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ORIGINAL PAPER

Multidisciplinary surgical approach for cerebrospinal fluid leak in children with complex head trauma

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Abstract
Introduction Post-traumatic cerebrospinal fluid leak from the anterior cranial fossa in children may be isolated or combined with severe facial and calvarial injury. Untreated leak may result with meningitis, hydrocephalus, and abnormal neurocognitive development.
Patients and methods We present nine children, ages 4–16 years, with complicated craniofacial injury treated by a combined subcranial and intracranial approach. A continuous lumbar drainage was kept for several days, and prophylactic antibiotics and anti-convulsive medications were routinely given. A multidisciplinary approach including discussion before surgery about other surgical options (endoscopic extracranial and intracranial alone) were performed.
Results None of the operated children had episodes of meningitis/leak after the combined approach, suggesting that appropriate sealing of the base of the skull has been achieved. There was no mortality, and the long-term follow-up showed good developmental and cosmetic results. Most of the children had significant brain contusions prior to surgery; however, these did not progress as minimal retraction was enabled by the extensive subcranial and intracranial approach.
Conclusions Child's age, anatomy of the bone, extent of cranial injury, and clinical parameters should be seriously considered when choosing the technical methods as for sealing base of skull and reconstruction of facial/cranial bones. Young age does not seem to be a contraindication to the combined approach, thus, we recommend considering it in extensive base of skull fractures when concomitant cranial, maxillofacial, and orbital fractures coexist, as alternative options may not suffice in these cases.

Keywords Base of skull · Fractures · Pediatric head trauma · Craniofacial trauma · CSF leak · Reconstruction · Craniotomy · Combined extracranial-intracranial approach

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Introduction

Cerebrospinal fluid (CSF) leak from the anterior cranial fossa may occur in children due to congenital or acquired pathologies. Congenital defects of the skull base are termed anterior basal encephalocele. Acquired etiologies include neoplastic or infectious diseases, conditions after surgery to the skull base or paranasal sinuses, and trauma. Base of skull fractures may be isolated or in combination with other skull (frontal-temporal) and maxillofacial fractures [2, 17, 22]. Base of skull fractures may lead to CSF leak and

central nervous system infections. They may also cause herniation of brain tissue (traumatic encephalocele), epilepsy, and neurological deficits. When fractures occur without significant displacement but with CSF leak (otorrhea and/or rhinorrhea), they are initially dealt conservatively with bed rest, serial lumbar punctures, and continuous lumbar drainage. Surgery in such situations is quite rare and is reserved for those who fail conservative measures. For cases with bone displacement, disfiguring of the face, suspected dural tear, and active leak, surgery may be indicated [2, 15]. A variety of conservative and surgical techniques has been described in order to prevent the intracranial complications associated with CSF leak [2, 8, 13, 17, 19, 21, 22, 27]. Conservative measures are recommended by some authors, while others have recommended surgical closure in every case of CSF leak in the anterior cranial base [3, 18]. Surgical interventions can be divided to intracranial and extracranial approaches, each has its own advantages and disadvantages. During recent years, an extracranial endoscopic approach has been utilized in specific defects [3, 14, 18], and recently, a large series of combined intracranial extradural and intradural approach has been reported by Scholsem et al. [22]. In many cases of severe craniofacial injuries, there is involvement of the anterior skull base. These injuries are often characterized by multiple dural tears, intracranial displacement of bony fragments with CSF leak, compression of the optic nerve, and pseudo-hypertelorism. Few papers have focused on the surgical treatment of such compound fractures with CSF leak in the pediatric group [2, 12]. Children with severe base of skull interruption create a real challenge of management given the different anatomy and size of the cranial and facial bones, and combined approach of intra and extracranial techniques has a special role in these cases. We present a distinct group of children with head trauma and CSF leak who were treated by a combined subcranial and subfrontal approach (combination of extracranial and intracranial open approaches). The combined method enabled repair of their CSF leak as well as reconstruction of other associated maxillofacial and skull base injuries in a single one-stage procedure with multidisciplinary collaboration. The paper will discuss the surgical technique and the outcome in this young population.

Patients and methods

We reviewed the hospital charts and the outpatient clinical and neuroimaging data of nine consecutive children with CSF leak due to complicated base of skull trauma, which were operated between 2002 and 2007 in our institution. All reconstruction procedures were conducted via combined subcranial (extracranial) and subfrontal (intracranial) approach. Six males and three females, ages 4 to 16 years (mean 10.4 years), were included in this report. Preoperatively, all the children were evaluated by a combined team, which included a pediatric neurosurgeon, a head and neck surgeon, and a maxillofacial surgeon. Neurodiagnostic imaging studies included axial and coronal or sagittal reconstructions on computerized tomography (Fig 1); magnetic resonance imaging (MRI) was performed additionally when needed or when possible (depending on the clinical situation of the patient and the possible additional data that would be available from the MR images). Usually, MRI was performed in the non-acute setup. All images were discussed prior to surgery by the multidisciplinary team and a radiologist, and stages of the combined surgery in a specific child were pre-planned. Evaluation of clinical stability to allow lengthy surgery was performed together with the pediatric intensive care staff in cases of acute trauma.

Surgical technique

A bicoronal flap was raised through an incision approximately 2 cm behind the hairline (Fig. 2). The flap was then elevated anteriorly beyond the supraorbital ridges and glabella. The supraorbital nerves and vessels were identified and carefully dissected from the supraorbital notch. Both orbits were then entered by exposing the roofs and the medial walls up to the apex, and the anterior ethmoidal arteries were identified and clipped. The bicoronal flap was elevated forward, rotated over the face, and held in position with fishhooks or self-retaining retractors (Fig. 1). Bilateral ethmoidectomies were then performed, including exposure of the ethmoidal roof and a sphenoidotomy. In cases in which the defect was localized to the posterior frontal sinus wall, we approached by drilling out the inferior sinus walls bilaterally. The upper portion of the nasal septum was removed. Removal of the frontal sinus septum allowed further visualization of this area. At this point, the entire anterior skull base has been exposed, and the bony and dural defects were identified. In general, in some cases, only partial evaluation of the intracranial injury and the dural defects can be accomplished by a subcranial approach. A combined craniotomy is performed by the neurosurgeon with subsequent dissection of the dura from the bone from above, and intracranial exposure of dural tears, bone defects, and sometimes, brain herniation into the nasal or orbital cavities. In cases of intradural bleed that coexisted, meticulous irrigation, hemostasis, and maximal effort to minimize brain retraction and contusion was made. The drainage of CSF by the spinal drain that was inserted prior to craniotomy allowed minimal retraction to the brain and was stopped whenever needed. The reconstruction technique, initially described by Raveh and followed by

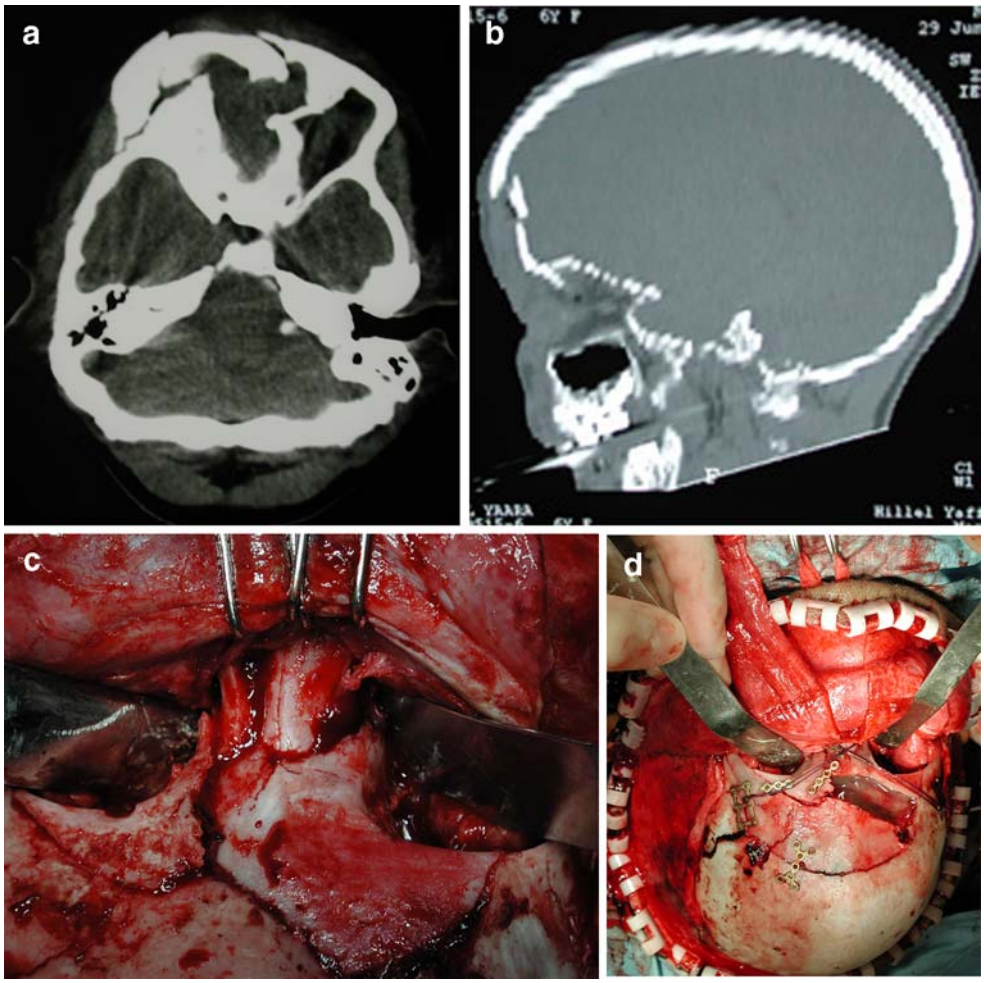

Fig. 1 A 6-year-old girl, severe craniofacial injury in a road traffic accident, arrived with active leak of CSF and brain tissue content, comatose. Intracranial and subcranial combine approach was chosen several days after arrival. Frontal contusion was evident on CT (**a–d**). **a** Axial CT demonstrating the multiple frontal fractures. **b** Reconstruction CT, sagittal paramedian demonstrating multiple fractures including base of skull. **c** After elevation of flap, the subcranial and cranial fractures are evident suggesting major injury to anterior base of skull as well. **d** After craniotomy, sealing of the base of skull intra and extradurally with fascia and biological glue (evident through the opening in the craniotomy just before closure) with miniplate reconstruction of cranial and facial bones

others [6, 20, 21] is designed according to the size of the cranial defect based on radiological and intraoperative calculations. Primary closure of the dura is performed whenever possible. A graft of temporalis fascia is used if the defect is limited. In cases of extensive skull base defects, a second surgical team simultaneously harvests a large (10–20 cm) fascia lata sheath. The size of the fascia used for reconstruction is tailored to the dimensions of the dural and skull base defects. The fascia is tucked under the edges of the dura and carefully sutured in place. In cases of major dural tears, two separate layers of fascia lata carpet were planned: an inner layer intradurally and outer layer to suture from outside and push towards the extradural layer against the base of skull. The repaired dural defect is then covered with another layer of fascia applied against the entire undersurface of the ethmoidal roof, sellar, and sphenoidal area (Fig. 3). Fibrin glue is used to provide additional protection against CSF leak. Concomitant fractures are reconstructed and stabilized at this stage. Polyethylene (Portex no. 4; SIMS Portex, Hythe, Kent, UK) tubes are inserted in the subcranial area and externalized in the nasal lumen. These are left in situ for 6 months in order to avoid obliteration of the draining pathways. Reconstruction (Figs. 2 and 3) of the frontal bone was performed in some cases with absorbable plates (Lactosorb, LactoSorb® SE) in order to optimize cosmetic results and taking into account the growth and fusion of bone within less than a year in a child—a period that takes for absorption of the plates. All other areas (orbit and zygoma) were fixed as needed by miniplates (Leibinger). Reduction of telecanthus was achieved by using the centripetal compression method [20]. A Vaseline gauze tamponade is then applied to the reconstructed base of skull and externalized into the nasal lumen. This is left in place for 7–10 days.

Results

The etiology of the leaks was post-traumatic in all patients. The extent of trauma is detailed in Table 1. Five of the patients underwent early surgery (days 3–14 from trauma). The timing of surgery depended on clinical status on arrival, presence of active leak of CSF, face and tissue swelling (delaying surgery for a few days in some cases to allow better results and manipulation of tissues), and on intracranial findings on computed tomography (CT). In

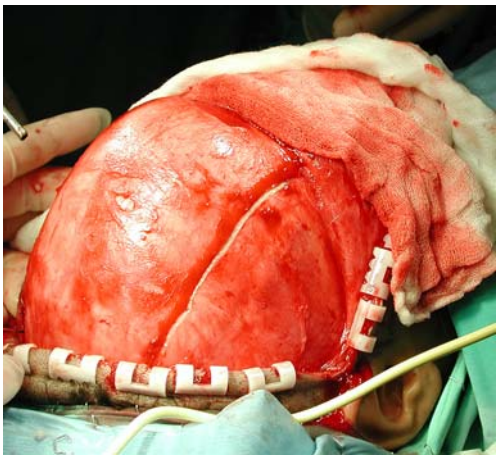

Fig. 2 Technique for pediatric combined subcranial-intracranial approach for reconstruction of base of skull fractures and defects: opening of scalp with preservation of galea and pericranium for later reconstruction of the base

addition to the bony fractures of acute trauma, all patients showed brain contusions (from minimal to significant, uni or bilateral) and evidence of subarachnoid hemorrhage. Two patients had meningitis episode(s) before the combined surgery (cases 4 and 9 in Table 1). In one patient (case 1 in Table 1), CSF leak was observed during eye enucleation surgery that was performed in another institute before transfer to our service. Patients with "chronic" CSF leak after old trauma (more than 1 month) were operated on elective basis. None of the patients had active meningitis at surgery. Patient 6 (Table 1) was referred to us after failure of two endoscopic attempts of repair (nasal approach) in another hospital. In eight patients, clinically evident CSF leak was present at the initial physical examination. In all cases, the assumption of the multidisciplinary team was that defects would not be treatable by endoscopic approach subcranially; therefore, a combined approach was planned. Before surgery, broad-spectrum antibiotic therapy consisting of a combination of cefuroxime and metronidazole was instituted, adding vancomycin intra and 24 hours postoperatively. Antibiotic treatment was continued until nasal plugs were removed. All patients underwent surgery in the supine position with minimal head extension. One patient had tracheotomy as the initial step of the combined-team surgery to allow closure of the mouth and fixation of the maxillofacial fractures. This patient remained anesthetized and ventilated as a pre-planned regime for 7 days to avoid jaw movement. A lumbar spinal continuous drainage was inserted to facilitate frontal lobe retraction and kept for a period of 3 to 6 days for CSF drainage in order to reduce the risk of postoperative CSF leak and to allow sealing of the base of skull construct. All patients suffered from uni or bilateral loss of smell sensation that was noted after recovery from surgery. None of the patients had meningitis or systemic infection after surgery. Some suffered from headache that was related to overdrainage; however, it was impossible to differentiate clearly between post-traumatic, post surgical, and post drainage symptoms. Following the combined procedure, none of the children had to undergo craniotomy for contusions or pneumocephalus. Anticonvulsants (mostly hydantoin, unless allergic reaction was suspected) was administered in all patients since the day of admission until 1–3 months after surgery. The mean hospitalization period for the pediatric group was 16 days (mean at intensive care unit (ICU) stay, 8 days); however, four of them needed rehabilitation periods of 2–8 weeks before gradual restoration of normal daily life was attempted. Some of the children attended outpatient clinics of pediatric rehabilitation with temporary behavioral and learning problems. One patient needed temporary Ritalin treatment because of attention deficit disorder (ADD) and improved 1 year after her major trauma. Cosmetic results were satisfactory in all patients except for the child who underwent acute post-traumatic eye enucleation (case 1 Table 1).

Discussion

Surgical approach

Base of skull fractures are not infrequent in pediatric head trauma, as an isolated injury to the skull or in combination with other cranial vault and maxillofacial fractures [2, 17]. The anatomy of sinuses, the size of extracranial structures that may be involved including nasal cavity and bone, the thickness of skull, and the fragility of the young bone that may result in complicated maxillofacial skull injury make the pediatric population a true challenge in tailoring the surgical approach. The primary goals are to avoid CSF leak that may result with meningitis and to achieve a good cosmetic result. CSF leak may be related to acute trauma but has been reported in children many years after injury as well [8, 10], sometimes, resulting in recurrent meningitis. Given the nature of bone growth in children, and the fact that the bone is thin, and the sinuses are not yet developed, different reconstruction techniques and suitable surgical approaches are needed as compared to the adult patients [7]. In this paper, we presented a group of nine children with major base of skull injury and associated skull and maxillofacial fractures. The various surgical techniques have been evaluated by the surgeons; however, in this particular group, the combined subcranial and intracranial (subfrontal) approach has been chosen, with good results as for CSF leak avoidance and final outcome. Skull base approaches have been previously discussed in children with base of scull involvement, with a high complication rate partially attributed to damage to integrity of the base. Teo et

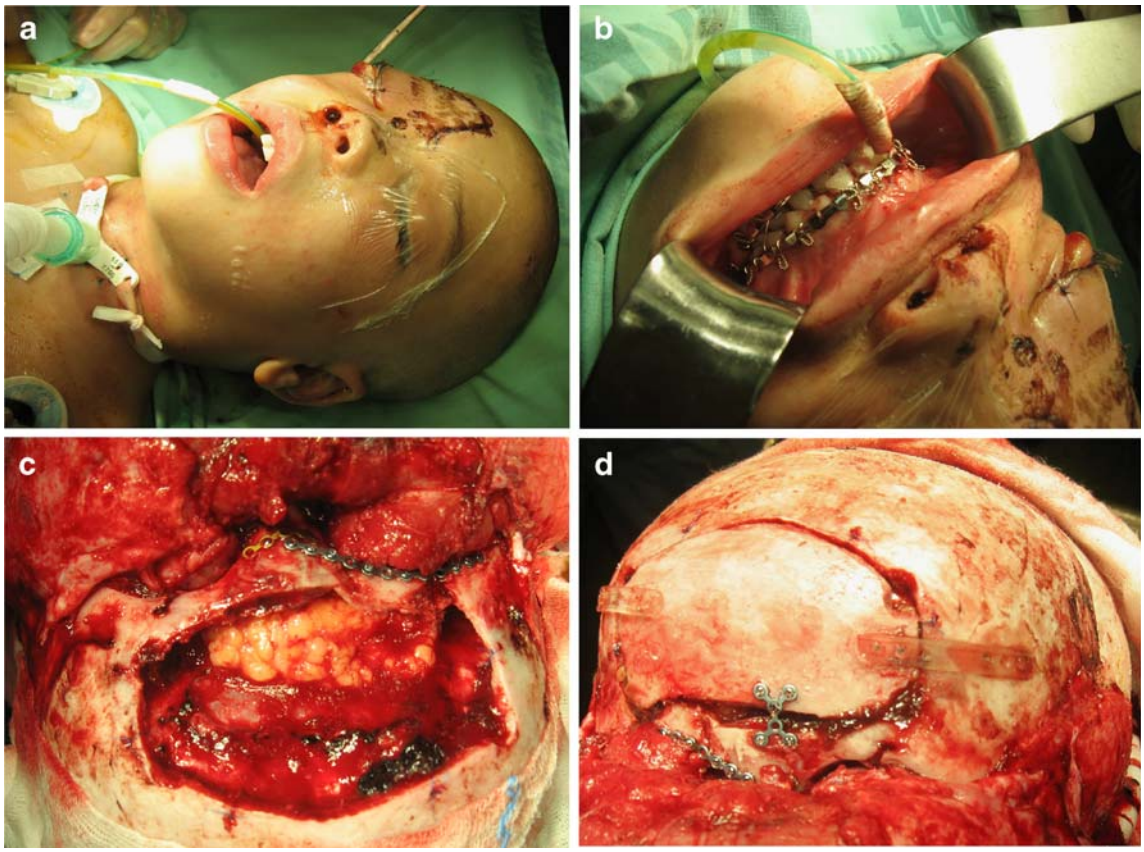

Fig. 3 Pediatric combined subcranial-intracranial approach for reconstruction of base of skull fractures by multidisciplinary team including maxillofacial; ears, nose, and throat; and neurosurgery: **a**, **b** The 4-year-old child suffered maxillary, zygomatic, and orbital fractures as well as frontal and anterior basal fractures. Tracheostomy was followed by repair of the Lt zygoma and closure of mouth (**b**). **c** Combined subcranial-intracranial approach to release the bone impingements into the torn dura and frontal brain and remove bone chips. A dissector was inserted subcranially through the broken orbital wall and the ethmoid into frontal cavity. Reconstruction of the orbit and nasal bones with miniplates after intracranial surgery has been performed to close the dural defects and pack with fascia, fat, and biological glue. **d** Final cranial reconstruction with absorbable (Lactosorb) plates to optimize cosmetic result of the forehead when bone is fused and plates are absorbed

al. reported 26 pediatric patients who underwent skull base approaches with an overall complication rate of 57%, which included temporary cranial nerve palsies (permanent complications 37%), CSF leak, and infection. Despite the fact that this series reported patients with base of skull involving tumors, some of the morbidity is attributed to the surgical approach [25]. Thus, one may postulate that improved visualization of the base from extracranial in combination with intracranial views may improve sealing of the base, reconstruction, and minimize brain retraction and some subsequent neurological damage. In a recent paper, Scholsem et al. reported 209 patients with an anterior cranial base fracture complicated by a CSF fistula [22]. Among those patients, 109 had a persistent CSF leak or radiological signs of an unhealed dural tear. All underwent only intracranial surgery with combined extradural and intradural closure of the dural tears. Of the 109 patients, 98 patients (90%) were cured after the first operation. Persistent postoperative CSF rhinorrhea occurred in 10%. Since children may not always report silent CSF leak (rhinorrhea or postnatal-drip like leak), meningitis may occur without early warning sign. Complications of meningitis in the young population are well known and include subsequent deafness, hydrocephalus, and intellectual loss. The success rate of our small population in avoiding CSF leak after the combined extracranial-intracranial approach was 100%. Series that have reported alternative approaches with endoscopic extracranial surgery or only conventional intracranial approaches (including extra and intradural approaches) have shown lower rates of success [2, 11, 14, 17, 18, 22, 25]. Each approach has its own benefits and disadvantages as has been reported in adults and in children as well [8, 10, 12–14, 16, 17, 27]. The benefits of extracranial endoscopic techniques are evident when avoiding craniotomy and brain retraction [9, 10, 12, 16]. However, this approach may not be always suitable or sufficient to seal completely the dural basal tears or in treating concomitant cranial volt and facial bone injuries. In cases of severe diffuse and complex

Table 1 Clinical data of the pediatric group with complex base of skull fractures

Case no.	Age (years), gender	Location of skull/ dural defect	Associated injuries	Time of repair (since trauma)	Preoperative meningitis	Outcome	Follow-up (months)
1	11, M	Frontal bone: orbital roof	Temporo-zigomatic and maxillary fractures, multiple orbital wall fractures with severe eye damage and unilateral blindness	3 days	No	Rt eye enucleation, normal schooling and neurological oc, temporary learning problems	72
2	8, M	Frontal bone: orbital roof	Fronto-temporal fractures	8 days	No	Normal schooling and neurological oc, temporary learning problems	84
3	10, F	Frontobasilar	Frontal bone fractures	10 days	No	Normal schooling and neurological oc	8
4	12, M	Frontal lobe	Frontal bone fractures	24 months	X4	Normal schooling and neurological oc	Lost for follow-up
5	12, M	Frontal lobe	Fronto-ethmoid, sphenoid fractures	14 days	No	Normal schooling and neurological oc	36
6	16, M	Cribriform plate	Frontal bone fractures	2 months	No	Normal schooling and neurological oc, behavioral problems	84
7	4, M	Cribriform plate	Fronto-ethmoid and maxillary fractures	7 days	No	Normal schooling and neurological oc	8
8	6, F	Cribriform plate	Fronto-ethmoid, temporal, maxillary fractures	4 days	No	Normal schooling and neurological oc, ADD (temporary Ritalin treatment)	84
9	15, F	Cribriform	Fronto-ethmoid fractures	14 years	X1	Myopia, normal schooling, and neurological oc	69

fractures of the base of skull or combination of basal fracture with calvarial fronto-temporal fracture and involvement of orbital bones, this approach will not provide complete cure in one session. Recently, Locatelli et al. reported a series of 12 children with base of skull defects, five of whom had CSF leaks due to trauma to base of skull [14]. They have used the endoscopic endonasal approach and reported excellent results with no CSF leak after surgery and no neurological or other complications. However, the patients they reported suffered from small areas of fractures of the craniofacial complex, and none was reported to have major comminuted fractures of skull and base of skull. Others have advocated the endoscopic method in post-traumatic encephaloceles [12].

The main disadvantages of an only intracranial approach include the need for significant brain retraction in order to get to posterior tears of the anterior or middle base, the limitation in fixing extracranial fractures of the orbital walls and sinuses, and the possibility of persistent CSF leak and thus resulting meningitis [11, 25]. Significant brain retraction may increase the risk for brain contusions or worsen present contusions and may cause significant frontal and other neurological damage.

The present series of pediatric patients who sustained significant trauma to head and face, with complex and diffuse (extensive) base of skull fractures is a unique group of patients and should not be compared to patients with focal or localized limited base or skull fracture. The combined intra and extracranial approach has been previously described in different pathologies, including repair of encephaloceles, surgery for base of skull tumors, and trauma [2, 6, 8, 12, 16, 17, 20, 21, 23, 25, 27], and the technical aspects of subcranial approach in children was discussed by some authors [2, 12, 23, 27]. The subcranial approach to the cranio-orbito-frontal junction allows direct access to the central anterior cranial base for repair of fractures, dural tears, and CSF fistulae. It provides good visualization without brain retraction and is suitable in primary or delayed traumatic cases [6]. The intracranial component allows better intradural carpeting of the torn dura, evacuation of intracranial bleed, and appropriate reconstruction of the cranial vault fractures. In the present series, the combination of the two strategies had indeed additive value with minimal brain retraction and single-stage reconstructive surgery for the different areas injured together with maximal sealing of the leak areas in the base.

Since the operative results were promising with no complications attributed to surgery itself, this extensive approach should be considered even in young children when appropriate. The duration of surgery, fear from brain or neurological injury, concern from extensive bleeding, and the specific limitations that may theoretically derive from the anatomy of young children should not be considered as discouraging factors to use this specific technique. The possibility that such an extensive surgical technique may interfere with long-term bone growth of facial and skull bones does not seem to be relevant. Our series includes children with long-term follow-up with no late complications or dismal cosmetic results that may have occurred during the years of growth. We already showed in our previous study that the subcranial approach minimally affects facial growth and development [23]. Moreover, this approach has been used by our group in operating younger children (less than 1 year old, data not presented) for congenital encephaloceles, and follow-up of more than 4 years have not shown any interference with bone growth even in infants. The disadvantages of the technique, however, should be explained to the parents: the major and most common morbidity anticipated would be loss of smell sense (if the fractures involve the posterior part of the anterior fossa or extend into middle fossa as well). The need for CSF drainage, for sedation and ventilation for several days (in some cases more than 3 days), and the minimal risk for brain contusion should be mentioned. In our series, all patients recovered and eventually achieved normal schooling and had no focal neurological deficit except for smell loss. Some children had behavioral changes (including ADD in one patient) that may have been actually the result of the pre-surgical traumatic contusions they had suffered from. The population of children in the present series represents major trauma to the skull and base of skull, most of them as early leak; therefore, the multidisciplinary team was in agreement that an endoscopic procedure would not be adequate due to size and complexity of fractures. Moreover, one patient in our series had previously undergone endoscopic approach, but CSF leak seemed to be persistent, and combined approach enabled open exploration that revealed multiple areas of fractures rather than a localized focus as was initially suspected by imaging. The important step in decision making was the ability to discuss among the multidisciplinary team surgeons who are familiar with all approaches and deciding together about the eventual surgical plan. The indications for the specific technique applied in a specific child should mainly take into account the whole extent of trauma to skull and face bones, the philosophy of minimal damage to brain with best cosmetic result, maximal chance to stop CSF leak, and the possibility to *achieve these goals in one single surgery.*

Reconstruction

In the pediatric group, reconstruction of base of skull and other fractures is an issue in itself. In our series, reconstruction of the fractures was modified to allow best cosmetic results, taking into account the physiology of bone growth in the child; thus, different plates were used for frontal, orbital, and other bones. Previously, some have reported successful use of absorbable plates in skull reconstruction [2, 7]. The neurosurgical team in our institution has been using Lactosorb plates extensively in reconstructive craniosynostosis surgeries in infants. Thus, we preferred titanium miniplates to fix maxillofacial fractures, and whenever possible (if fragmentation of bone was not a limiting factor) the use of absorbable plates for cranial (mainly frontal bone) reconstruction, taking into account the fusion of fractures within the months until plates are completely absorbed. In children with non-absorbable craniofix plates, there was some discomfort years after surgery from the fact that the craniofix buttons could be palpated under the skin in the frontal area. The children who were fixed in the frontal area with absorbable plates were very happy, and the cosmetic result was nice, so, one may consider using the absorbable plates for reconstruction of the calvarium mainly in the frontal areas.

Timing of surgery and postoperative management

Timing of surgery is an important issue to be discussed with the ICU people. In the setup of acute trauma, when the child is unconscious and ventilated, the skin of the injured face may become swollen, preventing appropriate opening of the flap and optimal cosmetic reconstruction. The brain as well may be acutely injured with fresh contusions, and any hemodynamic instability may worsen brain damage even if brain retraction during surgery is minimal. However, if major intracranial bleed or contusions are present, there may be no choice but to urgently operate [19]. In these cases, it is probably better to operate either immediately upon arrival to treat life-threatening intracranial pathology and use the window before major facial swelling occurs or to wait several days (usually within 4–7 days the selling will improve) and then perform on a sub-acute stage the lengthy definitive surgery [2, 20, 21]. The active CSF leak in itself, including the presence of multiple unstable fractures, are not indications to operate upon arrival if the swelling has not yet come down or if there is no neurological emergency. However, it is important to state that there is no specific randomized prospective study concerning this issue in the pediatric population, thus, the consideration for and against immediate surgery upon arrival must be discussed with all surgeons involved together with the pediatric ICU people. If surgery is

delayed by several days, some measures are taken to minimize morbidity: appropriate ventilation and supportive treatment is mandatory, and if contusion exists, a repeat CT scan may be needed to make sure there is no evolving intracranial emergency on the anesthetized child; anti-convulsive medication (usually hydantoin, or if allergy occurs, phenobarbiton, loading, and then maintenance dose) should be administered to all patients with contusions; it may be beneficial to introduce a continuous lumbar drainage mainly to follow the CSF for signs of infection even though in many cases, the drainage will not stop CSF leak completely; and antibiotics should be given while waiting to surgery, and even though there is no clear consensus about the type of antibiotics before surgery, it is probably advised that the regimen cover anaerobic bacteria and pneumococcal and should include a drug with good penetration to the CSF (and through the blood brain barrier) [1, 4, 5, 24, 26, 28]. If needed, tracheostomy should be put in order to avoid lengthy intubation through the mouth and to allow during surgery stabilization and closure of the mouth if unstable maxillofacial and mandibular fractures are present [19]. Usually, in the setup of active leak in children and in major base of skull fractures, we do not recommend placing and intracranial pressure (ICP) monitoring, unless there is additional indication (such as intraventricular hemorrhage that mandates positioning of a ventriculostomy). The reason is that ICP monitoring will usually not be reliable in the presence of significant leak and mainly will not change strategy of treatment. The issue of possible deterioration due to bleeding or contusions is dealt with continuous monitoring of the patient and repeat CT scan even in the absence of clinical deterioration. In general, for choosing appropriate timing for surgery, one should take into account the following parameters: patient's clinical situation, hemodynamic stability (multisystem trauma), CSF leak being acute or chronic, the past history of meningitis or the appreciated risk for meningitis, and the extent of surgical intervention planned. This discussion must be performed together with the pediatric ICU people and with the surgeons who will take part in the multidisciplinary approach surgical treatment. In a fully conscious patient with "late" CSF leak, the argument for surgery as soon as possible is to mainly avoid meningitis since there is no way actually to anticipate when and if it occurs.

Conclusions

We have shown that in cases of major base of skull involvement and combined face and base of skull injury in children, a multidisciplinary approach including discussion before surgery about the optimal strategy per case has been beneficial. None of the operated children had episodes of meningitis after the combined approach, suggesting that appropriate sealing of the base of skull has been achieved. In conclusion, we recommend considering this combined approach in extensive base of skull fractures and in cases when concomitant cranial (frontal-temporal) and maxillo-facial and orbital fractures coexist. Minimal surgery using endoscopic approach or craniotomy alone may not suffice in these cases. Child's age, anatomy of the bone, extent of cranial injury, and clinical parameters should be seriously considered when choosing the timing of surgery and the technical methods as for reconstruction of base of skull and cranial vault.

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