Open Approaches to the Anterior Skull Base in Children: Review of the Literature

Oshri Wasserzug¹ Ari DeRowe¹ Barak Ringel¹ Gadi Fishman¹ Dan M. Fliss¹

¹Department of Otolaryngology – Head and Neck Surgery and Maxillofacial Surgery, Tel Aviv University, Tel-Aviv Sourasky Medical Center, Affiliated to the Sackler School of Medicine, Tel Aviv, Israel

J Neurol Surg B 2018;79:42–46.

Address for correspondence Oshri Wasserzug, MD, Department of Otolaryngology – Head and Neck Surgery and Maxillofacial Surgery, Tel Aviv University, Tel-Aviv Sourasky Medical Center, Affiliated to the Sackler School of Medicine, 6 Weizman Street, Tel Aviv 6423906, Israel (e-mail: droshriw@gmail.com).

Abstract

Introduction Skull base lesions in children and adolescents are rare, and comprise only 5.6% of all skull base surgery. Anterior skull base lesions dominate, averaging slightly more than 50% of the cases. Until recently, surgery of the anterior skull base was dominated by open procedures and endoscopic skull base surgery was reserved for benign pathologies. Endoscopic skull base surgery is gradually gaining popularity. In spite of that, open skull base surgery is still considered the “gold standard” for the treatment of anterior skull base lesions, and it is the preferred approach in selected cases.

Objective This article reviews current concepts and open approaches to the anterior skull base in children in the era of endoscopic surgery.

Materials and Methods Comprehensive literature review.

Results Extensive intracranial–intradural invasion, extensive orbital invasion, encasement of the optic nerve or the internal carotid artery, lateral supraorbital dural involvement and involvement of the anterior table of the frontal sinus or lateral portion of the frontal sinus precludes endoscopic surgery, and mandates open skull base surgery. The open approaches which are used most frequently for surgical resection of anterior skull base tumors are the transfacial/transmaxillary, subcranial, and subfrontal approaches. Reconstruction of anterior skull base defects is discussed in a separate article in this supplement.

Discussion Although endoscopic skull base surgery in children is gaining popularity in developed countries, in many cases open surgery is still required. In addition, in developing countries, which accounts for more than 80% of the world’s population, limited access to expensive equipment precludes the use of endoscopic surgery. Several open surgical approaches are still employed to resect anterior skull base lesions in the pediatric population. With this large armamentarium of surgical approaches, tailoring the most suitable approach to a specific lesion in regard to its nature, location, and extent is of utmost importance.

Keywords

- skull base
- children
- open approaches
- subcranial approach
- reconstruction

Introduction

Skull base lesions in children and adolescents are rare, and comprise only 6.4% of all skull base surgery.¹ It includes a wide range of pathological conditions originating from neural, mesenchymal, notochordal, and epithelial origin.²

Anterior skull base lesions dominate, averaging slightly more than 50% of the cases.³

There are several differences between cranial base lesions and tumors in adults and in children. First, the types of tumors, their biological behavior, and oncologic management vary

between adults and children.⁴ Second, anatomic differences in children may influence the choice of surgical approach.^{3,5,6} Third, in addition to the different anatomy, the surgeon should also consider the growth centers in children, trying to avoid damage to these important structures.⁷

In sharp contradiction to the adult population, the most common lesions of the anterior skull base in the pediatric population are congenital lesions: encephaloceles and fibrous dysplasias. Nevertheless, malignant tumors, of which sarcomas are the most frequent, are not uncommon in children.

In this article, we review the literature on the current role of open approaches to the anterior skull base in children.

Open Approaches to the Anterior Skull Base in Children

The following approaches are currently applied for surgical extirpation of anterior skull base tumors in children: (1) subfrontal, (2) subcranial, (3) transfacial/transmaxillary, (4) combined subcranial–transfacial approach, (5) combined subcranial–midfacial degloving, and (6) combined subcranial–transorbital.^{1,3,4,8–14}

The approaches which are used most widely for surgical resection of anterior skull base tumors are the transfacial/transmaxillary, subcranial, and subfrontal approaches.^{3–5}

Bilateral/Unilateral Subfrontal Approach

This approach is primarily used for tumors of the anterior skull base with intracranial involvement. It has the advantage of minimizing brain retraction due to wider exposure of the floor of the anterior cranial fossa. The patient is placed supine with his head held in a Mayfield headholder. The skin is cut posterior to the frontal hairline from one zygoma to the other, and the scalp flap and the pericranial flap are reflected anteriorly. Craniotomy is performed involving both the anterior and posterior tables of the frontal sinuses¹⁵ (→Fig. 1). If an obliteration of the frontal sinus is performed, the pericranial flap is used after meticulous removal of all visible mucosa. In cases in which cranialization is performed, the

Fig. 1 The bilateral subfrontal approach.

posterior wall of the frontal sinus is drilled out and the anterior wall osteotomized segment is repositioned in its original location. When the tumor extends more inferiorly into the orbits and the cribriform area, nasal osteotomies are performed along the mid-portion of the nasal bones and along the nasolacrimal suture line. The dura is dissected off the bone and then orbital osteotomies are done, i.e., the roof and lateral wall of each orbit are removed. By that stage, the tumor is widely exposed and extirpated.

The Subcranial Approach

The subcranial approach is the most widely used approach to the anterior skull base in our institution.

The main advantage of the subcranial approach is wide exposure of the anterior skull base from below, providing superb access to the sphenothmoidal, clival, nasal, and orbital regions. Another advantage is minimal manipulation of the frontal lobe and the avoidance of facial scars.

A skin incision is made 2 cm behind the hairline with its lateral border being the supra-auricular area and a bicoronal flap is raised in a supraparietal plane. The flap is raised anteriorly beyond the glabella and the supraorbital ridges. The dissection is then continued superficial to the temporalis fascia laterally. The supraorbital nerve, vein, and artery are dissected from the supraorbital notch. Exposure of the roofs and the medial and lateral walls of both orbits is done and the anterior ethmoidal arteries are clipped. The periosteum overlying the nasal bones is dissected. The bicoronal flap is then reflected forward over the face and held in position with fishhooks.¹⁵ The next step is osteotomy of the anterior or the anterior and posterior walls of the frontal sinus, the proximal segment of the nasal bone and part of the medial wall of the orbit. Miniplates are applied to enable precise repositioning of the bony fragments at the end of the surgery.

A type A osteotomy signifies osteotomy of the anterior frontal sinus wall and nasal bone which are removed en bloc. A type B osteotomy signifies drilling burr holes, after which the posterior frontal sinus wall is resected. The fronto–nasoorbital segment is then extracted and stored in saline. Bilateral sphenoidotomy and bilateral ethmoidectomy ensues, and by that time the tumor is fully exposed and oncological resection can be undertaken.

→Fig. 2 depicts the subcranial cavity postsubcranial excision of a pediatric sarcoma. The nasofronto orbital segment has been elevated. On the right, the superior, medial, and inferior walls of the orbit have been reconstructed with three-dimensional (3D) titanium mesh.

Subcranial–Transfacial Approach

Anterior skull base tumors involving the lateral, anterior, or posterior maxillary walls or the alveolar bone can be exposed and extirpated via a combined subcranial–transfacial approach.^{4,5} The transfacial approach includes a Weber–Fergusson incision and maxillectomy. This approach enables wide exposure of the superior and inferior margins of the tumor and its complete en bloc resection including the maxilla and skull base.

Fig. 2 The subcranial cavity postsubcranial excision of a pediatric sarcoma.

Reconstruction for the subcranial part of the operation is performed identical to the repair of a subcranial defect, while the maxilla can be reconstructed either with an obturator or a bony free flap (e.g., scapula or fibula).

► **Figs. 3A and B** depict the combined subcranial–transfacial approach. In this case, a maxillectomy has been performed and the subcranial and maxillary defect has been reconstructed with a soft tissue free flap (rectus abdominis) and a prefabricated obturator.

Midfacial Degloving Approach

The midfacial degloving approach is suitable for small tumors of the anterior skull base which do not invade the superior craniofacial skeleton or skull base but extends inferior and lateral to the midface.^{4,9,15}

Its main advantage is cosmetic, as it leaves no scars on the face.

An incision is made at the gingivobuccal sulcus 0.5 cm above the teeth from the first molar on one side to the first molar on

the other side. Next, transfixion incision is made and connected bilaterally with a complete intercartilaginous incision which separates the lower lateral cartilage from the upper lateral cartilage. The intercartilaginous incision is continued caudomedially through the periosteum of the nasal floor and pyriform aperture. Release and elevation of the soft tissue overlying the maxilla and laterally till the tuberosity and superiorly till the orbital wall (“degloving”) follows. Care should be taken not to injure the infraorbital nerve.

Next, the maxillary walls involved are osteotomized on one or two sides, and the tumor is removed after completion of the osteotomies.

► **Figs. 4A and B** show a case in which midfacial degloving was followed by anterior, medial, and lateral maxillectomy. Care has been taken to avoid injury to the infraorbital nerve. The tumor is seen emerging from the pterygomaxillary fossa in the left.

The Combined Subcranial–Midfacial Degloving Approach

In tumors of the anterior skull base with caudal extension into the lower and posterior craniofacial planes, the subcranial approach may not provide an adequate exposure. In these cases, the combined subcranial and midfacial degloving technique may be required.^{4,9,15}

Upon completion of the subcranial approach with resection of the upper part of the tumor, the midfacial degloving technique follows. Lidocaine is infiltrated in the gingivobuccal sulcus, the collumella, and the intercartilaginous area. A gingivobuccal incision is done down to the periosteum. The soft tissues overlying the maxilla are raised with preservation of the infraorbital nerves and vessels. Intercartilaginous incisions are made and are continued into a full transfixion incision around the nasal vestibule. Lateral retraction of the soft tissues exposes the maxilla further and enables antrotomy. By that time, the tumor should be completely accessible both from its superior and lower extensions.

Fig. 3 (A and B) The combined subcranial–transfacial approach. (A) Reconstruction of the subcranial defect with multilayered fascia lata and a soft tissue free flap (rectus abdominis). (B) The lower maxillary defect is reconstructed with a rectus abdominis free flap and a prefabricated obturator.

Fig. 4 (A and B) Midfacial degloving including anterior, medial, and lateral maxillectomy. (A) Elevation of the soft tissues of the face. (B) Postanterior medial, posterior, and lateral maxillectomy, the tumor is seen in the pterygomaxillary space.

Subcranial–Transorbital Approach

A combined subcranial–transorbital approach is used for tumors that penetrate the bony orbit and infiltrate the orbital content and the anterior skull base.^{9,15,16} The subcranial approach is performed as described, followed by orbital exenteration. The eyelids can be spared if there is no tumor involvement, allowing for a better cosmetic result and insertion of an orbital implant in the future. If the tumor extends to the maxilla, a combined subcranial–transorbital–transfacial approach with total maxillectomy should be performed. The defects created by this combined surgical approach are usually reconstructed by a free flap.

Subcranial–Le Fort I Approach

This approach is used to resect large tumors originating in the clivus with intracranial extension.

The combined subcranial–Le Fort I approach enables wide exposure of the lesion from the cribriform plate to the inferior part of the clivus.¹¹ Upon completion of the subcranial approach, an osteotomy and down-fracture of the alveolus are performed via a gingivobuccal incision. A partial maxillectomy follows, making the inferior aspect of the tumor and its extension to the nasal cavity and clival region accessible. Specifically, we use the subcranial approach, which provides excellent exposure of the tumor and its circumference for anterior skull base tumors that involved the sphenoid clivus. Most surgeons choose a combination of the subcranial approach with a Le Fort I down-fracture osteotomy when the tumor extends from the anterior skull base inferoposteriorly to involve the lower part of the clivus.

Reconstruction

Anterior skull base defects require reconstruction to provide a barrier between the intracranial compartment and the nasal and paranasal cavities.

The type of reconstruction depends on the location, the size, and the extent of the defect, which can be estimated based on preoperative imaging studies and eventually dictated by the intraoperative findings.¹⁵

The general principles of anterior skull base reconstruction in adults are also applicable to children. However, because children are more likely to suffer from soft tissue sarcomas than adults, the surgical defect is often relatively large and can cause significant aesthetic, psychological, and functional problem. In addition, the effect on facial growth and development should be taken into account. Hence, minimizing developmental and aesthetic complications is of utmost importance.

Whenever possible, primary closure of the dura should be undertaken. When primary closure is not feasible, locoregional flaps should be used. When the defect is small, temporalis fascia which is in the surgical field may be sufficient. When the defect is larger, double layer fascia lata sheath is used to repair the dura. The fascia is inserted under the dura and sutured, trying to achieve watertight closure. To protect against cerebrospinal fluid (CSF) leak, fibrin glue is applied to the external layer.¹²

Soft tissue free flaps are the mainstay of treatment for large, 3D defects or defects involving more than one region of the skull base. This method provides soft tissue which is reliable, well vascularized, can cover mucosa, skin, and bone, and can obliterate dead space.

Reconstruction with free flap should also be performed^{17,18} in cases of preoperative radiation therapy, osteoradionecrosis, huge median defect, failed anterior skull base reconstruction, or multiple previous surgeries.

Due to its possible influence on facial skeleton growth, bony flaps are used only in adolescents who have reached skeletal maturity.

Reconstruction of the medial orbital wall is undertaken in cases in which complete removal of this segment is

mandatory or if the periorbit is excised. Fascia lata sling, split calvarial bone graft, or a titanium mesh covered with pericranium may be used.

Conclusion

Although endoscopic skull base surgery in children is gaining popularity in developed countries, in many cases open surgery is still required, and as for now open surgical approaches still remains the gold standard for the extirpation of anterior skull base lesions.

Limited access to expensive equipment precludes the use of endoscopic surgery in developing countries, which accounts for more than 80% of the world's population.

Several open surgical approaches are employed to resect anterior skull base lesions in the pediatric population. With this large armamentarium of surgical approaches, tailoring the most suitable approach to resect and reconstruct a specific lesion in regard to its nature, location, and extent is of utmost importance.

The paucity of evidence-based data in the management of anterior skull base tumors in children resulting from the rarity and the heterogeneity of these lesions is still a major limit in the anterior skull base discipline and many issues remain unanswered.

Well planned multinstitutional studies with large cohorts of pediatric patients that enable a powerful statistical analysis may provide us with answers to the role of open surgical approaches in this endoscopic era.

References

- Gil Z, Patel SG, Cantu G, et al; International Collaborative Study Group. Outcome of craniofacial surgery in children and adolescents with malignant tumors involving the skull base: an international collaborative study. *Head Neck* 2009;31(03):308–317
- Kassam A, Thomas AJ, Snyderman C, et al. Fully endoscopic expanded endonasal approach treating skull base lesions in pediatric patients. *J Neurosurg* 2007;106(2, Suppl):75–86
- Mandonnet E, Kolb F, Tran Ba Huy P, George B. Spectrum of skull base tumors in children and adolescents: a series of 42 patients and review of the literature. *Childs Nerv Syst* 2008;24(06):699–706
- Gil Z, Constantini S, Spektor S, et al. Skull base approaches in the pediatric population. *Head Neck* 2005;27(08):682–689
- Brockmeyer D, Gruber DP, Haller J, Shelton C, Walker ML. Pediatric skull base surgery. 2. Experience and outcomes in 55 patients. *Pediatr Neurosurg* 2003;38(01):9–15
- Stapleton AL, Tyler-Kabara EC, Gardner PA, Snyderman CH, Wang EW. Risk factors for cerebrospinal fluid leak in pediatric patients undergoing endoscopic endonasal skull base surgery. *Int J Pediatr Otorhinolaryngol* 2017;93:163–166
- Shlomi B, Chaushu S, Gil Z, Chaushu G, Fliss DM. Effects of the subcranial approach on facial growth and development. *Otolaryngol Head Neck Surg* 2007;136(01):27–32
- Youssef CA, Smotherman CR, Kraemer DF, Aldana PR. Predicting the limits of the endoscopic endonasal approach in children: a radiological anatomical study. *J Neurosurg Pediatr* 2016;17(04):510–515
- Fliss DM, Zucker G, Amir A, Gatot A. The combined subcranial and midfacial degloving technique for tumor resection: report of three cases. *J Oral Maxillofac Surg* 2000;58(01):106–110
- Rastatter JC, Snyderman CH, Gardner PA, Alden TD, Tyler-Kabara E. Endoscopic endonasal surgery for sinonasal and skull base lesions in the pediatric population. *Otolaryngol Clin North Am* 2015;48(01):79–99
- Lewark TM, Allen GC, Chowdhury K, Chan KH. Le Fort I osteotomy and skull base tumors: a pediatric experience. *Arch Otolaryngol Head Neck Surg* 2000;126(08):1004–1008
- Fishman G, Fliss DM, Benjamin S, et al. Multidisciplinary surgical approach for cerebrospinal fluid leak in children with complex head trauma. *Childs Nerv Syst* 2009;25(08):915–923
- Gao X, Zhang R, Mao Y, Wang Y. Childhood and juvenile meningiomas. *Childs Nerv Syst* 2009;25(12):1571–1580
- Hassler W, Zentner J. Pterional approach for surgical treatment of olfactory groove meningiomas. *Neurosurgery* 1989;25(06):942–945, discussion 945–947
- Fliss DM, Abergel A, Cavel O, Margalit N, Gil Z. Combined subcranial approaches for excision of complex anterior skull base tumors. *Arch Otolaryngol Head Neck Surg* 2007;133(09):888–896
- Fliss DM, Zucker G, Amir A, Gatot A, Cohen JT, Spektor S. The subcranial approach for anterior skull base tumors. *Oper Tech Otolaryngol–Head Neck Surg* 2000;11:238–253
- Li Z, Li H, Wang S, Zhao J, Cao Y. Pediatric SBM. Clinical features and surgical outcomes. *J Child Neurol* 2016;31(14):1523–1527
- Turazzi S, Cristofori L, Gambin R, Bricolo A. The pterional approach for the microsurgical removal of olfactory groove meningiomas. *Neurosurgery* 1999;45(04):821–825, discussion 825–826