Cerebrospinal fluid rhinorrhea is a serious and potentially fatal condition because of an increased risk of meningitis and brain abscess. Approximately 80% of all cases occur in patients with head injuries and craniofacial fractures. Despite technical advances in the diagnosis and management of CSF rhinorrhea caused by craniofacial injury through the introduction of MRI and endoscopic extracranial surgical approaches, difficulties remain. The authors review here the pathophysiology, diagnosis, and management of CSF rhinorrhea relevant exclusively to traumatic anterior skull base injuries and attempt to identify areas in which further work is needed.

**Key Words**  
- craniomaxillofacial trauma  
- head trauma  
- cerebrospinal fluid rhinorrhea  
- meningitis  
- dural repair  
- endoscopic surgery  
- skull base fracture

Furthermore, the issues related to CSF leak caused by traumatic injury are complex and multiple. Having conducted a thorough review of existing literature, we discuss here the pathophysiology, diagnosis, and management of CSF rhinorrhea relevant to traumatic anterior skull base injuries and attempt to identify areas in which further research is needed.

**Methods**

For this review, primary and secondary neurosurgery, otorhinolaryngology, craniofacial surgery, and general surgery literature in the English language and published in the period from 1926 to 2009 was searched on Medline. The key words used for our search included “anterior or skull base fracture,” “skull base endoscopy,” “surgical treatment of skull fractures,” “head trauma,” and “CSF rhinorrhea.” All publications referring to CSF rhinorrhea not of traumatic origin were excluded from our analysis, and only those referring to the CSF rhinorrhea following traumatic anterior skull base fractures were included. We also excluded publications that classified postsurgical CSF rhinorrhea as posttraumatic. Furthermore, we excluded all publications referring to patients younger than 18 years of age.

We focused our review on the methods of clinical, chemical, and imaging diagnosis of CSF rhinorrhea following traumatic injury. We reviewed the literature on nonsurgical and intracranial and extracranial surgical treatment of posttraumatic CSF rhinorrhea.

Regarding the extracranial endoscopic repair of posttraumatic CSF leakage, we reviewed the English literature.
published in the period from 1980 to 2009. We found 37 articles that discussed patients with posttraumatic CSF rhinorrhea (Table 1). We were unable to find any articles that reported studies exclusively on accidental posttraumatic CSF rhinorrhea. We excluded those studies in which the number of leaks, rather than the number of patients, were reported.\textsuperscript{121}

### Results

#### A Historical Overview

In 1745 Bidloo the Elder was the first to describe CSF rhinorrhea after a traumatic skull fracture and correlate them.\textsuperscript{29} It was not until the advent of radiographic techniques that the presence of a communication between the

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<th>Authors &amp; Year</th>
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* NS = not specified; that is, did not specify the rate of success for postaccidental trauma repairs.
† Total number of cases reported with the initial success rate.
‡ Patients with postaccidental traumatic CSF rhinorrhea extrapolated from all patients reported.
Cerebrospinal fluid rhinorrhea after anterior skull base trauma

Cranial and nasal cavities was diagnosed in a live patient. Luckett was the first, in 1913, to publish this event by describing the presence of an intracranial aerocoele. In 1937 Cairns, a British neurosurgeon, was the first to propose a classification of CSF rhinorrhea. He divided them into acute traumatic, postoperative, delayed traumatic, and spontaneous. Ommaya and then Vrabec and Hallberg later refined this classification. In his series, Ommaya reported a 2% incidence of CSF leaks in all head injuries. The incidence increased to 5% when considering only patients with skull base fractures. In addition, he noted that 90% of CSF leaks were caused by traumatic events.

In 1926 Dandy described the first successful intradural closure of a CSF fistula by suturing autologous fascia lata behind the posterior wall of the frontal sinus. In 1937 Cairns demonstrated that CSF leaks could also be repaired with the extradural application of fascia lata. Nevertheless, reports that spontaneous cessation of a CSF leak was possible led some to think that surgical intervention was unnecessary and unproven. Calvert and Cairns, in a discussion of war injuries to the frontal and ethmoidal sinuses, described a number of cases in which CSF rhinorrhea healed spontaneously.

Other treatment modalities were advocated as well. In his paper published in 1944, Schroeder described a patient with CSF rhinorrhea who recovered after treatment with sulfonamides and a lumbar puncture. Also in 1944 Dandy advocated the surgical repair of any CSF leak within 2 weeks of its onset to prevent meningitis. The review of Lewin of the British combat experience and a large series of skull fractures built the case for adopting more aggressive operative management of CSF leaks as the standard of care. In 1948 Dohlman performed the first extradural repair of spontaneous CSF rhinorrhea via a naso-orbital incision. In 1981 Wigand was the first to use an endoscope for the extradural repair of a CSF leak. It appears that Mattox and Kennedy, in 1990, were the first to use an endoscope for the diagnosis and transnasal repair of CSF rhinorrhea in a series of patients with accidental craniofacial fractures. Over the last 30 years, the transnasal endoscopic approach has become a very important part of the armamentarium for repairing most cases of CSF rhinorrhea, with reported success rates of approximately 90% (Table 1).

Classification of Anterior Skull Base Fractures and CSF Rhinorrhea

Cerebrospinal fluid rhinorrhea can be classified based on etiology, anatomical location, age of the patient, or extent of bony defect. The most frequently used type of classification is based on the etiology of the CSF fistula. Several such classifications have been proposed, and the main difference among them is in grouping CSF rhinorrhea due to accidental trauma and postsurgical CSF rhinorrhea together under the posttraumatic category (Fig. 1). Because of the different types of defects created, diagnosis, time of presentation, underlying brain pathology, and speed of injury impact, we prefer to consider the postsurgical CSF fistula and postaccidental traumatic CSF leak in separate categories (Fig. 1 upper). The type of classification used should consider the timing of the diagnosis, type and extent of skull defect, and duration of symptomatology and suggest the possible timing and type of repair to be undertaken.

The most favorable groups of patients to treat appear to be those who suffer head injuries resulting in a narrow fracture of the skull base. In contrast, those groups that suffer multiple or large fractures and a broad or multifocal injury, as well as those that are victims of penetrating injury with significant comminuting fractures of the skull base, represent the most difficult groups to treat.

The relationship between skull fractures and CSF leaks is well described throughout the literature, and we know that given the close relationship of the meninges and the skull, these fractures can cause CSF fistulas and leaks. Identifying the types of skull fractures that would suggest an increased risk for persistent CSF leaks and/or meningitis and those refractory to conservative management is crucial in determining appropriate management. Anterior skull base fractures include a significant number of injuries resulting in rhinorrhea from a CSF fistula. Friedman and colleagues reported that CSF fistulas in 84% of 51 patients were attributable to skull fractures most commonly involving the frontal sinus, followed by the orbital and petrous bones.

The anterior cranial base consists of a number of segments that vary significantly in rigidity and orientation relative to the horizontal plane and in their proximity to different compartments and constructs of subarachnoid spaces, and as a consequence is exposed to different “local” CSF flow pressures and velocities. Building on these principles, multiple groups have suggested classifications that allow more precise localization and a better understanding of the relationship between specific fracture types and the risk of subsequent CSF fistula. In an effort to find a relationship between the location and size of cranial base fractures and intracranial infection, Sakas et al. classified anterior cranial base fractures into 4 types: Type I, cribriform, a linear fracture through the cribriform plate without involvement of the ethmoid or frontal sinuses; Type II, frontoethmoidal, fracture that extends through the medial portion of the anterior cranial fossa floor where it directly involves the ethmoid sinuses and/or walls of the medial frontal sinus; Type III, lateral frontal, fracture that extends through the lateral frontal sinus (superomedial wall of the orbit) and may involve the superior or inferior walls of the lateral frontal sinus; and Type IV, complex, any combination of the prior types. Using this classification scheme, Sakas and colleagues concluded that Type I cribriform fractures have the highest risk for infection at 60%, with Type II frontoethmoidal fractures a close second at 43%. This finding was probably attributable to a higher incidence of larger fracture sizes and CSF rhinorrhea in these groups. The authors concluded that after an anterior skull base fracture, patients with Type I and II fractures (fractures close to midline), fracture displacement > 1 cm, and prolonged rhinorrhea (> 8 days) have an increased risk of posttraumatic meningitis.

Using this classification scheme, Madhusudan and colleagues developed an expanded nomenclature of frontobasal fractures to include the frontobasal region in
involved, the associated midfacial injury, and the mode of injury. In this scheme, the frontobasal region is divided into frontal, basal, and combined frontobasal regions, with the basal region described as the floor of the anterior fossa formed by the bony ethmoid labyrinth, planum sphenoidale, and lateral orbital walls. These regions are then subdivided sagittally into central, lateral, and combined areas. The authors’ results revealed that the frontobasal type is the most common skull fracture. They reported that the incidence of a CSF leak was significantly higher in impure types of frontobasal fractures, defined as the presence of a midface fracture.

While anterior skull base fractures appear to be the most common types of fractures resulting in rhinorrhea, Brodie and Thompson indicated that CSF rhinorrhea can also result from temporal bone fractures. In their study of 820 temporal bone fractures, these authors found that 72% of patients with temporal bone fractures and CSF fistulas presented with CSF rhinorrhea.

When evaluating traumatic CSF leaks involving the anterior skull base, one must also take into account the possibility of paradoxical rhinorrhea. Simply stated, paradoxical rhinorrhea is rhinorrhea from the naris contralateral to the site of CSF leakage. It can occur with displaced fractures of the midline structures, the crista galli and vomer, and can also be seen in the setting of mucocele formation obstructing the ipsilateral naris. Paradoxical rhinorrhea should also be considered after temporal bone fractures when the temporal dura is torn and CSF travels from the origin of the leak, down the eustachian tube into the nasopharynx, and ultimately to the site where CSF exits the naris. The majority of paradoxical CSF leaks have been managed conservatively with good success.

Pathophysiology and Anatomy of Posttraumatic CSF Rhinorrhea

Accidental trauma can lead to a variety of skull base defects, and thus accidental traumatic CSF leaks are associated with a heterogeneous group of injuries needing highly individualized care. To this purpose, understanding basic CSF physiology and ICP changes will be helpful when developing treatment plans for patients with CSF leaks.

Cerebrospinal fluid is formed by the choroid plex-
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uses as capillary ultrafiltrate during various metabolic processes at a rate of 0.35 ml/minute (350–500 ml/day). The total volume of CSF in an adult at any given time is approximately 90–150 ml. The cycle of continual production and absorption results in the total volume of CSF being turned over 3–5 times/day. Arachnoid villi are the anatomical structures where CSF absorption occurs. A pressure gradient of 1.5–7 cm of water is required to drive CSF through these structures.

Cerebrospinal fluid rhinorrhea refers to CSF leakage through the nose. For this to occur, both a communication between the intracranial space and the nasal cavity and a breach in the dura mater should be present. Traumatic CSF leaks usually begin within 48 hours of injury, and 95% of them manifest within 3 months. More than 85% of traumatic CSF rhinorrhea cases cease with observation or nonsurgical treatment, such as bed rest and CSF flow diversion. It has been suggested that leaks that close without surgical repair are probably covered by a layer of fibrous tissue or regenerated nasal mucosa since dura mater does not regenerate. In some instances, the presence of an encephalocele or a meningocele through the bony defect may disallow the healing process. Furthermore, the size of the defect is an important factor in predicting the possibility of spontaneous cessation of the leak. Hence, treatment approaches must be individualized, especially when considering patients with closed-head injuries and small fractures versus those with large and comminuted fractures or those with penetrating injury to the skull base.

Another important factor in determining the appropriate treatment for CSF leakage is the anatomy of the dura at the location of the fracture. In other words, the native dural integrity and its relation to the skull base play a role in the formation of a CSF fistula. As discussed above, a large portion of CSF leaks and subsequent cases of meningitis appear to be more common in instances of frontobasal fractures. Sakas and colleagues remind us that the cribriform plate is thin and fragile, covered only by the arachnoid layer, and is missing a true dural investment. Without protection from the dura mater, the delicate arachnoid layer is easily violated by even a small fracture. Additionally, since the cribriform plate is located in the midline of the anterior fossa, at the bottom of a slight medial slope of the skull base floor, CSF may gravitate to this area. If a small portion of the brain cannot herniate through the defect and create an effective seal, spontaneous resolution and nonoperative management may prove difficult.

Presentation of CSF Rhinorrhea

Cerebrospinal fluid rhinorrhea in the acute phase after trauma has been reported in as many as 39% of the patients with skull base fractures. Patients present with a variety of symptoms depending on the acuteness of the event. In the acute phase following the traumatic event, patients may present with epistaxis, nasal discharge, periorbital ecchymosis, chemosis, oculomotor impairment, anosmia, motor deficit, open-head injury with CSF leakage, loss of vision, cranial nerve deficits (most frequently, first–third and fifth–seventh cranial nerve injuries), meningitis, and pneumocephalus. In the chronic phase, patients may present with recurrent meningitis, intermittent nasal discharge, headaches, salty or sweet taste in the retropharyngeal space, hyposmia, and brain abscesses.

The risk of recurrent meningitis after posttraumatic CSF leakage has been reported to range from 12.5% to 50%, with a 29.4% neurological complication rate. Eljamel and Poy have reported an overall 30.6% risk of meningitis before surgical repair and a risk of 1.3% per day in the first 2 weeks after injury, 7.4% per week in the 1st month after injury, and a cumulative risk of 85% at the 10-year follow-up. Infection is the most feared complication because of its association with increased mortality and morbidity. As such, its prevention, in parallel with management of the primary injury, is critical to optimizing outcome.

Diagnosis of CSF Rhinorrhea

Differentiating CSF rhinorrhea from other types of nasal secretions is the cornerstone in diagnosing the CSF fistula. In patients with profuse posttraumatic CSF leakage, the diagnosis is obvious and needs only to be confirmed. However, in the acute posttraumatic phase and especially in obtunded patients, the diagnosis could be complicated by the presence of sanguineous fluids exiting from the nasal cavities as the result of other existing facial fractures. Furthermore, it is not rare for CSF rhinorrhea to be intermittent and sometimes start even years after a traumatic event, when that event has been forgotten. It is in these cases that the diagnosis of CSF leakage could be challenging and frustrating.

The “reservoir sign,” which is the ability of a patient to leak CSF by flexing the head, is taken to be specific for a fistula, although the sign is not always positive even when the leak exists. “Target sign” refers to the ability of CSF to migrate further, creating a bull’s-eye stain with blood in the center, on a filter paper or gauze. This has been reported as a very unreliable sign since watery nasal secretions and blood are mixed, and the same pseudochromatographic patterns can occur.

Chemical Diagnosis. Chemical analysis of the discharge is the oldest method of diagnosing CSF leaks. Chemical examination of the nasal fluid became the standard of care after Sir St. Clair Thomson published his book The Cerebrospinal Fluid in 1899. In it he described in detail the chemical and physical characteristics that distinguish CSF fluid and nasal secretions based on differences in glucose concentrations. The concentration of glucose in CSF exceeds 50% of the serum concentration except during meningitis, subarachnoid hemorrhage, or some other unusual circumstance. The glucose concentration in nasal secretions is 10 mg/dl or less. Nonetheless, a glucose test is not definitive because the glucose oxidase assays used nowadays are too sensitive, turning positive even at low values of glucose; therefore, even normal nasal secretions can elicit false-positive reactions. As a result, the glucose test for CSF rhinorrhea has become obsolete.

The asialo form of transferrin, β2-transferrin is produced by neuraminidase activity in the brain and found abundantly in CSF. It occurs in lower concentrations in
the perilymph of the cochlea and the aqueous and vitreous humor of the eye.\textsuperscript{103,115} Since it is not normally contained in nasal secretions, its detection allows indirect diagnosis of CSF rhinorrhea. Samples of suspected CSF are obtained by direct drip collection or via the placement of intranasal sponges. The samples are sent to the laboratory with a serum sample, and \( \beta \)-2-transferrin is detected by immunoblotting or immunofixation and silver stain in the majority of large diagnostic laboratories.\textsuperscript{83,103,115} Since its introduction in 1979,\textsuperscript{87} \( \beta \)-2-transferrin detection has been widely used for the diagnosis of extracranial CSF leakage, with a reported sensitivity and specificity up to 99% and 97%, respectively.\textsuperscript{115} Nevertheless, multiple disadvantages have been cited for this test, the most important being the highly intensive work and length of time required to perform the assays (1–2 days) and the need for high expertise in the interpretation of the results (Table 2).\textsuperscript{85}

Another protein proposed as a potential marker for the diagnosis of CSF rhinorrhea is \( \beta \)-trace protein, or \( \beta TP \).\textsuperscript{85,83,85,98,103,112} It is the second most abundant protein in human CSF following albumin\textsuperscript{83} and is mainly produced in the epithelial cells of the choroid plexus and in the leptomeninges in the CNS.\textsuperscript{83,103} The CSF concentration of \( \beta TP \) is approximately 35-fold higher than in plasma.\textsuperscript{103} It is found in nasal secretions and other body fluids as well, but in very low concentrations.\textsuperscript{83} The rationale for the \( \beta TP \) test relies on the large concentration difference between CSF and nasal secretions and an easy-to-use serum/CSF concentration gradient.\textsuperscript{112} By utilizing a highly sensitive nephelometric measurement, this immunological test can even detect very low amounts of CSF in nasal secretions.\textsuperscript{83} \( \beta TP \) is identical to prostaglandin-D synthase and is thought to be important for maturation and maintenance of the CNS.\textsuperscript{83,86} \( \beta TP \) has been identified by rocket immunoelectrophoresis with a reported sensitivity of 91%.\textsuperscript{7} An immunonephelometric \( \beta TP \) assay has been proposed for routine use in clinical practice for the diagnosis of CSF rhinorrhea.\textsuperscript{98} The overall accuracy of this method in diagnosing CSF leaks has been reported to approach 0.974, with a negative predictive value of 0.971 and a positive predictive value of 1.\textsuperscript{8} The advantages of using \( \beta TP \) rather than \( \beta \)-2-transferrin as a marker for CSF rhinorrhea have been described by Meco and colleagues\textsuperscript{88} as less time consuming, less labor intensive (< 15 minutes), and less expensive. Furthermore, the \( \beta TP \) test carries all the advantages of the \( \beta \)-2-transferrin test: noninvasive, repeatable, same sample collection methods, and high sensitivity and specificity. The wide use of \( \beta TP \) for this purpose has been slow because the test is not suitable in patients with bacterial meningitis or those with reduced glomerular filtration because of variation in the levels of this protein.\textsuperscript{95,113} Furthermore, at concentrations between 1.31 and 1.69 mg/L in the nasal secretions, there is an overlap of individuals with and without CSF leakage.\textsuperscript{95,103} For these patients, other tests are required to confirm the pathological condition (Fig. 2).

Intrathecal injection of a sodium fluorescein solution following a thorough endoscopic examination has been used to establish the diagnosis of CSF rhinorrhea. However, its ability to precisely localize the leak is limited. Nonetheless, the accuracy of the test has been reported\textsuperscript{102} to be around 96%. The usefulness of this test depends on the extent of the dural defect, rate of leakage, timing of the intrathecal injection, and rate of CSF turnover that could dilute or disperse the fluorescein. Reported complications of the solution’s injection, and thus limitations to its use, have ranged from mild tinnitus, headache, nausea and vomiting, transient pulmonary edema, confusion, seizures, and coma, to death. Keerl et al.\textsuperscript{58} analyzed 420 administrations of fluorescein solution and their complications as reported in Europe and the US. The reasons for the complications were found in the method of administration, formulation of the solution, idiopathic reactions, and concentration or dose of fluorescein.\textsuperscript{58} Other authors have come to the same conclusions.\textsuperscript{89,117} At concentrations of 5% or lower, side effects are transient. Schlosser and Bolger\textsuperscript{102} recommend the use of 0.1 ml of 10% fluorescein diluted in 10 ml of the patient’s CSF with slow injection over 10–15 minutes. They reported no complications with this method of injection. Keerl and colleagues\textsuperscript{58} reported that the intraoperative use of a maximum dose of 1 ml (50 mg of fluorescein) or 0.1 ml per 10 kg of body weight in Germany, and 0.5–2 ml (2.5–10 mg) of the more diluted or hypodense 0.5% solution in the US, was without any complications. Informed consent and a comprehensive discussion with the patient regarding the advantages of using fluorescein in detecting the CSF leak, reported risks of fluorescein intrathecal injection, and information about the lack of FDA approval are recommended.\textsuperscript{58,102}

**Imaging Diagnosis.** After confirming the presence of CSF rhinorrhea, the next step in its management is localization of the leakage site. Localizing this site assists in surgical planning and increases the chance for a successful repair. Imaging studies play a very important role in this step.

High-resolution CT examination with axial, coronal, and sagittal reconstructions has replaced plain radiography of the skull in diagnosing skull fractures. Very few studies have been done exclusively to assess the accuracy of HRCT in posttraumatic CSF leaks. In a retrospective review of 47 cases of traumatic and nontraumatic CSF leaks visualized on HRCT, Zapalac and colleagues\textsuperscript{119} reported a sensitivity and an accuracy of 87% each. Yilmazlar and colleagues\textsuperscript{118} reviewed 81 patients who were treated for CSF leakage due to skull base fractures. They found that coronal bone window HRCT scans are important in identifying the site of CSF leakage, whereas axial images are important in demonstrating fractures of the posterior wall of the frontal sinus. Lund and associates\textsuperscript{23} suggested that HRCT can accurately demonstrate the position of the fracture as well as the size of the defect. Nevertheless, HRCT scans show the bony fracture, but the presence of a fracture is not always correlated with the presence of a CSF leak.

Computed tomography cisternography is useful when there is an active leak at the time of intrathecal contrast administration or when the leak can be induced by Valsalva maneuver or bending down. Schlosser and Bolger\textsuperscript{102} reported that the greatest utility of CTC is in frontal or sphenoid sinus leaks because these sinuses act as reservoirs of the contrast material. They also asserted that in cribiform
plate olfactory groove defects, contrast material can drain into the pharynx and never collect to a volume substantial enough to be detectable on imaging. If the leak is not active, CTC is not more useful than noncontrast HRCT. Moreover, CTC can provide further proof of the presence of a leak but not its precise location. Cisternography with radioactive isotope injected intrathecally has been used in cases of intermittent low-flow CSF rhinorrhea. This technique requires endoscopic transnasal placement of pledgets at the anterior cribiform plate, middle meatus, or sphenethmoidal recess. Although detection of radioactivity in the pledgets indicates a leak, this technique does not provide information about the precise location of the fistula. Note that the sensitivity ranges from 62% to 76% and that false readings occur in up to 33% of cases. The success rate for preoperative localization of CSF fistulas has been reported as 62.5% with radioisotope cisternography and 95.7% with CTC.

Magnetic resonance imaging has been suggested as a very valuable technique for localizing CSF fistulas because CSF gives a hyperintense signal on T2-weighted imaging and because, in general, this imaging technique can demonstrate cranial anatomy in detail and in multiple planes. Magnetic resonance imaging without contrast medium has been used with an accuracy of 60%–94%, but high false-positive rates up to 40% have been reported (reviewed in the study by Goel et al.). These false-positive rates have been attributed to the difficulty in differentiating CSF from mucosal thickening and fluid that can be seen within a sinus. Some authors have reported very high sensitivity in localizing the side of the leak in patients with intermittent CSF rhinorrhea based on demonstrations of brain hernia or the presence of a high signal that is continuous and similar to that for CSF in the basal cisterns through the cribiform plate or paranasal sinuses. When interpreting the literature, one must pay attention to the nomenclature, because some authors use the term “MR cisternography” to describe routine MRI studies that rely primarily on T2-weighted sequences to highlight CSF rather than on those in which intrathecal contrast medium is used. Nowadays, MRI for CSF leak detection refers to a technique that uses a fast spin echo sequence with fat suppression and image reversal. Some authors have reported good results using this technique to detect intermittent CSF leaks, with an accuracy up to 89%, 85%–92% sensitivity, and 100% specificity.

Another diagnostic methodology is MRC performed with the intrathecal injection of Gd-enhancing contrast medium (GdMRC), first described in monkeys in 1985 by Di Chiro and colleagues and in humans in 1994 by el Gammal and Brooks. Few reports have been published on this method and its accuracy in the diagnosis of CSF leakage. The method still requires the performance of lumbar puncture with injection of contrast medium. Behavioral, neurological (focal seizures, ataxia, and delayed tremor), and histological changes (loss of oligodendroglia, hypertrophy of astrocytes, and formation of eosinophilic granules) have been described in animal studies. In human studies, no gross behavioral changes, neurological alterations, or seizure activity at any time after the procedure has been reported. Symptoms, such as postural post–lumbar puncture headache, nausea, and episodes of post–lumbar puncture headache. 

Fig. 2. Modified algorithm for the diagnosis of posttraumatic CSF rhinorrhea in a stepwise fashion by first confirming the leak and then localizing the side of the fistula. + = positive results; − = negative results; +/− = indeterminate values of bTP to make a diagnosis. Modified and reprinted with permission from Sage Publications, Inc. (Zapalac et al.119).
vomiting, were documented, but all resolved within the first 24 hours of the lumbar puncture with conservative bed rest.\(^{109}\) In a prospective pilot trial in 20 patients, Aydin and colleagues\(^ {5}\) used a total volume of 0.5–1.0 ml of intrathecal contrast medium without any significant gross neurologic, CSF, electroencephalography, or MRI changes related to the medium on the initial follow-up examination.\(^ {109}\) In this trial, the estimated intrathecal dose used per gram of brain was much less than that used in animal experiments (0.07–0.36 \(\mu\)mol/g brain vs 2.5–15 \(\mu\)mol/g brain).\(^ {5}\) The authors reported successful CSF localization with positive MRC studies and confirmation at the time of surgery in 14 patients and with positive MRC studies in 2 other patients who did not undergo the surgical procedure. Since there were no false positives in the surgically treated patients, they reported 100% accuracy of GdMRC in this group. In a later publication, Aydin and colleagues\(^ {4}\) reported the use of GdMRC in 51 patients with CSF rhinorrhea; in 59% of these patients, the etiology was accidental trauma. The GdMRC studies were positive for CSF rhinorrhea in 44 of the 51 patients, and in 43 of them the leak was confirmed during surgical repair, for an accuracy of 98%. None of the patients demonstrated any acute adverse reaction that could be attributed to the procedure.\(^ {4}\) Furthermore, none of them exhibited any neurological symptoms or signs caused by the intrathecal Gd injection during a mean follow-up of 4.12 years.\(^ {6}\) Unfortunately, as in many other studies, the authors did not report the specific accuracy, specificity, and sensitivity exclusively for the posttraumatic patients. Of note, Aydin and colleagues\(^ {5,6}\) have suggested the use of GdMRC with fat suppression sequences to enhance the accuracy of CSF leak detection. The sensitivity of this method for all CSF rhinorrhreas is 84%–87%, and the accuracy ranges from 78% to 100%.\(^ {5,6,49}\) It is believed that GdMRC is more sensitive and more accurate than CTC because the high viscosity of the contrast agents used in the latter contributes to a difficulty in being distributed to the entire subarachnoid space and in penetrating the small dural tears in some patients. However, even for GdMRC, the patient must have an active leak at the time of imaging for the diagnosis to be revealed. Furthermore, GdMRC is more expensive than CTC.

In conclusion, GdMRC is another safe imaging method with good accuracy and sensitivity that is part of the surgeon’s armamentarium in localizing CSF leaks during preoperative planning (Table 2). No clear criteria have been defined for when to use GdMRC versus CTC. El Gammel and colleagues\(^ {51}\) suggest using HRCT in combination with GdMRC for an optimal imaging approach in the diagnosis of CSF rhinorrhea. While the diagnosis of acute CSF rhinorrhea caused by comminuted and complex skull base fractures appears easy, that of intermittent and chronic leakage is more challenging. In Fig. 2, we show a modified version of the algorithm provided by Zapalac et al.,\(^ {119}\) integrating all the new chemical and imaging tools that would be more suitable and cost effective for the diagnosis of posttraumatic CSF fistulas. Unfortunately, the diagnosis of an occult fistula in a patient who presents with meningitis and without CSF rhinorrhea becomes more difficult, and all effort should be made to find the fistula by using all the imaging studies deemed necessary.

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**Nonsurgical Management**

Nonsurgical therapy begins with bed rest, head elevation (to prevent a negative gradient between intracranial and paranasal sinus cavities that would allow an ascending path for the bacteria intracranially), and strict CSF rhinorrhea precautions (avoid nose blowing, Valsalva maneuvers, the use of straws, the use of an incentive spirometer, and so forth). In a retrospective study of 735 craniofacial traumas, with 34 patients presenting with CSF rhinorrhea (9 patients) and CSF otorhea (25 patients), Bell and colleagues\(^ {40}\) reported that these nonsurgical measures alone provided resolution in 85% of the 34 cases. Only 3 (33%) of the 9 patients with posttraumatic CSF rhinorrhea did not respond to any of the nonsurgical measures and required surgical intervention to close the CSF leak. Mincy\(^ {88}\) reported that spontaneous closure occurs in 68% of posttraumatic CSF fistulas within 48 hours of injury and 85% within 1 week.

If bed rest, head elevation, and strict CSF rhinorrhea precautions fail, then CSF diversion has been advocated.\(^ {5,6,10}\) In the majority of cases, lumbar draining is the method of choice for CSF diversion. External ventriculostomy draining is another method that provides CSF diversion. The use of an EVD for this purpose has not been explored in the literature, most likely because it is considered to be more invasive than a lumbar drain. Yilmazlar and colleagues\(^ {118}\) reported on 81 patients with CSF leakage due to traumatic skull fractures and divided the patients into 2 groups based on their GCS scores at presentation. While lumbar drains were used in patients with a GCS score ≥ 8, there was no mention of the CSF diversion method in patients with a GCS score < 8, for whom the traumatic brain injury guidelines\(^ {44}\) suggest placement of an ICP monitor. Nevertheless, we believe that placement of an EVD instead of a lumbar drain can be considered in selected cases. Placing an EVD should be considered first in patients who might benefit from an ICP monitoring device given the severity of the traumatic event and a low GCS score. In such cases, the EVD plays the dual role of ICP monitor and CSF diverter. Placement of an EVD could be preferred over a lumbar drain in patients who present with increased supratentorial pressure due to cerebral edema, intraparenchymal contusions, or other lesions not amenable to surgical evacuation. Evaluation of the EVD as a CSF diverter in posttraumatic CSF rhinorrhea warrants further study.

In general, there are still some questions to be answered on CSF diversion for CSF rhinorrhea. Which patients would most benefit from CSF diversion? When is the best time to proceed with lumbar or ventricular drain placement? How long should one wait before deciding that CSF diversion has failed and proceed to surgical management? Knowing that 85% of posttraumatic CSF fistulas close spontaneously (within 48 hours in 68% of cases and within 1 week in 85%),\(^ {42}\) that the meningitis risk is 0.62% in the first 24 hours after injury, and that the cumulative meningitis risk is 9.12% at the end of the 1st week and 18.82% at the end of the 2nd week after injury,\(^ {42}\) some have suggested a waiting period of 72 hours—I week before attempting any invasive treatment for acute posttraumatic CSF rhinorrhea.\(^ {71,118}\) In contrast, surgical intervention has been advocated as the first line of treatment.
for delayed posttraumatic CSF rhinorrhea. We think that there is a need to further study this argument and evaluate whether even those patients with delayed CSF rhinorrhea could benefit from a trial of nonsurgical management. The duration of nonsurgical management with leak precautions and diversion of CSF has ranged from 7 days to 6 weeks. Unfortunately, it is unknown whether there is any difference in the rate of closure of a CSF fistula between 7 days and 6 weeks of nonsurgical trials. Nevertheless, one could argue that with a 7.4% meningitis risk per week within the 1st month, surgical management should be considered within the 2nd week after CSF rhinorrhea fails to resolve with conservative management, as first suggested by Dandy in 1944.

As stated above, meningitis is the most frequent complication of posttraumatic CSF rhinorrhea. Although 11%—38% of patients with CSF rhinorrhea become infected, the use of prophylactic antibiotics continues to be a controversial issue. The incidence of meningitis after posttraumatic CSF rhinorrhea is higher in the 1st few weeks, and

<table>
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<tr>
<th>Diagnostic Test</th>
<th>Advantages</th>
<th>Disadvantages</th>
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<tr>
<td><strong>chemical</strong></td>
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<tr>
<td>β2-transferrin</td>
<td>noninvasive repeatable sensitivity up to 99% specificity up to 97% protein detectable only in CSF, perilymph, &amp; aqueous humor</td>
<td>labor intensive &amp; time consuming requires high expertise for interpretation &amp; performance performed in only a few specialized laboratories</td>
</tr>
<tr>
<td>βTP</td>
<td>noninvasive repeatable sensitivity 91%–100% specificity 86%–100% not labor intensive &amp; less time consuming not expensive protein is second most abundant protein in CSF</td>
<td>not suitable in patient w/ bacterial meningitis or low glomerular filtration rate values 1.31–1.69 mg/L need other confirmatory test</td>
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<td><strong>imaging</strong></td>
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<tr>
<td>radioisotope cisternography</td>
<td>may detect presence of CSF leak even if intermittent</td>
<td>invasive, requiring intranasal endoscopic procedure &amp; intrathecal injection of radioactive material no details on site of leak sensitivity 62%–76%</td>
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<tr>
<td>HRCT</td>
<td>diagnose site of fracture diagnose size of defect noninvasive sensitivity &gt;87% accuracy approximately 87%</td>
<td>fracture not always correlated w/ presence of leak risks of radiation</td>
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<tr>
<td>CTC</td>
<td>diagnose site of fracture diagnose size of defect possibility of correlating site of fracture w/ leak sensitivity 48%–96% 95% success rate in diagnosis</td>
<td>invasive intrathecal injection of contrast material active leak must be present at time of CT scan high viscosity of contrast material reduces its penetration in small fractures or defects risks of radiation</td>
</tr>
<tr>
<td>MRI</td>
<td>noninvasive valuable for localizing fistula anatomy in 3 planes accuracy 60%–94% increased specificity to 92% &amp; sensitivity to 100% (in intermittent leaks) if using fast spin echo w/ fat suppression sequences</td>
<td>high false-positive rate (40%) not every patient can undergo MRI expensive</td>
</tr>
<tr>
<td>MRC</td>
<td>contrast less viscous than CT contrast &amp; better penetrates small fractures or tears sensitivity 85%–92% specificity up to 100% increased accuracy if fat suppression sequences used</td>
<td>invasive w/ intrathecal injection of contrast material very few studies done so far severe complications reported in animal studies active leak must be present at time of study expensive</td>
</tr>
<tr>
<td>intrathecal sodium fluorescein</td>
<td>may detect leak possibility of repairing leak when test performed</td>
<td>limited ability to localize leak depends on timing &amp; rate of leak, timing of injection, rate of CSF circulation &amp; turnover reported complications such as coma, seizures, death</td>
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the cumulative risk increases with persistence of the leak.\textsuperscript{42} That is why early reports recommended the use of prophylactic antibiotics for at least 7 days from the time of injury in all patients who presented with a CSF leak or pneumocephalus.\textsuperscript{27,57,68} Conversely, more recent retrospective and prospective controlled studies have discouraged the use of prophylactic antibiotics in this situation.\textsuperscript{27,57,60–62} Choi and Spann\textsuperscript{27} retrospectively reviewed 293 patients with posttraumatic skull base fractures, and a CSF leak was diagnosed in 115. The authors found that the use of prophylactic antibiotics increased the risk of infection when considering all patients with skull fractures. They did not find a significant difference in the occurrence of meningitis even when they considered only those patients with clinical evidence of a CSF leak. Interestingly, they found that there was an increase in the rate of meningitis soon after the antibiotics were stopped. This finding strengthened the argument against the prophylactic use of antibiotics in these situations.\textsuperscript{92,94,110} A working group of the British Society for Antimicrobial Chemotherapy,\textsuperscript{2} after reviewing the current available studies on this matter, argued against the routine use of prophylactic antibiotic treatment following traumatic skull base fractures: first, because the commonly used antibiotics poorly penetrate the noninflamed meninges, and second, because antibiotics are unlikely to eradicate potential pathogens, such as pneumococci from the upper respiratory tract. Additionally, treatment may lead to colonization with strains that are resistant to antibiotics, complicating the management of any future episodes of meningitis.\textsuperscript{49} It can be further argued that the prophylactic administration of antibiotics for an arbitrary period of 5–7 days does not reduce the risk of later meningitis, especially when the CSF leak frequently persists beyond 7 days and sometimes even years.\textsuperscript{47} Ratilal and colleagues\textsuperscript{95} performed a meta-analysis of all the published randomized controlled trials on this matter and concluded that given the current data, it is not possible to recommend the use of prophylactic antibiotics following traumatic skull base fractures. Eljamel\textsuperscript{41} retrospectively reviewed 215 patients with a definitive diagnosis of posttraumatic CSF fistula, 106 of whom were treated with antibiotics prophylactically and 109 who were not. They did not find a significant difference in the risk of meningitis between the 2 groups. They concluded that it is ethically justifiable to withhold antibiotic prophylaxis in patients with CSF fistulas until a prospective controlled double-blind trial has settled the question.\textsuperscript{41}

### Surgical Management

Surgery is reserved for the treatment of CSF leaks that do not spontaneously close or respond to conservative management with CSF diversion.\textsuperscript{110} Furthermore, early surgical intervention has been recommended in cases in which the intracranial pathology requires acute intervention (Fig. 3) or the anatomy of the skull fracture suggests that spontaneous closure would be impossible, such as in a large depressed skull base fracture, a fracture accompanied by complications (for example, cranial nerve deficits), or tension pneumocephalus.\textsuperscript{104,118} Two types of approaches for the repair of a posttraumatic dural defect and a consequent CSF leak have been described in the literature: transcranial approach and extracranial approach. Transcranial approaches were first described by Dandy\textsuperscript{31} in 1926, as he reported the first successful dural defect repair. Extracranial approaches have improved over recent years with the advancement in endoscopic sinus surgery and the transnasal endoscopic route, which has been used successfully for the closure of posttraumatic CSF fistulas in properly selected patients (Fig. 4).

Eljamel and Foy\textsuperscript{43} conducted a long-term analysis of 160 patients with acute posttraumatic CSF fistula; 149 patients underwent surgical dural repair. Forty-seven patients had a first episode of meningitis before the surgical repair. The overall risk of meningitis was reduced from 30.6% before surgery to 4% after surgery, and the cumulative risk at the 10-year follow-up was reduced to 7%.
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After surgical repair from more than 85% prior to repair. The recurrence rate of CSF leakage after the first dural repair was reported as 17% in this series, with an operative mortality of 1.3%, regardless of whether a bicoronal or unilateral approach was used. At the end of this retrospective study, the authors\textsuperscript{43} concluded that surgical repair seems to be the only durable long-term prophylaxis against the development of meningitis in patients with posttraumatic rhinorrhea and therefore should be undertaken as soon as the patient is fit for surgery.

Friedman and colleagues\textsuperscript{46} published a study of posttraumatic CSF leaks in 101 patients. Spontaneous resolution of the CSF leaks occurred over an average of 4.8 days in 26 (60%) of the 43 patients with clinically evident leaks. Twenty-four patients (47%) were surgically treated, and the median time from the initial traumatic event to surgery was 45 days among them all. A variety of surgical approaches were used, including intracranial, extracranial, and combined intracranial-extracranial. Of the 24 surgically treated patients, 3 (12.5%) experienced further CSF leakage requiring reoperation. No patient suffered recurrent leakage after a reoperation. Lumbar drainage was used in only a few patients in this series, and no meaningful conclusions could be drawn regarding its efficacy. However, the authors did conclude that the rate of surgical repair may have been lower had they more aggressively pursued lumbar drainage and conservative management.\textsuperscript{46}

Rocchi and colleagues\textsuperscript{99} reported their experience with 58 patients who had posttraumatic CSF rhinorrhea, 36 of whom underwent surgical repair according to specific criteria that have been reported\textsuperscript{100} to increase the long-term risk of infection. Early surgery was performed in 18 patients with compressive hematoma, open trauma, severe bone derangement, and severe CSF discharge.\textsuperscript{99} Delayed surgery was undertaken in 10 patients after conservative treatment failed and in 8 patients after stabilization of the vegetative parameters and regression of the cerebral edema. There was no mention of what conservative measures were attempted to stop the CSF leak in these 8 patients while waiting for stabilization. The leak ceased within 1 week in the 22 patients who were treated conservatively. Five of these 22 patients returned later with a recurrent leak and/or meningitis. Dural defects were closed using vascularized pericranium and fibrin glue. The authors further suggested that some types of cranial fractures—such as compound, comminuted, depressed, or craniofacial fractures larger than 1 cm, fractures close to the midline, or those involving the cribiform plate—require surgical intervention since they do not heal spontaneously. In addition, surgical repair was suggested in cases with an encephalocele or meningocele in the fracture crease, since they would not heal spontaneously, and in cases in which conservative treatment fails after 8 days.\textsuperscript{99,100}

Yilmazlar and colleagues\textsuperscript{118} described a series of 81 patients with persistent CSF otorrhea and rhinorrhea for more than 24 hours after the traumatic event. Conservative measures for 72 hours were undertaken in all patients except those who required emergent surgical treatment due to intracranial pathology, open fractures, and cranial nerve compression. Overall, spontaneous cessation of the leak was achieved in 39.5% of the patients. The authors suggested a treatment algorithm in which bed rest measures were applied for 72 hours–7 days, and if that failed, a CSF external drain was placed for 7–10 days. Surgical intervention was undertaken after conservative measures failed. Thirty-two patients underwent surgical repair: 12 of them within 3 days, 10 within 10–30 days, and 10 others at 3 months–22 years after the traumatic event. The authors observed that patients with GCS scores ≤ 8 at presentation had a poorer disease prognosis and a high risk of meningitis regardless of the method of treatment for the CSF leak, as compared with patients with GCS scores > 8.

The type of transcranial approach undertaken for closure of rhinorrhea depends on the fistula location and the type and size of the fracture. Several surgical techniques have been described in the literature, ranging from the classic frontal craniotomy, which can be bilateral or unilateral, to the suprasinus transfrontal approach with lateral extension.\textsuperscript{10,43,46,70,99,100,104} If primary repair of the dura is not feasible, dural substitutes, such as pericranial graft, fascia lata, temporalis muscle fascia, or other autologous (preferably) or nonautologous grafts, can be used. Each fracture associated with a CSF leak is unique, and the type of approach used to repair the leak depends on the specific situation and cannot be organized in an algorithmic form. The same can be said about the use of graft materials. The type of graft material depends on the location and size of the defect, extent of dural laceration, and availability of the graft. Until clinical trials evaluate the superiority of one surgical approach over another and...
Extracranial repairs can be achieved through different types of approaches. The most frequently used has been the transnasal approach, first described by Hirsch in 1952.

Since 1981 when Wigand first described the successful extracranial repair of a CSF leak, the endoscopic approach has progressively become preferred. Although this technique has a high rate of success and a lower rate of morbidity, limitations do exist. It may be most appropriate for specific cases, such as for a leak due to a precisely located small tear or in the absence of associated brain injuries requiring surgical treatment.

McMains and colleagues reported an overall success rate of 94% in CSF leak repair via the endoscopic extracranial approach in 92 patients. Only 18 of these patients had suffered accidental trauma. The authors noted that in patients in whom the endoscopic repair had failed, the defects were larger than 1.5 cm. The specific success rate in the accidental trauma subgroup was not reported. Banks and colleagues described their 21-year experience with endoscopic CSF leak repair in 193 cases, with an overall success rate of 98%. They included 109 posttraumatic CSF leaks in their study, 15% of which had occurred after accidental craniofacial trauma. Recurrence of the leak was reported to occur within an average of 4 months after endoscopic repair. Cassano and Felippu documented a series of 125 patients at 2 different institutions who underwent endoscopic endonasal repair of CSF leaks. The duration of CSF rhinorrhea prior to surgical repair ranged from fewer than 7 days (32 patients) to more than 30 days (29 patients). Accidental trauma was the etiological factor in 41 patients (32.8%). These authors reported an initial overall success rate of 94.4% and a success rate of 100% in the posttraumatic patients. Kirtane and colleagues described their experience with 267 patients who underwent endoscopic transnasal repair, and a posttraumatic CSF leak was diagnosed in 119. These latter patients were first treated conservatively for 4–6 weeks in the form of complete bed rest, acetazolamide, broad-spectrum antibiotic prophylaxis, and the avoidance of straining. Cerebrospinal fluid drainage via repeated lumbar punctures was preferred rather than leaving a lumbar drain. The authors reported a success rate of 96.6%, with 9 patients having a postoperative recurrence of the CSF leak. Six of these patients underwent successful repair via an endoscopic approach and 2 via a transcranial approach, with an overall success rate of 98.8%; 1 patient was lost to follow-up. The authors did not mention how many of these 9 patients were in the accidental trauma group. They did recommend performing the transcranial approach in all patients with frontal sinus fractures and CSF leakage, as well as considering the transnasal endoscopic approach only in patients with sphenoid, cribiform, and ethmoid roof fractures. In their publication, they described only those patients in whom conservative management failed; hence, it is difficult to discern how many CSF leaks resolved with 4–6 weeks of conservative management. In the series of Locatelli et al. of 135 patients with CSF rhinorrhea, 39 cases were the result of accidental traumatic injury. These patients underwent surgical treatment after 2 weeks of conservative management had failed. The authors recommended conservative management first for acute posttraumatic CSF rhinorrhea and then surgical exploration and repair only if the first option fails. In contrast, for delayed posttraumatic CSF rhinorrhea, surgical treatment was recommended without a first trial of conservative management.

Although numerous, most of the reports published on the extracranial endoscopic repair of CSF rhinorrhea include patients with different etiological backgrounds, making it difficult to discern the specific success rate of this technique for posttraumatic leaks (Table 1). Furthermore, several authors group together in 1 category (Fig. 1 lower) the accidental traumatic leaks and the postsurgical ones. In addition, very few reports have addressed the utility of endoscopic treatment in the acute setting.

The techniques used for endoscopic transnasal repair of CSF rhinorrhea depend on the location of the leak, the size of the defect, and surgeon preference. A direct paraseptal approach with or without opening of the ethmoidal cells, an anteroposterior ethmoidotomy with preservation of the middle turbinate, and an ethmoidosphenoidotomy with complete removal of ethmoidal turbinates have been used for an olfactory groove defect. A sphenoidotomy with a direct paraseptal endonasal approach limiting enlargement of the natural ostium of the sphenoid and a transeptal–pterygospheonidial approach have been used for a sphenoid bone defect, depending on the anatomy of the sphenoid sinuses. Various authors have successfully used different types of autologous and nonautologous grafts, such as a mucoperiosteal flap from the middle turbinate or septum and mucoperichondrial, osseous, cartilaginous, fat, muscular fascia, middle turbinate, or septum pedunculated graft, or any combination of these grafts.

Another widely discussed issue in endoscopic transnasal repair is whether the grafts used for repair should be placed above (inlay) or beneath (onlay) the skull base defects. In a meta-analysis, Hegazy et al. found that both techniques yielded similar results. Nevertheless, there are no data on whether there is any difference in these techniques.

Still unsettled in the literature is the issue of placing a lumbar drain after endoscopic repair of CSF rhinorrhea. Indications for lumbar drain placement are not clear, and most surgeons insert them based on their past anecdotal results. Some authors report that there is no difference in CSF rhinorrhea repair with or without postoperative lumbar drain insertion. Furthermore, none of

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These authors specify the need for a lumbar drain in post-traumatic CSF rhinorrhea (Table 1).

There is a multitude of articles describing the success rates of endoscopic repair of CSF leaks, but none exclusively document the outcome in patients with traumatic fractures. In these articles, 1,585 patients underwent endoscopic repair of a CSF leak with a reported initial success rate range of 75% to 100%. Four hundred twenty-five of these patients presented with CSF rhinorrhea following accidental trauma. More than 13 studies with 255 patients with posttraumatic CSF leaks did not specify the recurrence rate in this group. In 170 posttraumatic patients, the success rate ranged from 50% to 100%, with failure of the first transnasal endoscopic repair in only 12 patients (7.05%).

After conducting a questionnaire survey of 72 otorhinolaryngologists who regularly performed this procedure, senior and colleagues reported a complication rate of 2.5% for transnasal endoscopic repair among a sample of 650 patients of different CSF rhinorrhea etiological groups. The complications after endoscopic repair of a CSF leak were seizure, meningitis, cavernous sinus thrombosis, temporary visual problems, sinusitis, intracranial hypertension, and death. In a meta-analysis of studies published after 1990, Hegazy et al. reported an incidence of less than 1% of major complications, such as meningitis, subdural hematoma, and intracranial abscesses, after endoscopic repair of CSF rhinorrhea.

Summary

Although the first report of the successful surgical treatment of CSF rhinorrhea due to posttraumatic anterior cranial injury dates back to 1926, many controversies regarding its optimal management still exist today. Diagnosis should start with a clinical suspicion, continue with chemical investigation to confirm its presence, and hopefully end with imaging studies to define the location and size of the fistula (Fig. 2). Starting with the simplest diagnostic tool and progressing to the most complex appears to be the most efficient and cost-effective route (Table 2).

While embarking on the treatment of these fistulas, we must remember that 85% of CSF rhinorrhea cases resulting from head trauma stop spontaneously and that the risk of meningitis is 0.68% in the first 24 hours after injury and increases up to 18.87% in the first 2 weeks after injury. Published reviews have not shown that prophylactic treatment with antibiotics makes a difference, and therefore such therapy should be discouraged.

It has been suggested that patients who need emergent surgical treatment for intracranial pathology should undergo intracranial repair of the fistula in the same setting. Nevertheless, this decision must be made while taking into consideration the amount of cerebral edema and the hemodynamic stability of the patient. In some instances, treating the intracranial pathology first and then repairing the CSF fistula later, when the patient’s vegetative parameters allow, may be wiser.

While there appears to be some consensus that the majority of patients should first undergo nonsurgical management with bed rest, head-of-bed elevation, and CSF external diversion to allow spontaneous healing to occur, there remains some controversy regarding the length of time such treatment should be pursued. While some authors suggest 72 hours–7 days of bed rest and then a 7- to 10-day trial of CSF diversion maneuvers, others recommend pursuing surgical treatment after the failure of 8 days of nonsurgical management. We found no randomized controlled studies that evaluated these treatment strategies, however.

The surgical management of posttraumatic CSF fistula depends on the impact of the trauma, the location of the fistula, and the temporal relationship between the leak and the traumatic event. It has been suggested that a CSF fistula located closer to the midline and associated with fractures > 1.5 cm, frontal sinus fractures, and meningoceles or encephaloceles inside the fistula will not heal spontaneously and therefore almost always require surgical repair. Nevertheless, other authors have recommended a trial of nonsurgical management in all pa-

![Fig. 5. High-resolution CT scans obtained in a patient with severe craniomaxillofacial fractures after a motor vehicle accident, showing involvement of the frontal sinus and bone, the ethmoid and sphenoid sinus (A and B), and a large left epidural hematoma (C). The patient underwent emergent craniotomy for evacuation of the hematoma. Because of hemodynamic instability, the reduction of his fractures was postponed. The next day CSF rhinorrhea was noted. In a combined approach performed by neurosurgeons and oromaxillofacial surgical specialists, the patient underwent bifrontal craniotomy for repair of craniomaxillary fractures as well as intracranial dural repair with autologous pericranial graft. The patient was discharged home a few days afterward without signs of meningitis or CSF rhinorrhea.](image-url)
Patients who do not need emergent surgical treatment for traumatic intracranial pathology (Fig. 6). No studies have indicated which specific type of craniotomy or intracranial approach works best for each type of fracture. The same can be said of the type of tissue adhesive to use in these situations, because no scientific studies have been conducted for this purpose. We believe that until these studies appear in the literature, each skull defect and CSF leak should be considered unique and that the choice of intracranial approach depends on surgeon preference.

The surgical repair of CSF fistulas caused by traumatic anterior skull base fractures has been performed through intracranial intradural or extradural repair. With the advancement of endoscopic technology, transnasal repair has been widely used with good results. Reported failure rates for intracranial repair of rhinorrhea range from 6% to 27%, and the corresponding range for extradural endoscopic repair is 2%–50% (Table 1). A direct comparison between the transcranial and the endoscopic extradural techniques is difficult without data from randomized clinical trials. Furthermore, the results of endoscopic repairs of CSF rhinorrhea have been reported without etiological differences, and very few reports have provided the specific success rate in the posttraumatic cases. Further research is needed to define the criteria for and which patients would benefit from endoscopic extradural approaches versus the transcranial approach and to determine the time to treatment as well as more specific technical issues of endoscopic intervention in this population, such as those pertaining to the type of graft, the overlay versus inlay technique, or postoperative lumbar drain placement. In conclusion, we believe that intracranial and extradural approaches for posttraumatic CSF rhinorrhea closure should be complementary instead of competing procedures.

**Disclosure**

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

Author contributions to the study and manuscript preparation include the following. Conception and design: Ziu, Jimenez. Acquisition of data: Ziu, Savage. Analysis and interpretation of data: all authors. Drafting the article: Ziu, Savage. Critically revising the article: all authors. Reviewed submitted version of manuscript: all authors. Approved the final version of the manuscript on behalf of all authors: Ziu. Administrative/technical/material support: Ziu, Jimenez. Study supervision: Ziu, Jimenez.

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