Extracranial Repair of Pediatric Traumatic Cerebrospinal Fluid Rhinorrhea

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Objective: To examine the methods of extracranial repair of traumatic defects in the cribriform plate and ethmoid roof resulting in persistent cerebrospinal fluid (CSF) rhinorrhea in pediatric patients.

Design: Retrospective case series.

Setting: A single-institution, tertiary care, pediatric hospital.

Patients: Four children, ranging in age from 3½ to 9 years, who sustained fractures in the cribriform plate or ethmoid roof.

Intervention: Transnasal endoscopic repair in 4 patients, with 2 patients also undergoing external ethmoidectomy because of the large bony defect and the need for further exposure for repair.

Main Outcome Measures: Time free from CSF leaks or recurrence, meningitis, and other postoperative complications.

Results: All patients except 1 have been free of recurrent CSF leaks, meningitis, and other postoperative complications. The 3 patients who solely underwent the extracranial approach did not experience the complications of the traditional intracranial approach.

Conclusions: In a select group of pediatric patients, the extracranial approach for the repair of CSF leaks is appropriate. Successful use of an extracranial approach in 3 of 4 patients supports this method.

CEREBROSPINAL fluid (CSF) rhinorrhea occurs when there is CSF flow caused from an abnormal communication between the subarachnoid space into the sinonasal area. There is usually a breach in the bone and the dural and arachnoid meningeal layers. The defect may originate from the anterior skull base, paranasal sinuses, or temporal bone, with CSF flow through the eustachian tube to the nasopharynx and egress from the nose.

Cairns' classified CSF rhinorrhea into 4 categories: acute traumatic, delayed post-traumatic, operative, and spontaneous. Ommaya et al divided traumatic CSF rhinorrhea into accidental and iatrogenic types and nontraumatic CSF rhinorrhea into high-pressure leaks (eg, from tumors or hydrocephalus) and normal-pressure leaks (from congenital anomalies, focal atrophy, or osteomyelitic erosion).

There have been many reports describing the surgical management of such defects, especially at the anterior skull base. Two approaches are intracranial and extracranial repair. Intracranial repair requires a bifrontal craniotomy with exposure of the bony or meningeal defect superiorly, repair of the dural tear, and restoration of the anterior cranial fossa floor defect with various grafts. Failure rates from the intracranial approach are between 19% and 40%.

The alternative is an extracranial approach. This was performed by Dohlman in 1948 in his naso-orbital dissection for a CSF leak at the cribriform plate. Similarly, an external ethmoidectomy approach for exposure of the ethmoid roof and placement of a pedicled mucosal flap from the nasal cavity was reported in other studies for repair of the defect. With these extracranial approaches, the initial success rate was 86% in 1 study.

Exposing the defect and repairing with grafts also has been successfully achieved as an endonasal procedure. This was reported as early as 1964 by Vrabec and Hallberg. With the popularity of
PATIENTS AND METHODS

All patients with traumatic CSF rhinorrhea diagnosed and treated at Children's Hospital of Los Angeles, Los Angeles, Calif, from January 1985 to December 1996 were identified. Review of medical records, operative reports, and radiologic studies was undertaken. Patients who underwent extracranial repair were identified and are summarized as case reports and in Table 1. Patients who underwent intracranial repair and nonsurgical management were also identified and are summarized in Table 2 and Table 3, respectively, for comparison with extracranial repair.

There have been no studies examining CSF rhinorrhea and its treatment in children using the extracranial approach. The purpose of this study is to describe our experience with the surgical management of posttraumatic CSF rhinorrhea in children.

REPORT OF CASES

CASE 1

A 5-year-old boy, who rode as an unrestrained passenger in the front seat, was involved in a motor vehicle crash and sustained blunt head trauma from frontal impact. Initial evaluation of the patient did not reveal any facial fractures or CSF rhinorrhea. Head computed tomography (CT) revealed bilateral frontal contusions but no intracranial bleeding. The patient also sustained left-sided upper and lower extremity fractures.

Five weeks later, while in the rehabilitation unit, the patient developed clear, watery rhinorrhea from the left nostril. A CT scan of the paranasal sinuses revealed a small defect in the left ethmoid roof located on only 1 coronal slice. Conservative measures consisting of strict bed rest, elevation of the head of the bed, and administration of stool softeners to halt the leak did not resolve the condition.

Extracranial repair began with an endoscopic ethmoidectomy to expose the ethmoid roof. A 2-mm defect was located laterally in the ethmoid roof without any brain herniation. A pedicled septal mucosal flap was raised to cover the defect. Fibrin glue was applied to the flap to promote adherence. An absorbable gelatin sponge (Gelfoam) was additionally used to support the flap from below.

The patient recovered well from surgery. There was no further recurrence of the CSF leak, and the patient remained free of any neurologic symptoms at 15-month follow-up.

CASE 2

A 3½-year-old boy was brought to the hospital by paramedics after falling from a height of 12 m onto a concrete floor and landing on the left side of his face. At the anterior skull base region, a fracture at the cribriform plate and ethmoid roof was identified (Figure 1). Intracranial injuries included a small left frontal epidural hematoma, left frontal lobe contusion, and small left temporal hematoma but no ventriculomegaly. Because of these intracranial findings and the absence of acute CSF rhinorrhea, the decision was made to observe the patient. No surgical intervention was undertaken.

During his prolonged hospital course, the patient developed clear rhinorrhea from the left side approximately 2 months later. Conservative measures and serial lumbar punctures failed to resolve the rhinorrhea. Approach to the anterior cranial fossa floor was performed by endoscopic and external ethmoidectomy. Endoscopic ethmoidectomy was performed first. On reaching the ethmoid roof, CSF was seen emanating from the supraorbital area; however, there was no identifiable bony defect seen from within the nose. Therefore, an external ethmoidectomy was performed. A bony defect was identified in the lamina papyracea, with a larger defect superiorly, adjacent to the supraorbital notch. A left cribriform plate and ethmoid roof fracture measuring 2.5 × 1 cm was identified, with a dural tear and brain herniation. Fascia lata was harvested for dural repair. Additional fascia was used to line the bony defect, and fibrin glue was applied. An

<table>
<thead>
<tr>
<th>Patient Age, y/Sex</th>
<th>Mechanism of Injury</th>
<th>Type of CSF Rhinorrhea</th>
<th>Source of Rhinorrhea</th>
<th>Surgical Approach for Repair</th>
<th>Outcome</th>
</tr>
</thead>
<tbody>
<tr>
<td>5/M</td>
<td>Passenger in motor vehicle crash</td>
<td>Delayed (5 wk)</td>
<td>Left ethmoid roof fracture</td>
<td>Transnasal endoscopy</td>
<td>Good</td>
</tr>
<tr>
<td>3½/M</td>
<td>3-Story fall</td>
<td>Delayed (2 mo)</td>
<td>Left cribriform plate and ethmoid roof fractures</td>
<td>Transnasal endoscopy and external ethmoidectomy</td>
<td>Good</td>
</tr>
<tr>
<td>8/M</td>
<td>Passenger in motor vehicle crash</td>
<td>Delayed (13 d)</td>
<td>Left cribriform plate fracture</td>
<td>Transnasal endoscopy and external ethmoidectomy</td>
<td>Good</td>
</tr>
<tr>
<td>9/F</td>
<td>2-Story fall</td>
<td>Delayed (13 mo)</td>
<td>Right cribriform plate and ethmoid roof fractures</td>
<td>Transnasal endoscopy</td>
<td>Good</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Recurrent (2 mo)</td>
<td>Frontoethmoidal flap and cranialization</td>
<td>Resolution of CSF rhinorrhea but with meningitis 2 mo later, necessitating intracranial repair</td>
<td>Good</td>
</tr>
</tbody>
</table>

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The absorbable gelatin sponge was then used to support and reinforce this area. The patient's postoperative course was uneventful, and he recovered well. The patient is free of CSF leak, meningitis, and other postoperative complications after 1 year of follow-up.

**CASE 3**

An 8-year-old boy, who rode as an unrestrained passenger in the back seat, struck his face into the back of the driver's head during a motor vehicle crash. Results of the initial examination revealed a depressed nasal fracture. A facial CT scan revealed a minimally displaced nasoethmoid complex fracture. No CSF rhinorrhea was documented at the time. Closed nasal reduction was performed 11 days later. In 2 days, the patient complained of a clear fluid flowing from the left nostril. Conservative measures failed to resolve this condition.

Another CT scan of the paranasal sinuses revealed a parasagittal left cribiform plate fracture, approximately 3 mm, with soft tissue interposed within the fracture site. Bicortical, nondisplaced frontal bone fractures to the level of the nasolacrimal duct were also present.

Endoscopic ethmoidectomy was performed first, followed by external ethmoidectomy to allow better exposure of the ethmoid roof. A longitudinal anterior-to-posterior dural tear through a 1-cm bony defect was identified at the ethmoid roof, with a slight herniation of the brain. Left temporal fascia and muscle were then harvested for repair. Several pieces of temporalis fascia were used to patch the dural defect and were tucked underneath the bony ledge, followed by application of cyanoacrylate (not approved by the Food and Drug Administration). This was reinforced using temporalis muscle, an absorbable gelatin sponge, and packing of the nose with petroleum jelly on gauze.
At 11-month follow-up, the patient was free of recurrent CSF rhinorrhea and neurologic sequelae.

CASE 4

A 9-year-old girl presented with fever, nonproductive cough, clear rhinorrhea, vomiting, and headache for 2 days. Results of examination showed signs consistent with acute meningitis. This was the patient's second admission for meningitis. The patient apparently was admitted 4 months earlier for presumed viral meningitis, but no CSF rhinorrhea was noted at that time.

The mother of this child reported a previous admission to another local pediatric hospital 13 months ago after the child fell from a 2-story height and landed on her head. A CT scan of the head revealed a nondepressed frontal bone fracture above an apparently intact frontal sinus but no intracranial bleeding. No surgical management was initiated and there was no clinical evidence of CSF rhinorrhea.

During this second admission for meningitis, the Otolaryngology Service was consulted to evaluate watery rhinorrhea from the right nostril. Results of CSF studies from lumbar puncture revealed *Staphylococcus aureus* meningitis. Head CT scan did not reveal any abscess. A CT scan of the paranasal sinuses revealed displaced right cribriform plate and ethmoid roof fractures (Figure 1), measuring 1.75 × 0.75 cm, with total opacification of the right frontal sinus and partial opacification of the right ethmoid air cells. The site of the leak was assumed to be at the displaced fracture site.

Endoscopic repair was performed using a free mucoperiosteal graft from the right middle turbinate, after performing middle turbinectomy to gain exposure of the cribiform plate and ethmoid roof areas. The size of the bony defect was approximately 1.5 × 0.5 cm. Cerebrospinal fluid could be seen trickling through the defect. The graft was then positioned through the defect and fibrin glue was used to seal the graft. An absorbable gelatin sponge was then placed to reinforce the repair.

There was no further evidence of CSF rhinorrhea for 2 months.

The patient then presented for a third time with meningitis 2 months later; however, there was no evidence of CSF rhinorrhea, even on endoscopic examination of the intranasal repair site. A metrizamide CT scan showed a CSF leak from the right frontal sinus. A coronal approach to the frontal sinus was then taken. An osteoplastic flap was created for access to the frontal sinus. A minimally displaced fracture of the posterior table of the right frontal sinus, representing an anterior extension of the cribiform plate and ethmoid roof fracture line, was then discovered. Cranialization of the frontal sinus was then undertaken, with identification of a dural tear at the base of the frontal lobe. A pericranial graft was used to patch the dural defect. The remainder of the pericranial flap was used to line the cribiform plate and ethmoid roof areas. The patient’s postoperative course was uneventful.

Two months later, she presented again with a fourth bout of meningitis. Bifrontal craniotomy was performed to expose the anterior cranial fossa. Breakdown of the previous dural repair and a new dural tear at the posterior cribiform plate were noted. Dural closure was then obtained. Her postoperative course again was uneventful.

The patient has now been free of meningitis, CSF leak, and neurologic sequelae for 6 months.

In this article, we describe 4 pediatric patients with posttraumatic CSF rhinorrhea from the anterior skull base region repaired using the extracranial approach. The extracranial approach has been reported previously in the adult population, with limited information regarding the pediatric group.

For the external ethmoidectomy approach, success rates between 82% and 100% have been reported. Calcatera reported his series of extracranial repair in 8 patients, performing a complete external ethmoidectomy and placing a mucoperiosteal flap and free fascia...
for repair of the defect. All his repairs were successful, but the ages of his patients were not mentioned. Persky et al\textsuperscript{10} reported an initial success rate of 86%, with repair of the remaining cases of persistent CSF rhinorrhea on a second attempt using an additional extracranial approach. The youngest patient in their study was 8 years old. Yessenow and McCabe\textsuperscript{18} reported their 20-year experience using the extracranial method and osteomucoperiosteal flap. Their youngest patient was also 8 years old. Park et al,\textsuperscript{3} who reported a success rate of 82% using the extracranial approach, included 2 children in their study, ages 6 1/2 months and 4 years, but did not mention which type of procedure was used for repair.

TRANSMAXAL ENDOSCOPIC repair success rates for CSF rhinorrhea, on the other hand, range from 86% to 100%.\textsuperscript{12-16} The largest series was reported by Dodson et al.\textsuperscript{13} In their study of 29 patients, 76% underwent successful repair on the first attempt, with subsequent success on the second attempt increasing their success rate to 86%.\textsuperscript{13} There were, however, no pediatric patients in this study. The only study that mentioned successful endoscopic repair in children was that of Mattox and Kennedy.\textsuperscript{10} Two of their 7 patients were children aged 7 and 8 years.

To date, their has been only 1 study to examine CSF rhinorrhea in children. Jones et al\textsuperscript{19} reported 27 cases of CSF fistulas in children between the ages of 7 months and 18 years. Nineteen of the 27 cases spontaneously resolved with conservative measures consisting of bed rest, elevation of the head of the bed, use of stool softeners, and avoidance of straining. The remaining 8 patients demonstrated persistent leaks that were repaired by intracranial procedures. No extracranial approach was taken. Length of follow-up was unspecified.

This is the first study examining surgical management of posttraumatic CSF rhinorrhea using the extracranial approach in the pediatric population. These 4 cases represent persistent CSF rhinorrhea that failed to resolve using conservative measures such as decreased activity, bed rest, elevation of the head of the bed, use of stool softeners, avoidance of sneezing and straining, serial lumbar punctures, or placement of a lumbar drain.

All 4 cases of extracranial repair represent posttraumatic delayed CSF rhinorrhea presenting 13 days to 13 months from the date of trauma. A large proportion of patients who underwent intracranial repair or no repair with spontaneous resolution also made up the delayed type of CSF rhinorrhea. Eighty-two percent of all the children presented with delayed CSF rhinorrhea. The significance of this finding is unknown.

In all patients, we started with endoscopic repair to gain exposure without creating an external incision and to visualize the source of the leak. If the entire extent of the defect was exposed, repair was undertaken using free mucoperiosteal grafts from the excised middle turbinate or pedicled septal mucoperiosteum or mucoperichondrium. This was performed in our 2 cases involving endoscopic repair.

If there was inadequate exposure at the ethmoid roof or cribriform plate after an endoscopic approach, we proceeded to perform an external ethmoidectomy to obtain additional exposure. When the whole bony defect was apparent, we used a free fascial graft to repair the defect. Dural repair occurred if the tear was identified.

The size of the defect, therefore, was not the determinant of the type of extracranial repair. Instead, accessibility of the defect with each approach was the most important factor. In this study, the endoscopic approach was used to repair defects 2 mm × 1.5 cm at their greatest diameter, and the external ethmoidectomy was used to repair defects 1 cm × 1.75 cm at their greatest diameter. In no patients did we start an extracranial approach and proceed with an intracranial approach because of inadequate exposure. This may be explained by proper patient selection for the extracranial approach. This will be discussed later when examining cases of intracranial repair.

In our most challenging case (case 4), multiple procedures were required to control the CSF rhinorrhea, which probably originated from different sources at different times. It seemed that endoscopic repair succeeded, but recurrence of meningitis prompted a metrizamide CT scan, localizing the source at the right frontal sinus from a posterior table fracture. Osteoplastic frontal sinusotomy revealed a dural tear. The tear was repaired and the sinus was cranialized. Bifrontal craniotomy was performed after the patient's fourth episode of meningitis. Dural repair dehiscence from her second operation was identified, as well as a previously unidentified dural tear at the posterior cribriform plate. These could have been potential sources for CSF rhinorrhea. In retrospect, it may have been better to obtain a CSF localization study earlier in light of this extensive injury.

Overall, our success with the extracranial approach has been good, with the exception of case 4, in our 6- to 15-month follow-up. In the 3 remaining cases, we prevented a craniotomy, which is associated with increased morbidity and risk of damage to the olfactory nerve fibers traversing the cribiform plate during mobilization of the frontal lobes.

Our review of children with posttraumatic CSF rhinorrhea requiring an intracranial approach revealed that the injuries sustained were often more severe than those repaired extracranially. There were several points that made the intracranial approach more appropriate: more than 1 site of injury or source of possible CSF rhinorrhea evident on CT scan; significant bony defect requiring extensive reconstruction with calvarial split-thickness bone graft; or another intracranial process, such as abscess, that required surgical evacuation by an intracranial approach anyway.

The 4 patients who did not require surgical therapy for resolution of the CSF rhinorrhea emphasize the point that not all patients require surgical intervention. Although this study focuses on surgical management of CSF rhinorrhea, we must not forget that a proportion of patients spontaneously healed with or without conservative measures. Jones et al,\textsuperscript{19} in their study of CSF fistulae in children, report that 19 (70%) of 27 children healed spontaneously and that spontaneous healing is most likely
to occur within 7 days. In our study, all 4 children who had spontaneous resolution did so in 1 to 3 days.

Although the number of children in our study is small, we believe that it is worthwhile to discuss our experience with the extracranial approach for repair in the pediatric population. The basics of repair, such as adequate exposure of the defect, do not fundamentally differ from those of adults. However, because of the small size of the nasal cavity in the pediatric population, adequate exposure of the defect may be limited, thus precluding endoscopic repair alone and requiring another extracranial approach, such as external ethmoidectomy, for repair.

Because our study population only included the post-traumatic type of CSF rhinorrhea, we cannot extrapolate and make conclusions about CSF rhinorrhea caused by high-pressure leaks or intracranial tumors. More recent methods of fluid characterization using transferrin levels to help verify the presence of CSF were not used in these patients because of the obvious nature of the CSF leaks with radiological confirmation of the leak sites.

In summary, whether an intracranial or an extracranial approach is chosen, the goal of repair is to obtain adequate exposure of the defect. The choice of an extracranial or an intracranial approach depends on various factors, such as the presence of other craniofacial or intracranial injuries, the possibility of more than 1 source of CSF rhinorrhea, or anticipated complex reconstruction at the skull base. These factors would preclude an extracranial approach alone because the patient may be better served with an intracranial approach, which offers wider exposure, direct visualization of the anterior skull base defect, and dural repair. In selected patients, the extracranial approach is appropriate for repair of CSF leaks in the cribiform plate and ethmoid roof areas sustained from trauma.

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