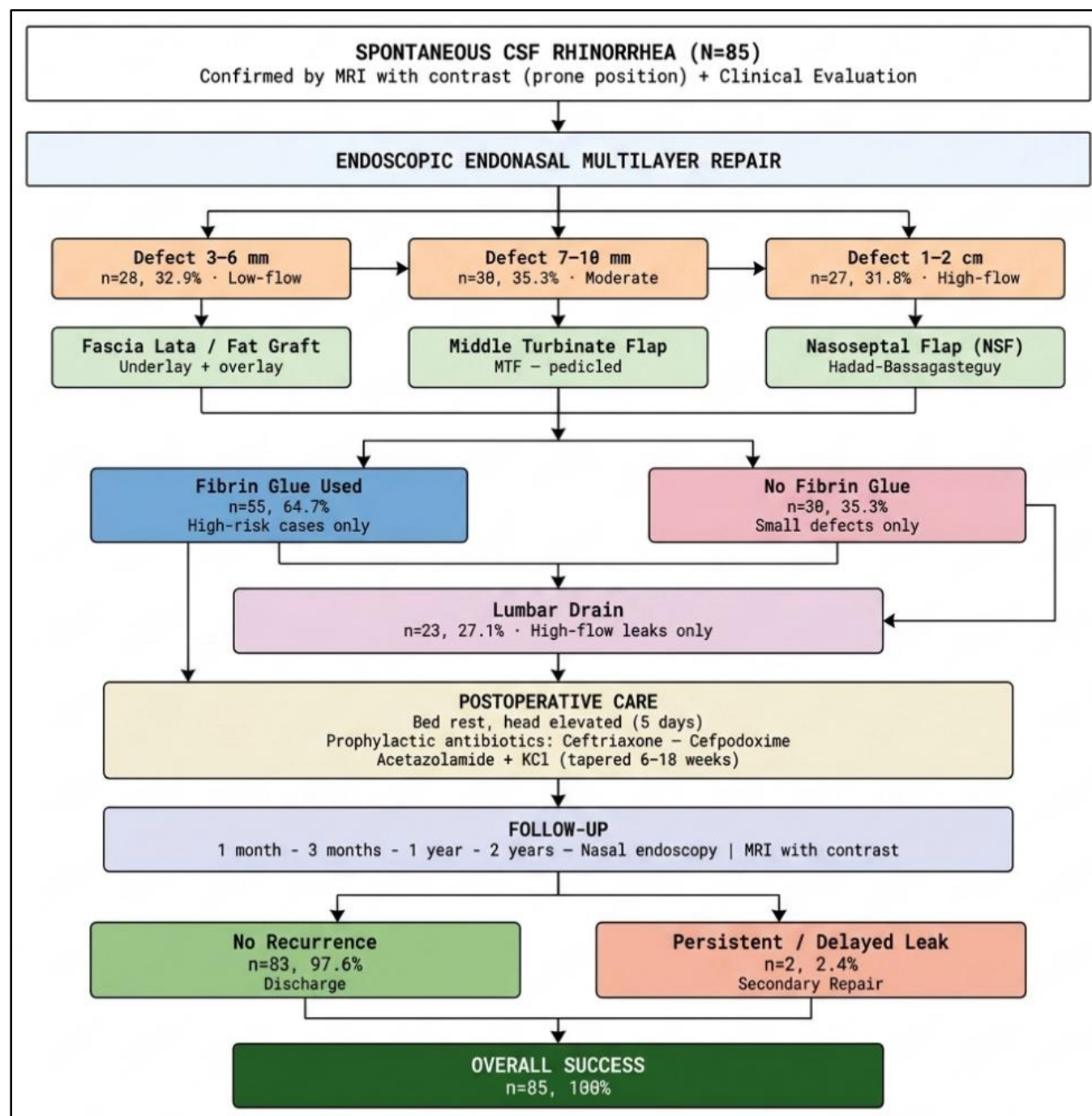


Figure-4: Standardized management protocol.



Figure 5: Axial T2-weighted MRI demonstrating a hyperintense CSF signal and brain tissue herniation (arrow) through a lateral wall defect of the right sphenoid sinus, consistent with a sphenoid meningo-encephalocele. (with permission from the patient).

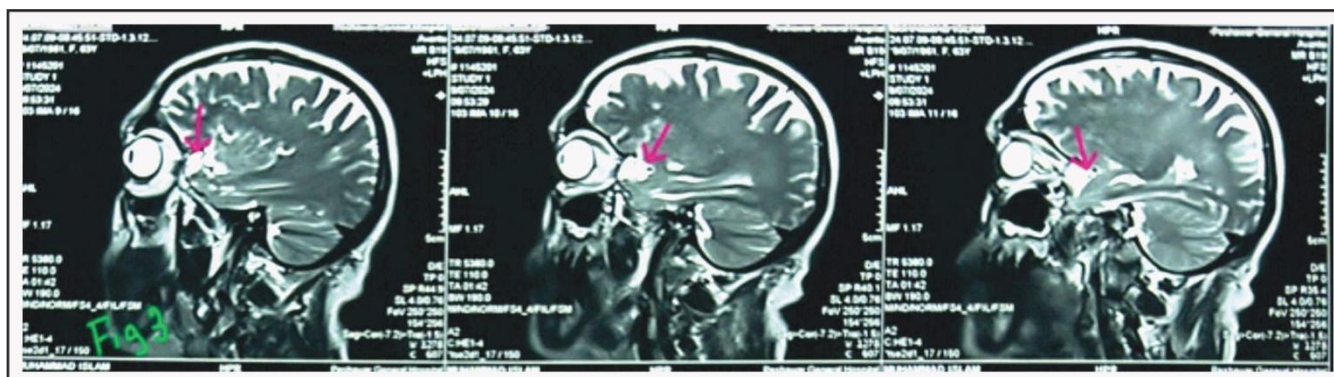


Figure 6: Sagittal T2-weighted MRI sequences illustrating the inferomedial herniation of the temporal lobe (arrows) into the right sphenoid sinus through the lateral wall bony defect. (with permission from the patient).

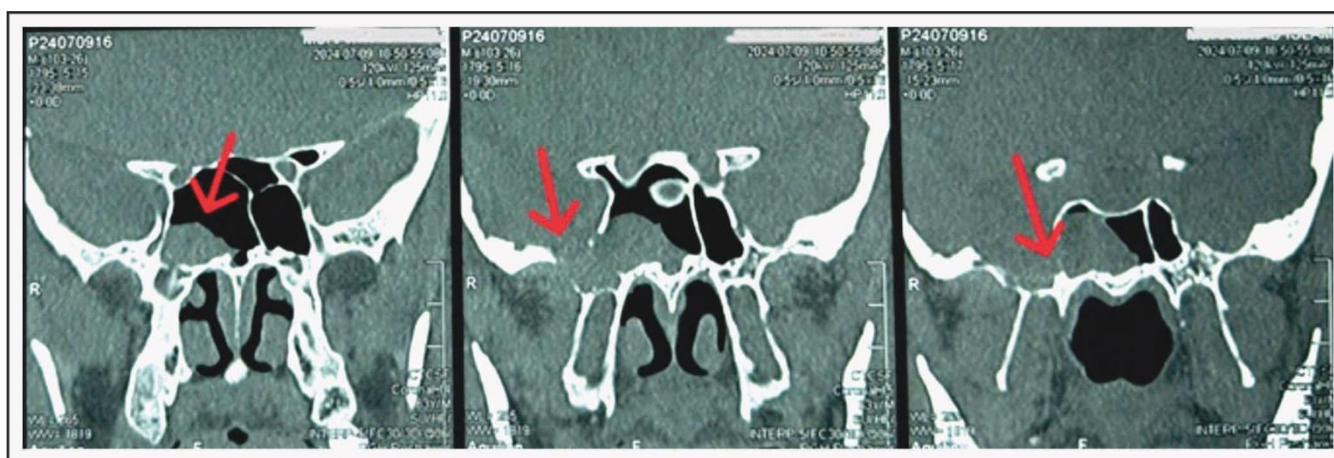


Figure 7: Coronal CT of the paranasal sinuses (bone window) revealing a significant osseous defect in the lateral wall of the right sphenoid sinus (arrows), providing the anatomical basis for the meningo-encephalocele seen on MRI. (with permission from the patient).

Illustrative Case 2

A second representative case involved a 43-year-old female presenting with a 12-day history of clear, watery rhinorrhea from her right nostril, with High-resolution CT (HRCT) of the paranasal sinuses and skull base precisely identifying the anatomical source of the leak (**Figure 5**). Multiplanar CT reconstructions demonstrated a definitive 3.2 mm osseous defect located in the right sphenoid sinus. On the axial view, the focal bone thinning and structural discontinuity were isolated along the lateral recesses of the sinus. Coronal and magnified bone-window views further highlighted a distinct osseous gap in the superolateral wall of the right sphenoid sinus, accompanied by a soft-tissue density protruding directly through the

bony defect, consistent with a small sphenoid meningocele. The patient underwent a successful endoscopic endonasal multilayer repair using an autologous fascia lata and adipose tissue graft. No fibrin sealant was utilized, in accordance with our protocol for small defects with low-flow leakage. Postoperative management included five days of bed rest and a tapered course of acetazolamide. At her 3-month follow-up, evaluation confirmed complete defect closure and zero recurrence.

Note: Written informed consent was obtained from the patient for publication of this case and any accompanying images/Scans (Figure 8). The patient has permitted the use of anonymized radiological scans and clinical images in this article. A copy of the written consent is available for review by the Editor-in-Chief of this journal upon request.

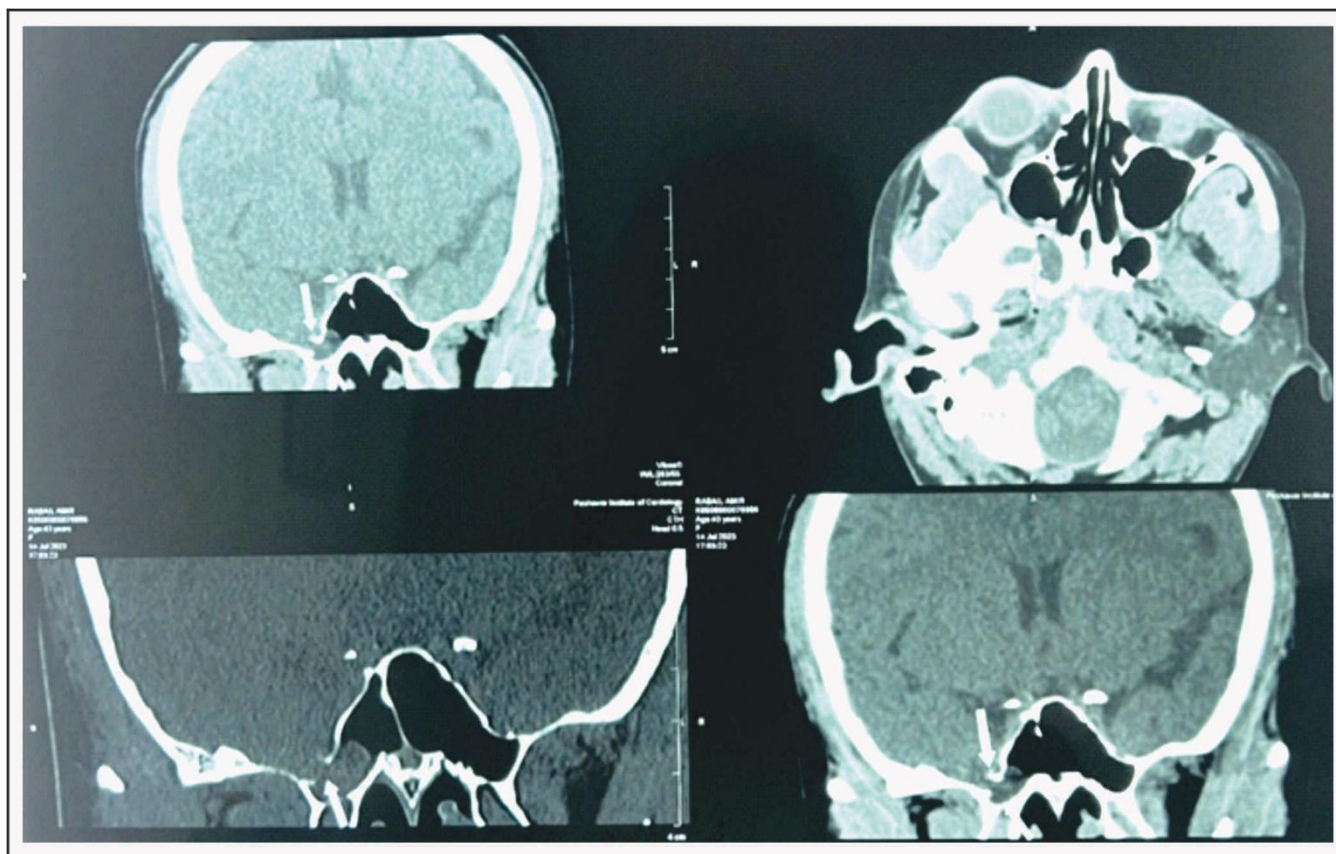


Figure 8: High-resolution multiplanar CT scan of the paranasal sinuses (bone window) revealing a 3.2 mm osseous defect in the right sphenoid sinus. The top-right axial panel highlights focal bony dehiscence along the lateral wall. The coronal panels (top-left, bottom-left, and bottom-right) clearly delineate the vertical osseous gap in the superolateral wall of the right sphenoid sinus (arrows) with an associated small meningocele protruding into the sinus cavity. (with permission from the patient).

Illustrative Case 3

A third representative case from our series involved an 8-year-old female patient who presented with a history of spontaneous clear fluid discharge from the right nasal cavity. This was a highly complicated case, further distinguished by a critical clinical history of preoperative meningitis related to the persistent skull base defect. High-resolution neuroimaging was deployed to map the pathology before surgical intervention. Axial, sagittal, and coronal multiplanar MRI sequences, complemented by thin-slice CT imaging, confirmed a localized skull base defect within the right anterior cranial fossa.

Radiological analysis demonstrated an 8 mm osseous defect within the right cribriform plate. MRI sequences illustrated a corresponding 8–9 mm fronto-ethmoidal meningoencephalocele, characterized by the herniation of a small component of the right frontal lobe parenchyma and matching cerebrospinal fluid (CSF) signal directly through the cribriform gap into the right ethmoid air cells. Persistent fluid accumulation was observed distending the right ethmoid sinus and extending inferiorly down the nasal cavity, accompanied by reactive fluid-mucosal changes within the bilateral paranasal sinuses. Due to the

complex nature of the leak and the patient's history of recurrent central nervous system infection, an aggressive reconstructive approach was selected. The patient underwent an endoscopic endonasal multilayer repair. Following the reduction of the herniated tissue, an autologous adipose (fat) graft was placed as an initial inlay plug. To provide a robust vascularized barrier against future infectious tracts, a pedicled Nasoseptal Flap (NSF) was harvested and rotated to completely cover the defect site. A two-component fibrin sealant tissue glue was selectively applied to secure the multilayer graft complex and eliminate any micro-gaps. Postoperative management included strict bed rest and systemic pressure management. At her 3-month clinical follow-up, endoscopic examination and contrast MRI confirmed complete flap integration, total mucosal healing, and absolute resolution of the leak with no structural recurrence (**Figure 9-14**).

Note: Written informed consent was obtained from the patient for publication of this case and any accompanying images/Scans (Figures 9-14). The patient has permitted the use of anonymized radiological scans and clinical images in this article. A copy of the written consent is available for review by the Editor-in-Chief of this journal upon request.

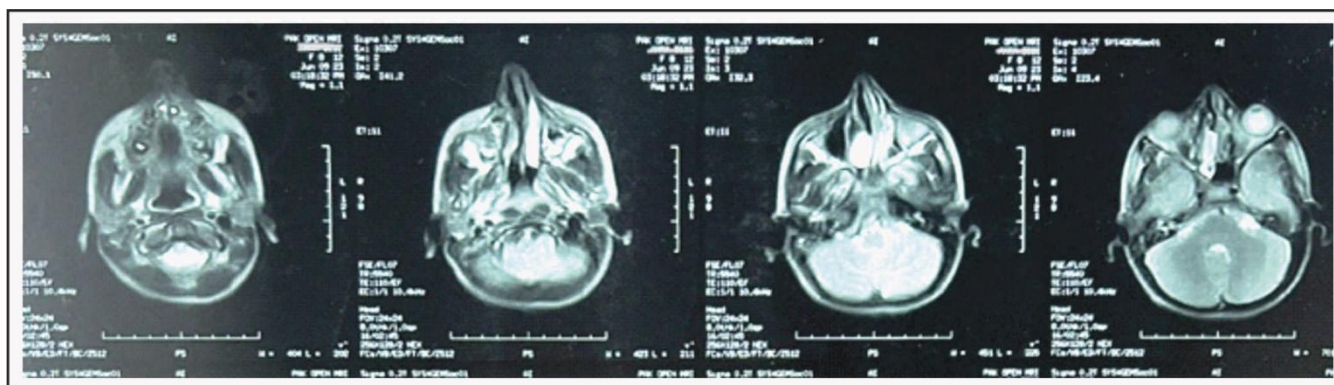


Figure 9: Axial T2-weighted MRI sequences showcasing a hyperintense CSF collection and focal structural pathway expansion within the anterior skull base, tracking asymmetric fluid accumulation directly along the right nasal pathway. This initial axial screen establishes clear lateralization of the active fluid trail into the right-sided nasal vault. Accurately locating early fluid asymmetric tracking on axial scans prevents unnecessary exploration of contralateral paranasal sinuses during endonasal mapping (with permission from the patient).

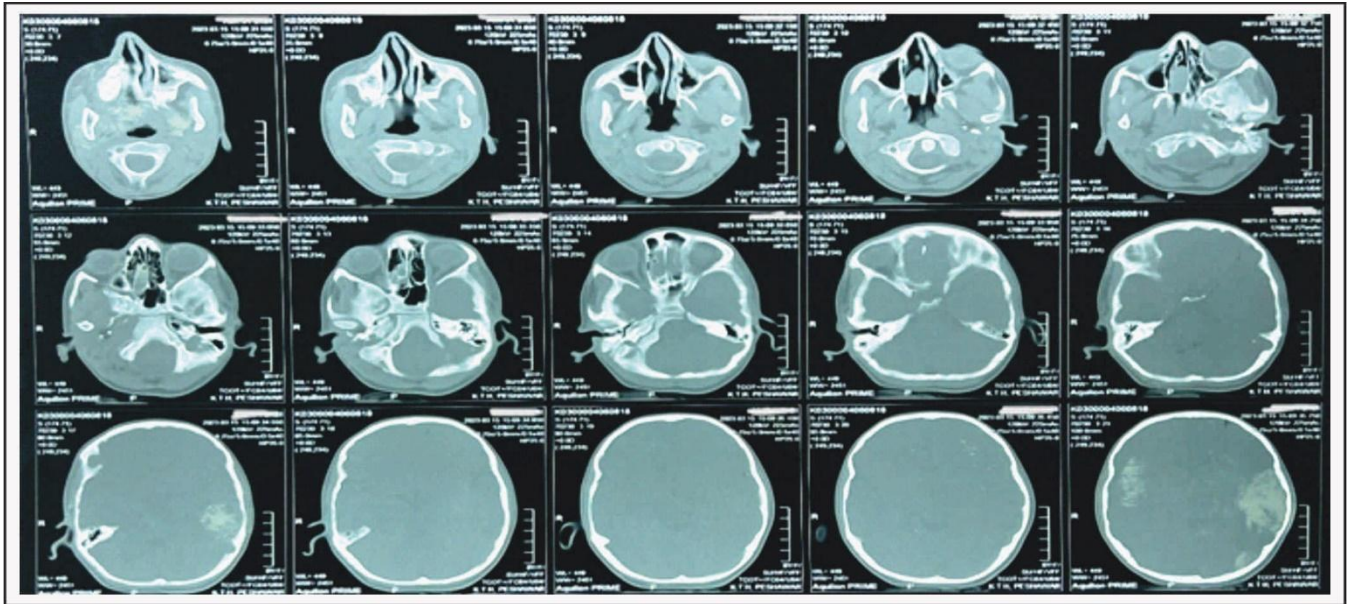


Figure 10: High-resolution sequential axial CT scans of the paranasal sinuses and skull base (bone window) delineating structural attenuation and focal bone-window gaps localized near the right ethmoid ceiling. The thin-slice CT series maps the exact micro-ossseous boundary layers surrounding the right cribriform anatomy. This skeletal delineation is fundamental to determining the absolute defect dimensions before choosing local vascularized flaps over free tissue flaps (with permission from the patient).

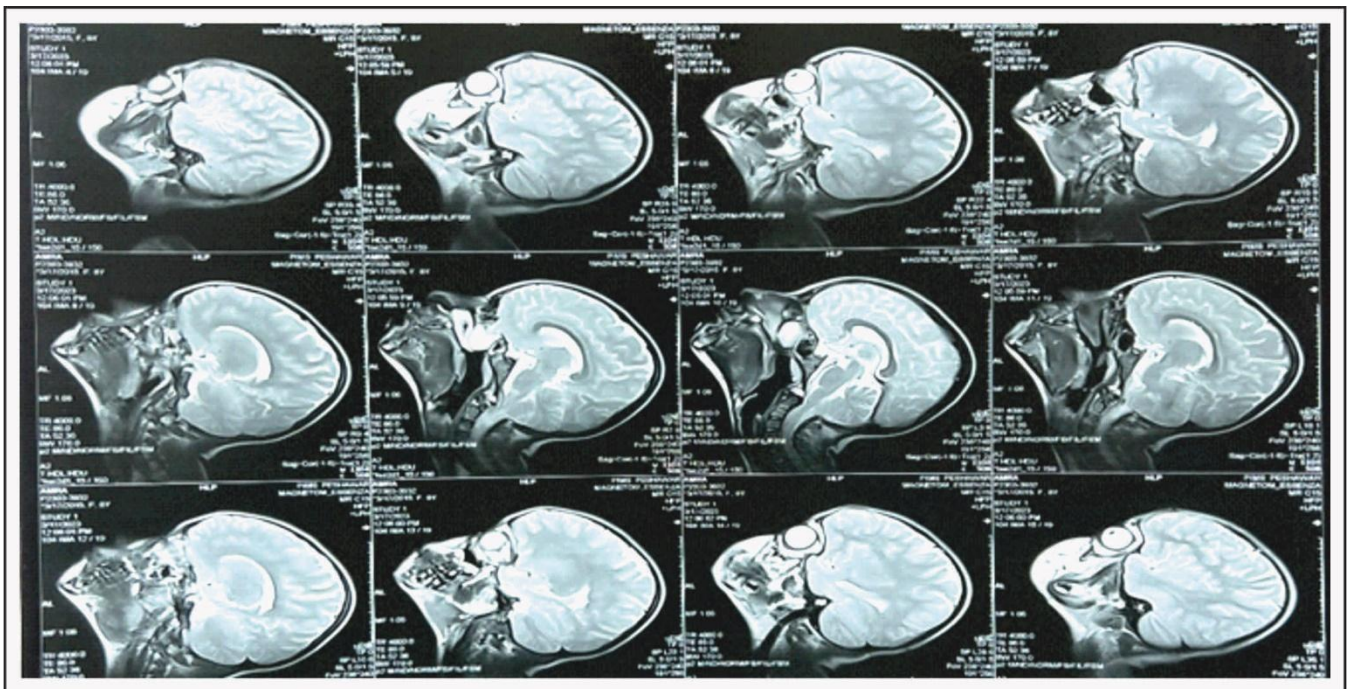


Figure 11: Multi-sequential sagittal T2-weighted MRI views demonstrating the explicit soft-tissue herniation of the inferior frontal lobe margin (meningoencephalocele) extending directly down into the ethmoid sinus boundaries. Sagittal imaging planes provide the best visual baseline to assess the vertical drop and mass effect of a herniated fronto-ethmoidal meningoencephalocele. Visualizing this deep downward path informs the surgeon of the necessary tissue depth required for an inlay reconstructive setup (with permission from the patient).

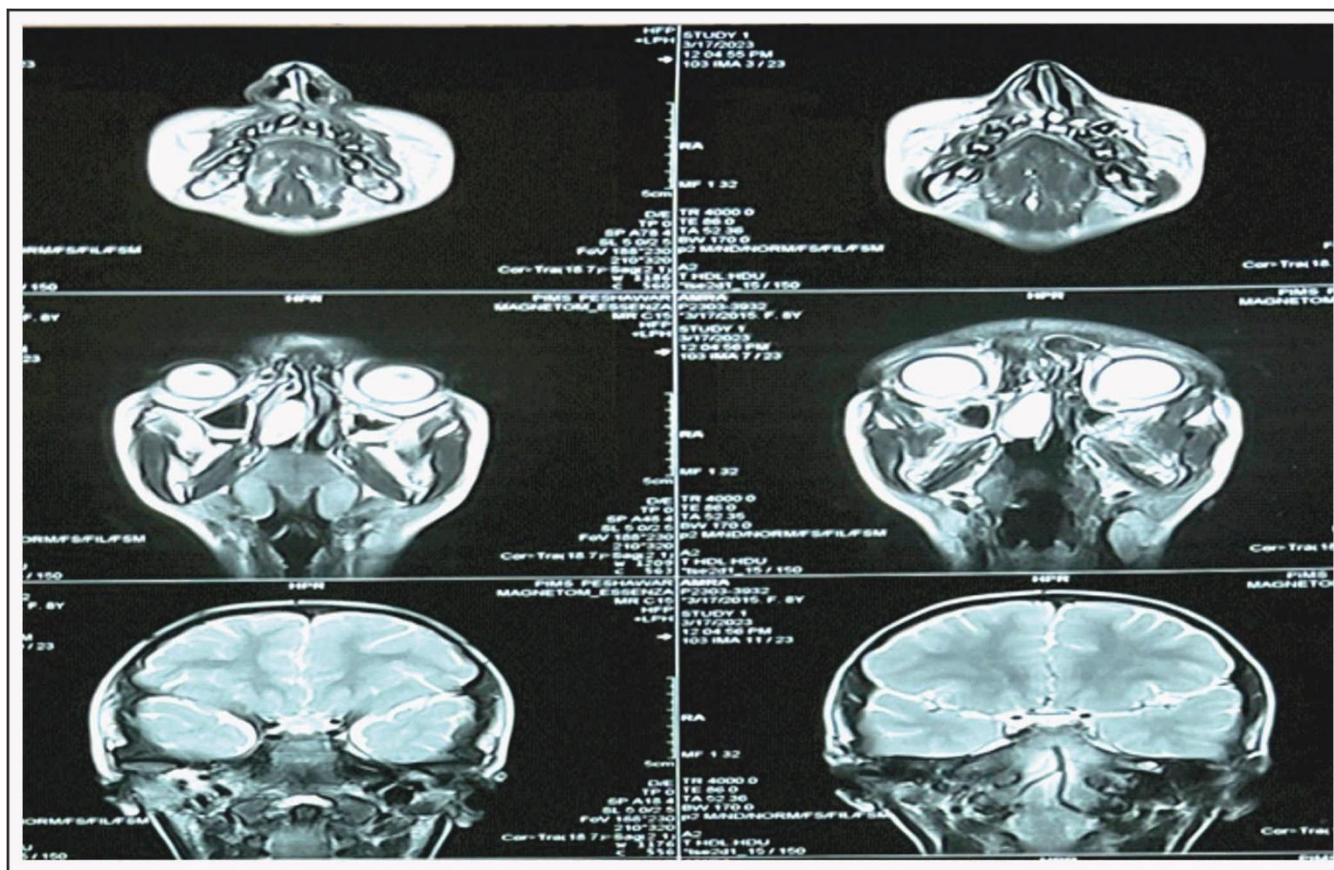


Figure 12: Coronal T2-weighted MRI frames highlighting a prominent soft-tissue mass configuration and fluid pocket within the right ethmoid sinus complex, passing directly through the right cribriform plate line. The coronal views visually validate the final diagnostic criteria by showing the horizontal boundaries of the 8 mm defect gap. To guarantee total coverage over the margins of the exposed skull base, this particular view helps in identifying the structural harvesting limits of the vascularized Nasoseptal Flap (NSF). (Permission granted by patient).

A zero-degree endoscope was introduced into the right nasal cavity under general anesthesia. The right middle turbinate (MT) was carefully sectioned and partially removed for direct visualization and surgical exposure of the anterior skull base defect (**Figure 13A, B**). The underlying pathology, a characteristic bony defect with a pulsating meningocele protruding from the cribriform plate region, was confirmed due to the wide exposure (**Figure 13B**). The herniated sac was reduced, and the bony margins of the defect were carefully skeletonized. From the nasal septum, a vascularized nasoseptal flap (NSF; Hadad-Bassagasteguy flap) was then harvested and adjusted to provide adequate surface coverage for effective skull base reconstruction (**Figure 13C**).

Multilayer skull base reconstruction was performed using a graded, defect-based approach. An autologous fat graft was first plugged into the osteo-dural defect to eliminate dead space and establish an inlay barrier. Surgicel was used to reinforce the site, and a two-component fibrin sealant (fibrin glue) was selectively applied for stronger tissue adhesion and initial waterproofing over the small-defect interface (**Figure 13D**). Finally, to guarantee structural integrity and long-term vascularized closure, the pedicled nasoseptal flap was rotated over the reconstructed site and carefully approximated to cover all exposed bone edges (**Figure 13D**).

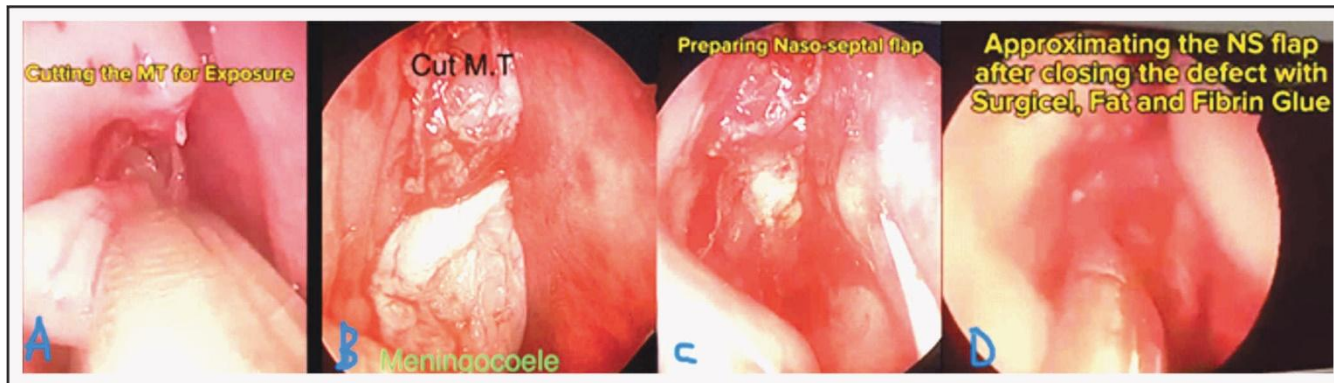


Figure 13: Intraoperative endoscopic views of the multilayer skull base repair for Case 3. **(A)** Partial sectioning and removal of the right middle turbinate (MT) for a broad surgical exposure of the anterior cranial fossa roof. **(B)** Clear visualization of the right cribriform meningocele following turbinate reduction. **(C)** Preparation, harvesting, and mobilization of the vascularized nasoseptal flap (NSF). **(D)** Final approximation and placement of the pedicled nasoseptal flap over the cribriform defect after achieving an initial multi-layered seal using Surgicel, an autologous fat graft, and selective fibrin tissue glue application (with permission from the patient).

Postoperative clinical monitoring via rigid nasal endoscopy confirmed excellent evolutionary healing of the reconstructive surgical site. At the 3-month follow-up visit, endonasal evaluation demonstrated stable graft positioning with localized, expected structural remodeling and healthy mucosalization surrounding the flap margins (**Figure 14A**). Long-term surveillance at the 2-year postoperative mark revealed complete, mature mucosal integration of the pedicled nasoseptal flap within the anterior skull base roof

(**Figure 14B, C**). The neocavity showed smooth, healthy, well-perfused respiratory epithelium with a total absence of localized crusting, chronic inflammatory synechiae, tissue necrosis, or structural breakdown. Most importantly, provocative endoscopic testing and patient history confirmed complete permanent closure of the defect site with zero clinical signs of recurrent cerebrospinal fluid (CSF) rhinorrhea over the extended 2-year monitoring period (with permission from the patient).

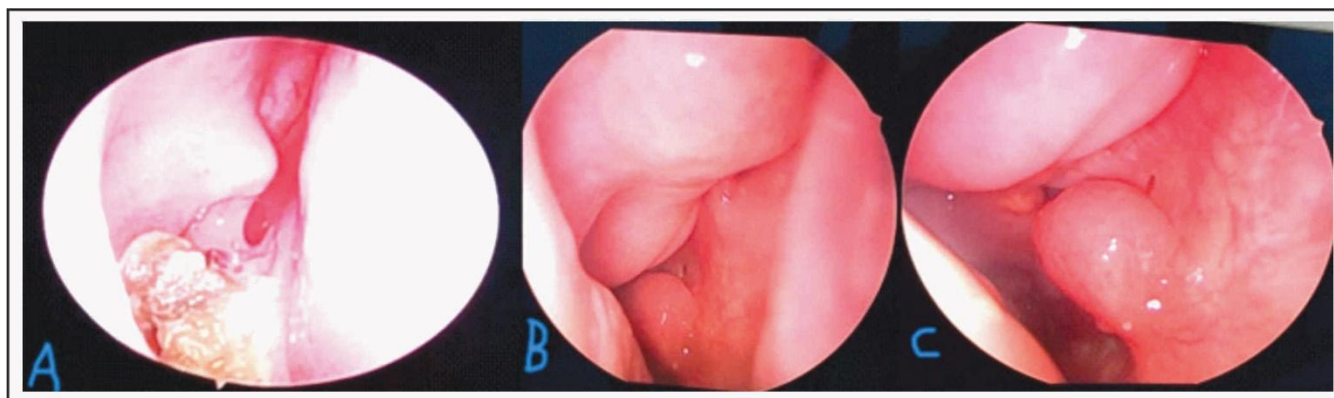


Figure 14: Postoperative rigid nasal endoscopy follow-up images for Case 3. **(A)** Endoscopic view at 3 months post-repair showing expected early mucosalization, stable flap positioning, and structural healing over the right anterior skull base. **(B and C)** Excellent structural preservation, mature epithelial integration of the vascularized nasoseptal flap, and a completely dry, healthy nasal cavity with no evidence of leak recurrence shown on long-term endoscopic evaluation at 2 years postoperatively. (with permission from the patient).

This retrospective study included a total of 85 patients with spontaneous cerebrospinal fluid (CSF) rhinorrhea. The patients were predominantly female (68.2%), with a mean age of 39 ± 14.3 years and mean body mass index (BMI) of 28 ± 3.6 kg/m². The most common comorbidity in the cohort was hypertension (11.8%). Low-flow intraoperative leaks were observed in 72.9% of patients, with the cribriform plate being the most frequent defect site (64.7%). Reconstructive technique was assigned based on defect size, which is as follows: fascia lata/fat graft for 3–6 mm defects (32.9%), middle turbinate flap for 7–10 mm defects (35.3%), and nasoseptal flap for 1–2 cm defects (31.8%). For high-flow leaks (27.1%), lumbar drains were placed, and fibrin glue was used selectively in high-risk cases (64.7%). Nasal crusting (15.3%) and sinusitis (11.8%) were the complications seen postoperatively. Postoperative CSF leak occurred in 5 patients (5.9%), of whom 2 (2.4%) required intervention. The primary success rate was 97.6% (83/85), and overall success after secondary repair was 100%. No significant differences were seen between male and female patients, apart from a slightly higher BMI in females (29 vs 26.5 kg/m²).

Table 1 represents the baseline demographics

Table 1: Demographic and Baseline Characteristics.

Parameter	Value
Age (years), mean $\pm$ SD	39 $\pm$ 14.3
Age (years), median (range)	38 (18–72)
Sex, n (%)	
Male	27 (31.8%)
Female	58 (68.2%)
BMI (kg/m ²), mean $\pm$ SD	28 $\pm$ 3.6
BMI (kg/m ²), median (range)	27.5 (17.5–42)
BMI Category, n (%)	
– Underweight (<18.5)	8 (9.4%)
– Normal (18.5–24.9)	28 (32.9%)
– Overweight (25–29.9)	39 (45.9%)
– Obese ($\geq$ 30)	10 (11.8%)
– Morbidly Obese (>40)	5 (5.9%)
Hospital stays (days), mean $\pm$ SD	2 $\pm$ 0.5
Hospital stays (days), range	1–4

characteristics of the 85 patients included in this study. The mean age was 39 ± 14.3 years, with a female predominance (68.2%). The mean body mass index (BMI) was 28 ± 3.6 kg/m², and the majority of patients were either overweight or obese.

Table 2 presents the clinical history and comorbid conditions of the study cohort. All patients (100%) presented with spontaneous CSF rhinorrhea, and 75.3% had no documented comorbidities. Among those with comorbidities, hypertension (11.8%) was the most common, followed by morbid obesity (5.9%).

Table 2: Clinical History and Comorbidities.

Parameter	n (%)
Etiology	
Spontaneous CSF leak	85 (100%)
IIH/BIH associated	3 (3.5%)
Comorbidities	
Hypertension	10 (11.8%)
Morbid Obesity (BMI >40)	5 (5.9%)
CRSwNP	3 (3.5%)
IIH (radiologic findings)	3 (3.5%)
None	64 (75.3%)
Presenting Symptoms	
CSF Rhinorrhea	85 (100%)
Headache	60 (70.6%)
Pre-op Meningitis	3 (3.5%)
Visual disturbance	2 (2.4%)
History of Pre-op Meningitis	3 (3.5%)

Table 3 details radiological and intraoperative findings, including defect location, size, associated anatomical abnormalities, and CSF flow characteristics. The cribriform plate was the most common site of CSF leak (64.7%), and most patients (72.9%) had low-flow intraoperative leaks. Lumbar drains were used in 27.1% of patients, primarily in cases with high-flow leaks.

Table 4 summarizes surgical and reconstructive details. All 85 patients underwent endoscopic endonasal multilayer repair. Reconstruction was defect size-based, with fascia/fat graft used for 3–

6 mm defects (32.9%), middle turbinate flap for 7–10 mm defects (35.3%), and nasoseptal flap for 1–2 cm defects (31.8%). Fibrin glue was used selectively in high-risk cases (64.7%), with the

highest usage was observed in nasoseptal flap cases (25.9%). Lumbar drains were placed for high-flow leaks (27.1%).

Table 5 reports postoperative complications observed during the follow-up period. The most common complications were nasal crusting (15.3%) and sinusitis (11.8%). Postoperative CSF leak occurred in 5 patients (5.9%), with spontaneous resolution in 3 cases and 2 requiring secondary repair. No cases of flap necrosis, postoperative meningitis, or new neurological deficits were observed.

Table 3: Radiological and Intraoperative Findings.

Parameter	n (%)
Defect Site	
Cribriform plate	55 (64.7%)
Ethmoid roof	23 (27.1%)
Sphenoid sinus	8 (9.4%)
Defect Size	
3–6 mm	28 (32.9%)
7–10 mm	30 (35.3%)
1–2 cm	27 (31.8%)
Associated Anatomical Abnormality	
Meningocele	5 (5.9%)
Meningoencephalocele	3 (3.5%)
Empty sella (IIH finding)	3 (3.5%)
None	74 (87.1%)
Intraoperative CSF Flow	
Low-flow	62 (72.9%)
High-flow	23 (27.1%)
Lumbar Drain Placed	23 (27.1%)

Table 5: Postoperative Complications.

Complication	n (%)
Nasal crusting	13 (15.3%)
Sinusitis	10 (11.8%)
Postoperative CSF leak (total)	5 (5.9%)
– Spontaneous resolution	3 (3.5%)
– Required secondary repair	2 (2.4%)
Flap necrosis/graft failure	0 (0%)
Postoperative meningitis	0 (0%)
Postoperative nasal bleeding	0 (0%)
New neurological deficit	0 (0%)

Table 4: Surgical and Reconstructive Details.

Parameter	n (%)
Surgical Approach	
Endoscopic endonasal	85 (100%)
Repair Technique	
Multilayer (inlay/onlay)	85 (100%)
Reconstructive Material (by defect size)	
Fascia lata / Fat graft (for 3–6 mm defects)	28 (32.9%)
Middle turbinate flap (for 7–10 mm defects)	30 (35.3%)
Nasoseptal flap (NSF) (for 1–2 cm defects)	27 (31.8%)
Adjunctive Measures	
Fibrin glue used (selective, high-risk)	55 (64.7%)
Lumbar drain placed (for high-flow leaks)	23 (27.1%)
Reconstructive Technique with Fibrin Glue Subgroup	
Fascia lata / Fat graft alone	15 (17.6%)
Fascia lata / Fat graft + Fibrin glue	13 (15.3%)
Middle turbinate flap alone	10 (11.8%)
Middle turbinate flap + Fibrin glue	20 (23.5%)
Nasoseptal flap alone	5 (5.9%)
Nasoseptal flap + Fibrin glue	22 (25.9%)
Total fibrin glue used (all techniques)	55 (64.7%)

Table 6 summarizes postoperative outcomes by technique at 3 months, 1 year, and 2 years. Primary success at 3 months was 100% for fascia/fat graft (n=28), 96.7% for middle turbinate flap (n=30), and 96.3% for nasoseptal flap (n=27). Two patients (2.4%) required reoperation (one MTF, one NSF), achieving 100% overall success after secondary repair. At 1 year, no additional recurrences were observed. At 2 years, success rates were 100% for fascia/fat graft, 93.3% for MTF, and 92.6% for NSF, with an overall success rate of 95.3%. Fibrin glue was used selectively in high-risk cases (64.7%), with the highest usage in the NSF group (25.9%).

Table 7 presents the extended follow-up outcomes at 3 months, 1 year, and 2 years for the entire cohort. At 3 months, the success rate was 97.6% (83/85). At 1 year, all 83 were successful

Table 6: Primary and Secondary Outcomes.

Technique	n (%)	Fibrin Glue Used	Primary Success (3 months)	Success at 1 Year	Success at 2 Years	Reoperation Rate
Fascia lata / Fat graft	28 (32.9%)	13 (15.3%)	28 (100%)	28 (100%)	28 (100%)	0 (0%)
Middle turbinate flap	30 (35.3%)	20 (23.5%)	29 (96.7%)	29 (96.7%)	28 (93.3%)	1 (3.3%)
Nasoseptal flap (NSF)	27 (31.8%)	22 (25.9%)	26 (96.3%)	26 (96.3%)	25 (92.6%)	1 (3.7%)
Total	85 (100%)	55 (64.7%)	83 (97.6%)	83 (97.6%)	81 (95.3%)	2 (2.4%)

repaired patients remained recurrence-free, maintaining a success rate of 97.6%. At 2 years, the success rate was 95.3% (81/85), with two late recurrences potentially occurring in patients with underlying IIH or elevated BMI.

Table 8 evaluates long-term durability stratified by risk factors, including IIH status, BMI, and intraoperative flow characteristics. Patients without radiologic evidence of IIH (n=82) demonstrated a 2-year success rate of 96.3%, compared to 66.7% in those with empty sella findings (n=3). Similarly, patients with BMI <30 (n=70) had a 2-year success rate of 97.1%, compared to 86.7% in those with BMI ≥30 (n=15). Low-flow leaks (n=62) were associated with a 2-year success rate of 98.4%, whereas high-flow leaks (n=23) had a rate of 87.0%. These findings highlight the importance of addressing underlying IIH and obesity in reducing the risk of late recurrence.

Table 7: Extended Follow-Up Outcomes.

Follow-Up Period	Patients Evaluated (n)	Success Rate (%)	Late Recurrence (n)	Cumulative Success (%)
3 months	85	83 (97.6%)	—	97.60%
1 year	85	83 (97.6%)	0	97.60%
2 years	85	81 (95.3%)	2 (2.4%)	95.3%

Table 8: Long-Term Durability by Risk Factor.

Risk Factor	n	Success at 3 Months	Success at 1 Year	Success at 2 Years
No IIH (radiologic)	82	80 (97.6%)	80 (97.6%)	79 (96.3%)
IIH (empty sella present)	3	3 (100%)	3 (100%)	2 (66.7%)
BMI < 30	70	69 (98.6%)	69 (98.6%)	68 (97.1%)
BMI ≥ 30	15	14 (93.3%)	14 (93.3%)	13 (86.7%)
Low-flow leak	62	62 (100%)	62 (100%)	61 (98.4%)
High-flow leak	23	21 (91.3%)	21 (91.3%)	20 (87.0%)

Table 9 compares the outcomes of our study with published literature on long-term success and late recurrence rates. Our 3-month primary success rate of 97.6% compares favorably with the 93.7% pooled rate reported in a 2026 meta-analysis by Mughal et al. Our 2-year success rate of 95.3% is consistent with landmark studies by Gassner et al,

Table 9: Comparison with Literature (Long-Term Outcomes).

Study	Follow-Up Duration	Success Rate	Late Recurrence Rate
Our Study	3 months	97.60%	—
Our Study	1 year	97.60%	0%
Our Study	2 years	95.30%	2.40%
Gassner et al. (1999)	Long-term (Mayo Clinic)	95%	5%
Kirtane et al. (2005)	Long-term (267 cases)	97%	3%
Lobo et al. (2017)	Systematic review	90%	10%
Mughal et al. (2026 meta-analysis)	Variable	93.7% (primary)	6.30%

(95% at Mayo Clinic) and Kirtane et al, (97% in 267 cases). The late recurrence rate of 2.4% at 2 years is within the 3-10% range reported in the literature.

Table 10 presents a descriptive comparison of key parameters between male and female patients. As no inferential statistical testing was performed in this descriptive case series, the findings are intended to be hypothesis-generating only. Females demonstrated a slightly higher BMI (29 vs. 26.5 kg/m²) and a marginally higher primary success rate (98.3% vs. 96.3%). One patient in each group required secondary repair. Late recurrence beyond 3 months was in one male (3.7%) and one female (1.7%).

Table 11 summarizes all continuous variables for the entire cohort, presented as mean, standard deviation, median, and range, to provide an overview of their distribution.

Table 10: Sex-Wise Distribution with Extended Follow-Up.

Parameter	Male (n=27)	Female (n=58)
Age (years), mean $\pm$ SD	38 $\pm$ 13.5	40 $\pm$ 14.8
BMI (kg/m ²), mean $\pm$ SD	26.5 $\pm$ 3.0	29 $\pm$ 3.8
Hospital stays (days), mean $\pm$ SD	2 $\pm$ 0.5	2 $\pm$ 0.5
Cribriform plate defect, n (%)	18 (66.7%)	37 (63.8%)
High-flow leak, n (%)	7 (25.9%)	16 (27.6%)
Successful primary repair, n (%)	26 (96.3%)	57 (98.3%)
Success at 1 year, n (%)	26 (96.3%)	57 (98.3%)
Success at 2 years, n (%)	25 (92.6%)	56 (96.6%)
Postoperative CSF leak, n (%)	2 (7.4%)	3 (5.2%)
Required secondary repair, n (%)	1 (3.7%)	1 (1.7%)
Late recurrence (after 3 months), n (%)	1 (3.7%)	1 (1.7%)

Table 11: Summary of Continuous Variables.

Variable	Mean	SD	Median	Min	Max
Age (years)	39	$\pm$ 14.3	38	18	72
BMI (kg/m ²)	28	$\pm$ 3.6	27.5	17.5	42
Hospital stays (days)	2	$\pm$ 0.5	2	1	4
Defect size (mm)	7.8	$\pm$ 3.2	8	3	18
Follow-up (months)	3	0	3	3	3

DISCUSSION

Prevalence of sCSF: Though far less common than traumatic or postsurgical leaks, spontaneous cerebrospinal fluid (CSF) rhinorrhea is a rare subtype of CSF leaks, and its occurrence seems to be rising, especially in some at-risk groups. This pool represents only a few percent of the total CSF rhinorrhea occurrences, all depending on the series and definitions. In older literature from 1991, about 3-4% of all CSF fistulas are classified as spontaneous.²¹ A systematic review of all etiologies in 2021 reports 28% spontaneous, 44% traumatic, and 12% iatrogenic cases.² In more recent studies, like in this clinical case series of 293 primary CSF leaks, the spontaneous CSF cases were found to be 42 (14.3%); the rest were post-traumatic. Among the 42 cases, 37 were associated with high CSF pressure readings.²² Even though the relative percent prevalence of sCSF leaks is not overwhelming, there is an absolute increase in

stats over the years that is parallel with the increasing obesity and IIH, which strongly supportive of causing the once spontaneous CSF leaks.

Demographics comparison: Spontaneous CSF rhinorrhea is consistently linked worldwide to specific demographic trends, including middle age, female sex, and elevated BMI, often with features of raised intracranial pressure. While Asian studies frequently depict overweight or obesity relative to generally slimmer baseline populations, Western reporting typically emphasizes blatant obesity. The mean age reported in our study was 39 $\pm$ 14.3 years, with a female predominance (68.2%). The mean body mass index (BMI) was 28 $\pm$ 3.6 kg/m², and the majority of patients were either overweight or obese. sCSF rhinorrhea cohorts in South and wider Asia have also consistently shown a mid-life mean age. A single-center experience of CSF rhinorrhea reports a

mean age of 36.7 ± 12.3 years (9–62 years).²³ Males had a lower average BMI (28.7) than females (32). A narrative review of 26 articles reported an average age of 46.8 ± 6.5 years and an average body mass index of 35.8 ± 4.8 ; even in this study, females are dominant with 74.33%.²⁴ Spontaneous CSF Rhinorrhea (sCSF) is obviously and consistently more common in women, usually those who are overweight or obese, in both Western and Asian/Middle Eastern contexts. In a retrospective study conducted in China about primary spontaneous CSF rhinorrhea, of a total of 21 patients, 18 were females, with the majority in the overweight/obese category.²⁵ Even in mixed etiological series, spontaneous CSF leaks were predominantly found in females with high BMI.²⁶ Similarly, an Indian study showed female predominance (70%).²⁷ A large narrative review of 943 patients with IIH and spontaneous CSF leaks reported a mean age of 46.8 ± 6.5 years, BMI of 35.8 ± 4.8 , and a female percentage of 74%.²⁸

IIH and associated symptoms/anatomical abnormalities: In our study, among 85 patients with spontaneous CSF leak, 3 patients (3.5%) were defined as cases of idiopathic intracranial hypertension. IIH and sCSF leak have a very close cause-and-effect relationship; sCSF leak is seen as a spectrum of IIH, rather than the former being truly idiopathic. These patients share similar demographic characteristics, radiological imaging, and intracranial pressure profiles, but an active leak masks the usual symptoms of associated IIH until after closure of the leak, when those reappear. Common clinical symptoms, anatomical abnormalities, and radiological signs that are present in cases of CSF leaks are headache, meningitis, clear rhinorrhea, empty sella, encephalocele, venous sinus stenosis, widened foramen ovale, etc. A literature review of 26 studies and 716 patients presented with headache in 32.5%, visual disturbances in 4.2%, a history of meningitis in 15.3%, and an empty sella in 77.7% of the cases.²⁹ Patients in our study results showed clear CSF rhinorrhea in all 85 patients (100%),

headache in 60 (70.6%), visual disturbances in 2 (2.4%), and a history of pre-op meningitis in 3 (3.5%) cases.

Flow rate/defect site: The most common defect site in our study was the cribriform plate 55 (64.7%); second to it was the ethmoid roof 23 (27.1%), and then the sphenoid sinus 8 (9.4%). The cribriform plate is documented as the most common site for spontaneous CSF leaks in retrospective studies at 39% and 43.24%, while the ethmoid sinus was recorded to be 25% and 11.11%, respectively.^{10,11} The thinnest portion of the bone in the anterior cranial fossa is the lamella of the cribriform plate, which explains this high prevalence, and it is also vulnerable to leaks due to its anatomical fragility and the arachnoid's attachment to the bone through which the olfactory nerve pierces the skull.^{11,12} The majority of the cases in our study, up to 62 (72.9%), were low-flow intraoperative leaks, and the remaining 23 (27.1%) were high-flow CSF leaks. In a retrospective study of 43 patients, 23 (53.5%) presented with high-flow intraoperatively; of these, 21 (48.8%) underwent temporary lumbar drain placement, while 2 (4.7%) required permanent CSF diversion via VP shunt.³⁰ Non-traumatic leaks can also be classified into "high-pressure" and "low-pressure" categories based on CSF pressure, which affects presentation and treatment approach, according to a multidisciplinary assessment of CSF leak management. High-pressure leaks are associated with hydrocephalus, IIH, and empty sella syndrome, while congenital anomalies usually lead to low-pressure leaks.³¹ The finding of high CSF pressure in individual patients further confirmed the importance of empty sella as an indication of elevated intracranial pressure.³² These studies back up our results that found 3 (3.5%) of the cases with radiological findings of empty sella and confirmed increased intracranial hypertension.

Lumbar drain: Usually, spontaneous CSF leaks are repaired surgically; lumbar drains are used as an adjunct to support the repair or treat persistent

leakage of CSF. But its routine use in every endoscopic repair case shows no reduction in recurrence rate or overall benefit; it shows benefit in cases of high flow or increased intracranial pressure, as evidenced by a randomized trial conducted, where only elevated intracranial pressure predicted failure (75 LD vs. 75 no LD) and revealed 95% with drain use vs. 92% success in cases without drain, respectively.³³ Our study follows lumbar drain placement intraoperatively, primarily in patients with high-flow leak (27.1%), while all 85 cases were given intracranial pressure-lowering agents pre- and postoperatively.

Surgical approach/ Repair technique/

Reconstructive material: With a high primary success rate in spontaneous leaks, many cases employ multilayer reconstruction. In this 2019 study, bilayer fascia lata was used as an overlay and inlay in a typical procedure for sCSF rhinorrhea and was strengthened by a vascularized nasoseptal flap (a composite multilayer inlay-onlay + flap), with a primary success rate of 92 percent, which rose to 100 percent when followed by ventriculoperitoneal shunts.³⁴ Further study strengthens this repair technique, where multiple autologous layers (fat, fascia lata, turbinate mucosa, and cartilage) were used in a multilayer method in a group of 21 totally spontaneous leaks that resulted in 100% success without a need for lumbar drains.³⁵ A meta-analysis of 47 endoscopic sCSF rhinorrhea series (2586 patients) revealed that multilayer (94.6%) was more successful numerically than single layer (87.6%). Thus, multilayer closure is generally preferred, particularly for high-flow and spontaneous leaks.¹⁶ Using the endoscopic endonasal approach, our study used the 100% multilayer inlay/onlay technique. Following spontaneous CSF rhinorrhea, reconstruction is typically individualized. The choice of reconstructive material should be tailored to the site, flow rate, and size of the defect rather than solely to the etiology. Across studies, the middle cranial fossa defects grouped as small (<1 cm) to large (>= 1 cm) were treated with soft tissue and

rigid reconstruction for small ones, while solely rigid reconstruction was used for large defects.³⁶ Free middle turbinate mucosa (FMT) was used for defects less than 1.5 cm in the comparative anterior skull-base tumor series (not restricted to spontaneous), and Hadad-Bassagasteguy nasoseptal flap (HBF) or fascia lata for abnormalities more than 1.5 cm.³⁷ In another retrospective study, defects were classified as small: 2-10 mm; mid-sized: 11-20 mm; and large: >20 mm, where large defects were reconstructed with nasoseptal flaps, while small and mid-sized defects were reconstructed with either the middle or inferior turbinate flap.³⁸ The use of a middle turbinate flap and nasoseptal flap as a vascularized option for skull base reconstruction shows no overall difference in outcome, with NSF having a transient 8.3% failure rate with later full recovery and MTF having a 100% success rate in the first procedure.³⁹ In another study of 20 patients, where all defects were small and medium-sized, repair was done using a middle turbinate flap; except for one transient post-op leak, all cases were a 100% success.¹⁹ The middle turbinate flap is a dependable, lower-morbidity option when its dimensions and defect size are compatible. Studies, as evidenced by the above examples, have shown that the middle turbinate flap is best suited for small to medium/moderate anterior skull base defects. Extensive defects typically require a nasoseptal flap with additional grafts. Our study followed strict categorization of defect size and specified the reconstructive material for each; we used a fascia lata/fat graft for 3-6 mm (small) defects, a middle turbinate flap for 7-10 mm (mid-size) defects, and a nasoseptal flap for 1-2 cm (large) defects. Across studies, fibrin glue is used in most cases without a defined criterion for true need. When compared to no sealant, a large meta-analysis of 27 ESBS studies (2,403 patients) revealed no significant decrease in postoperative CSF leak using tissue sealants in general or fibrin glue in particular.⁴⁰ Fibrin glue facilitates graft fixation for spontaneous skull base leaks. However,

it does not significantly reduce leak rates beyond careful multilayer closure, as this one study describes one group with fibrin use having a 96.1% success rate. In contrast, the group without fibrin glue has an 83% success rate.⁴¹ Our study involved the selective use of fibrin glue in 55 (64.7%) high-risk cases, in addition to 13 fascia lata flaps, 20 middle turbinate flaps, and 22 nasoseptal flaps. Fibrin glue is a helpful adjuvant for graft stabilization in endoscopic skull base repair for spontaneous leaks, but results are largely dependent on robust multilayer reconstruction rather than glue/sealant alone.

Post-op complication: The endoscopic endonasal repair technique is a far more advantageous and less traumatic approach for skull base pathologies in general and spontaneous CSF rhinorrhea in particular, with a high primary success rate of up to 97%⁴² as compared to the transcranial or open methods, yet it comes with its own, but fewer, complications and risks, given it is a surgical intervention of a kind. In the frontal sinus CSF-leak series (mixed etiologies, including spontaneous), while 100% of cases were treated successfully, only two individuals (7.4%) developed meningitis, which was managed conservatively; four patients (7.4%) had an infection with fever; and two patients had raised intracranial pressure (ICP).⁴³ The most common complications in our studied cases were nasal crusting (15.3%) and sinusitis (11.8%). Postoperative CSF leak occurred in 5 patients (5.9%). According to a systematic review of 67 studies, meningitis occurred only in 0.1% (1 of 1,736) of patients who did not report a post-op CSF leak, while in cases with postsurgical CSF leak, the odds ratio for meningitis development was 91.99 (95% confidence interval, 11.72–721.88; $p < 0.01$).⁴⁴ In our study, we found no post-op meningitis, and 3 post-op leaks resolved spontaneously; only 2 required revision. Preventing and rapidly repairing postoperative CSF leaks are the key determinants of meningitis risk for both primary and revision endoscopic endonasal repairs due to their association with

complex pathology and high leak risks. No cases of flap necrosis, postoperative nasal bleeding, or new neurological deficits were observed in our cases.

Outcomes in the context of algorithm validation: The 97.6% primary success rate observed in this study compares favorably with the pooled primary success rate of 93.7% reported in the 2026 meta-analysis by Mughal et al., across 47 endoscopic series, and the 100% overall post-revision success rate aligns with the 99.7% pooled overall repair rate from the same analysis.²⁰ The consistent outcomes across all three reconstructive categories — 100% for fascia/fat graft, 96.7% for middle turbinate flap, and 96.3% for nasoseptal flap — provide prospective validation for the defect size-based selection algorithm described in this study. Notably, the two patients requiring revision surgery were each from the middle turbinate flap and nasoseptal flap groups, both involving larger defects with high-flow characteristics, which is consistent with the established literature associating high-flow leaks with greater repair complexity and marginally lower primary success.^{9,20}

Sex and BMI as modulating factors: Despite the absence of sex-based inferential comparisons in this study, the descriptive data revealed certain differences. Females had a higher mean BMI (29 vs. 26.5 kg/m²), and a slightly higher late recurrence rate was seen in males (3.7% vs. 1.7% at 2 years), a finding that contrasts with the expected BMI-driven pattern. These observations likely reflect the small subgroup sizes rather than true biological differences. The higher total female representation (68.2%) and their higher BMI are consistent with the well-established epidemiological link between spontaneous CSF leaks, female sex, middle age, and obesity-driven intracranial hypertension.^{6,7,24} In our study, BMI values were generally lower than those reported in Western populations. Despite this difference, patients with higher BMI still appeared to have a greater risk of persistent disease. This may indicate that even moderate

overweight contributes to sustained intracranial pressure, particularly when venous outflow abnormalities are present. Based on these findings, weight-management counseling should be considered during postoperative follow-up.

This study has several limitations that must be

Implications

The results of our study carry many important clinical implications. Firstly, a high primary success rate of 97.6% was achieved through the structured, defect size-based algorithm. This supports the adoption of protocol-driven repair over individualized ad hoc decision-making, particularly in resource-constrained tertiary care settings in developing countries. In the present study, fibrin glue was used selectively in high-risk cases rather than routinely in all patients, as is practiced in many centers. This approach is supported by meta-analytic evidence, which has shown no significant benefit of routine fibrin glue use. This approach reduces procedural costs without compromising outcomes. Thirdly, a large proportion of patients in our cohort were either overweight or obese (63.5%). Given the association of elevated BMI with IIH and late recurrence, these findings highlight the need for a multidisciplinary approach to patient management. In the long-term follow-up protocols, postoperative weight management and acetazolamide tapering should be integrated, not merely the immediate surgical pathway. Fourthly, this study provides the first defect size-stratified outcome data from Khyber Pakhtunkhwa, Pakistan. Given the limited published data from this region, our findings contribute valuable information to an underrepresented population in the global skull base literature. The algorithm used in this study was reproducible, cost-effective, and feasible even in centers without advanced intraoperative navigation. Therefore, it may be particularly useful in other low- and middle-income country settings with similar resource limitations.

Limitations

acknowledged. First, this was a retrospective descriptive design without a comparator arm. Therefore, while we were able to describe outcomes, we cannot establish a causal relationship between the management approach and the results observed. In addition, the lack of inferential statistical analysis limited our ability to identify independent predictors of failure. Second, in this study, the intracranial pressure (ICP) was not formally measured in all patients preoperatively.

Idiopathic Intracranial Hypertension (IIH) was identified radiologically in only 3 patients (3.5%), which, given the BMI profile, likely underestimates the true prevalence of elevated ICP in this cohort. Third, the study was conducted across two institutions, which improves the generalizability of the findings. However, differences in surgical technique, graft selection, intraoperative decision-making, and postoperative management between surgeons may have influenced outcomes and could not be fully assessed in this retrospective review. Fourth, the pediatric case included (Case 3, age 8 years) falls outside the adult inclusion criteria of the study (≥ 18 years), representing an inconsistency that should be acknowledged and clarified. Another limitation of the study is the absence of a holistic assessment of surgical morbidity, which comprises postoperative olfactory outcomes, quality of life measures, and patient-reported satisfaction. Finally, this study doesn't provide a direct comparison of outcomes across treatment modalities due to the lack of a control group receiving conservative management.

Future Directions

Based on the findings and limitations of this study, several areas warrant further investigation in future research. Given the ongoing debate regarding the use of fibrin glue, a prospective multicenter randomized controlled trial comparing selective and routine application would be valuable. Our findings suggest that selective use is safe, but a

larger study is needed to determine whether it offers any advantage over routine use in endoscopic CSF rhinorrhea repair. Additionally, future studies should integrate formal intraoperative ICP measurement or preoperative fundoscopy for papilledema to better classify patients at risk for late recurrence due to occult intracranial hypertension. To define the true late failure rate in South Asian populations and guide the duration of post-repair acetazolamide therapy, longer structured follow-up beyond 2 years, with standardized documentation of clinical and radiological recurrence, should be adopted. To supplement the currently reported binary data on success and complications, comparative studies assessing quality of life outcomes, olfactory preservation, and nasal morbidity between the three reconstructive techniques (fascia/fat graft, middle turbinate flap, and nasoseptal flap) are needed. Finally, a risk-stratification scoring system based on BMI, defect size, flow rate, and IIH status could help guide individualized surgical planning and postoperative follow-up, once externally validated across different practice settings.

CONCLUSION

This retrospective series of 85 patients indicates that a structured, defect size-based endoscopic endonasal multilayer repair protocol achieves a primary success rate of 97.6% and an overall success rate of 100% for spontaneous CSF rhinorrhea in a South Asian tertiary care setting. The algorithm, which assigned fascia lata or fat graft for small defects (3–6 mm), middle turbinate flap for moderate defects (7–10 mm), and nasoseptal flap for large defects (1–2 cm), proved safe, reproducible, and effective across all defect categories. Selective use of fibrin glue in high-risk cases was not associated with an increased failure rate, supporting a move away from routine universal application. Lumbar drain placement, limited to high-flow intraoperative leaks (27.1%), adequately achieved durable closure without

exposing low-risk patients to unnecessary procedures. The safety profile of this approach is further validated by the absence of postoperative meningitis, flap necrosis, or neurological deficits. For patients with elevated BMI or radiologic features of intracranial hypertension, we recommend extended surveillance at 1 and 2 years, as these represent the primary risk factors for late recurrence. Taken together, the findings of our study support the broader adoption of a standardized, algorithm-driven approach for spontaneous CSF rhinorrhea repair, with concurrent management of underlying predisposing factors as an integral part of long-term success.

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Additional Information

Disclosures: No conflicts of interest are reported by the authors.

Ethical Review Board Approval: Ethical approval for the study was obtained from the Institutional Research and Ethical Review Board (IREB) of Khyber Medical College, Peshawar (Reference No. 887/DME/KMC) and Swat Medical College and Swat Medical Complex and Teaching Hospital, Saidu Sharif, Swat (Reference No.: RAC / SMC / 112-19/DME).

Human Subjects: Every patient and volunteer in this study gave their informed consent.

Conflicts of Interest: All authors affirm the following in accordance with the ICMJE uniform disclosure form: Financial Relationships: Each author has stated that they have no financial relationship to any organizations that might be interested in the submitted work, either now or within the last three years.

Other Relationships: Each author has stated that the submitted work was not impacted by any other relationships or activities.

Data Availability Statement: For data sharing, interested researchers can contact the corresponding author.

Funding: None.

Declaration of Generative AI and AI-Assisted Technologies in the Writing Process: No AI tools or AI-assisted technologies were used in the conception, design, data collection, analysis, interpretation, writing, or preparation of this manuscript.

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