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Locoregional flaps in pediatric anterior skull base surgery

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Management of skull base defects involves the separation of the cranial cavity from the nasal cavity in order to prevent cerebrospinal fluid leak, pneumocephalus, and intracranial infection. The size and location of the defect as well as donor tissue available will determine the type of reconstruction. Reconstruction options include free tissue grafts, locoregional flaps, and microvascular free flaps. In children, the size of potential flaps must be considered as well as the length of the pedicle, as often these differ in children. This article will discuss numerous reconstructive options, focusing on locoregional flaps in skull base reconstruction. In addition to outlining the surgical technique for each type, we will review considerations in pediatric patients for each reconstructive option.

Introduction

Skull base defects present themselves in the pediatric population primarily following tumor resection or trauma. Management of skull base defects involves the separation of the cranial cavity from the nasal cavity in order to prevent cerebrospinal fluid leak, pneumocephalus, and intracranial infection. Anterior skull base defects are now commonly approached via expanded endonasal approaches. Small defects (<5 mm) have reportedly been successfully closed via free grafting techniques.[1] Larger defects of the anterior skull base are successfully managed with multilayered closure.[2] The nasoseptal flap has gained popularity for its ease of harvest and reliability for anterior skull base defects in adults; however, there is debate as to whether pediatric anatomy allows for consistent results with this flap.[3,4] This volume discusses the use of endonasal flaps for the reconstruction of skull base defects elsewhere. This chapter will discuss the repair of anterior and skull base defects in the pediatric population via locoregional flaps, namely the pericranial flap, the temporoparietal fascia (TPF) flap, the temporalis muscle flap (TMF), and the paramedian forehead flap. In addition to their ability to cover a large surface area via a vascularized pedicle, these flaps offer large arcs of rotation that can be used reliably in the pediatric population.

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Pericranial flap

The pericranial flap is a workhorse for anterolateral skull base reconstruction and can be used for defects from

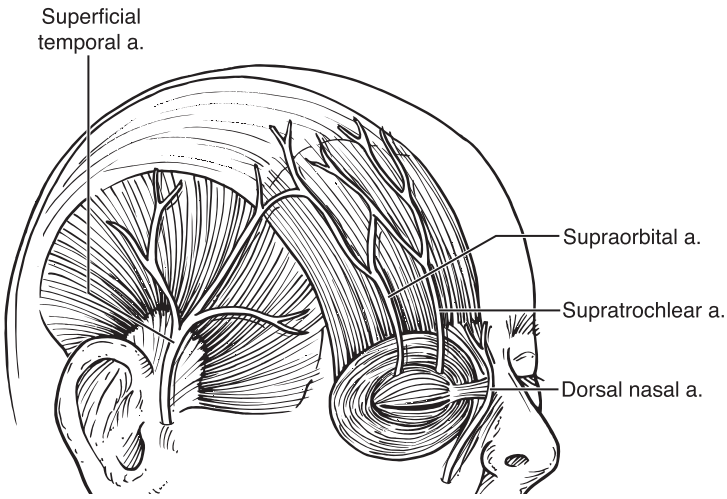

Figure 1 Vascular anatomy of the scalp.

the cribriform plate to the sella turcica. Although traditionally harvested via a coronal incision, it can also be harvested endoscopically, minimizing scarring. This flap is easy to harvest, adjacent to the operative site (skull base), provides good width and length, and can be combined with a bilateral approach for extensive defects.

Surgical anatomy

The pericranial flap consists of the pericranium and overlying loose areolar tissue. The galea can be incorporated into the flap if a thicker reconstruction is needed. The pericranium is continuous with the deep temporal fascia, the periorbita, and the nasal periosteum. Blood is supplied via the supraorbital and supratrochlear arteries.[5] The supraorbital artery can generally be found within 1 mm of the vertical tangent extended from the medial border of the iris at the level of the brow (Figure 1).[6]

Operative technique

Prior to raising the pericranial flap, any endonasal endoscopic portions of the procedure should be completed. Regardless of whether the open or endoscopic technique is used, parting of the hair can assist with visualizing the planned incision site. For an open approach, a single coronal incision can be made. The following discussion will highlight the endoscopic technique. The supraorbital and supratrochlear vessels are marked. A Doppler ultrasound may be used if desired. This flap may be designed on a supraorbital or supratrochlear vessel with a thinner pedicle; however, a wide flap and pedicle measuring 3 cm or more at the supraorbital rim is often used. With the endoscopic technique, a 2 cm midline incision and a 1 cm incision medial to the superior temporal line are marked (Figure 2).[7]

After the incision, dissection in a subgaleal plane can be performed bluntly as this is a relatively avascular plane, leaving the pericranium down on the calvarium. Endoscopic brow lift instruments (retractors and dissectors) are helpful. If additional length is needed, the flap can be dissected posterior to the incision site, toward the vertex of the scalp. After adequate dissection, incise the pericranium under direct visualization using an extended insulated needle-tip cautery. The distal portion of the flap should be wide enough to preserve the vascular supply. The proximal portion of the flap should be tapered to approximately 3 cm in width as it nears the supraorbital rim in order to ensure incorporation of the supraorbital and supratrochlear arteries. However, the flap may be customized as necessary and may be based on a single vessel. Extension of the incision to the supraorbital rim allows for sufficient flap rotation.

A 1-cm transverse glabellar/nasal or a Lynch-type incision is then made to allow the flap to be tunneled into the nasal cavity. Elevate the periosteum over the nasion to create a communication with the subperiosteal dissection superiorly. We use a 3-mm coarse diamond burr to create a defect into the nasal cavity (Figure 3). Endoscopic monitoring of the drill tip helps ensure that the defect opens into the nasal cavity inferior to the Draf III frontal sinusotomy, preventing inadvertent injury to the posterior table or frontal lobe. A Draf III frontal sinusotomy is necessary to avoid frontal sinus outflow obstruction via the flap pedicle.

Pass the pericranial flap through the nasion defect. Endoscopic visualization during this maneuver via the scalp incision allows for identification of torsion of the vascular pedicle. A combination of a narrow bone opening or a pedicle that is too wide may lead to flap strangulation. Nasal endoscopy then allows for the flap to be positioned to cover the inlay dural graft edges and bone edges in an onlay fashion (Figure 4). The proximal end of the flap can be placed to 1 side to allow for frontal sinus drainage via Draf III sinusotomy. Alternatively, the flap can be placed midline with the frontal sinus drainage stented open bilaterally. The flap is then covered with polyethelene glycol dural sealant and buttressed with petrolatum impregnated gauze. Packing is typically removed in 5-7 days. It should be noted that a watertight seal is not essential to a successful reconstruction. Healing is dependent on tissue

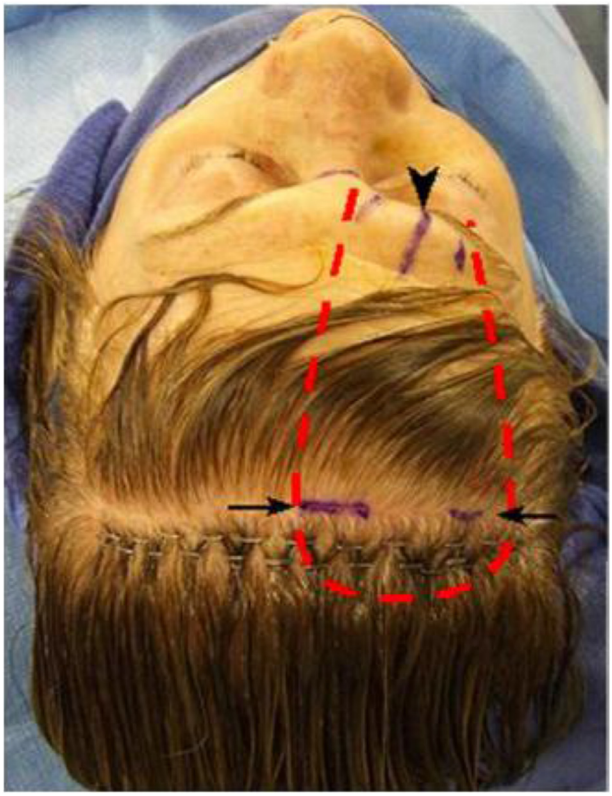

Figure 2 Pericranial flap incision planning. The hair is parted in the coronal plane. A 2 cm midline incision and a 1 cm incision medial to the superior temporal line are made for the use of endoscopic instruments (arrows). The approximate location of the supraorbital vessels above the medial limbus are shown (arrowhead). The dotted line represents the approximate dimensions of the flap in this case. Reprinted with permission from Bhakti AM et al: Reconstruction of the cranial base following endonasal skull base surgery: Regional tissue flaps. *Operative Techniques in Otolaryngology* (March 2010, Volume 21, Issue 1, Pages 83-90).

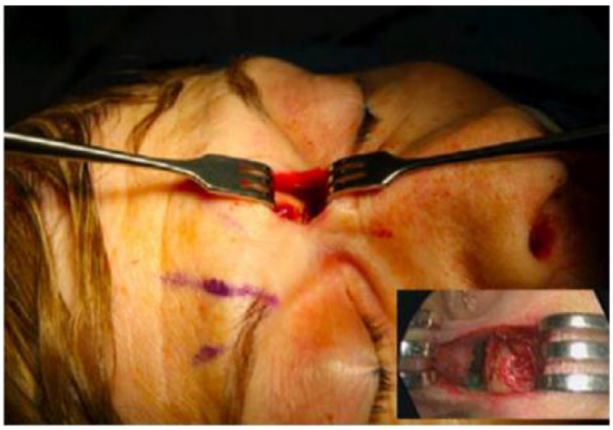

Figure 3 Glabellar incision and communication. The glabellar incision is taken down through the periosteum. Drill osteotomy creates a 4 mm × 15 mm window. The flap is then transposed through the flap. Reprinted with permission from Bhakti AM et al: Reconstruction of the cranial base following endonasal skull base surgery: Regional tissue flaps. *Operative Techniques in Otolaryngology* (March 2010, Volume 21, Issue 1, Pages 83-90).

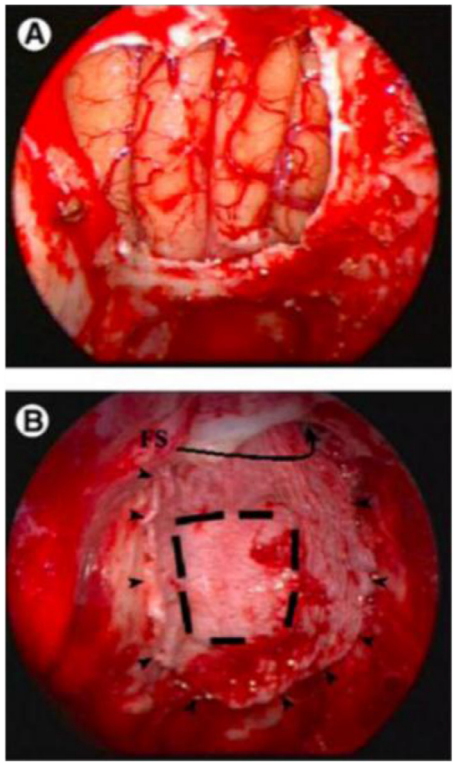

Figure 4 Anterior skull base repair. (A) Large dural defect at the anterior skull base. (B) Transposition of the pericranial flap closing the defect. Arrowheads identify the periphery of the flap. Notice that pedicle is placed on the ipsilateral side of the flap allowing for drainage of the frontal sinus via Draf III frontal sinusotomy (curved arrow).
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apposition provided by buttressing the repair with nasal packing and allowing the flap to heal, and thus seal, the defect.[5]

Tunneled paramedian forehead flap

While the paramedian forehead flap leaves vertical scars on the forehead, it is a well-vascularized flap that can be used to repair persistent, extensive defects that have failed other reconstructive techniques.

Surgical anatomy

The flap is based off of the supratrochlear artery, a branch of the ophthalmic artery that arises from the supratrochlear notch 1.7-2.2 cm lateral of midline. The artery courses superficial to the corrugator supercilii muscle and deep to the orbicularis oculi muscle. It pierces the orbicularis oculi and frontalis muscles approximately 1.5 cm above the orbit, roughly at the level of the medial eyebrow. The artery then passes superficially in the subcutaneous tissue. The pedicle can be as narrow as 1.2 cm to allow for

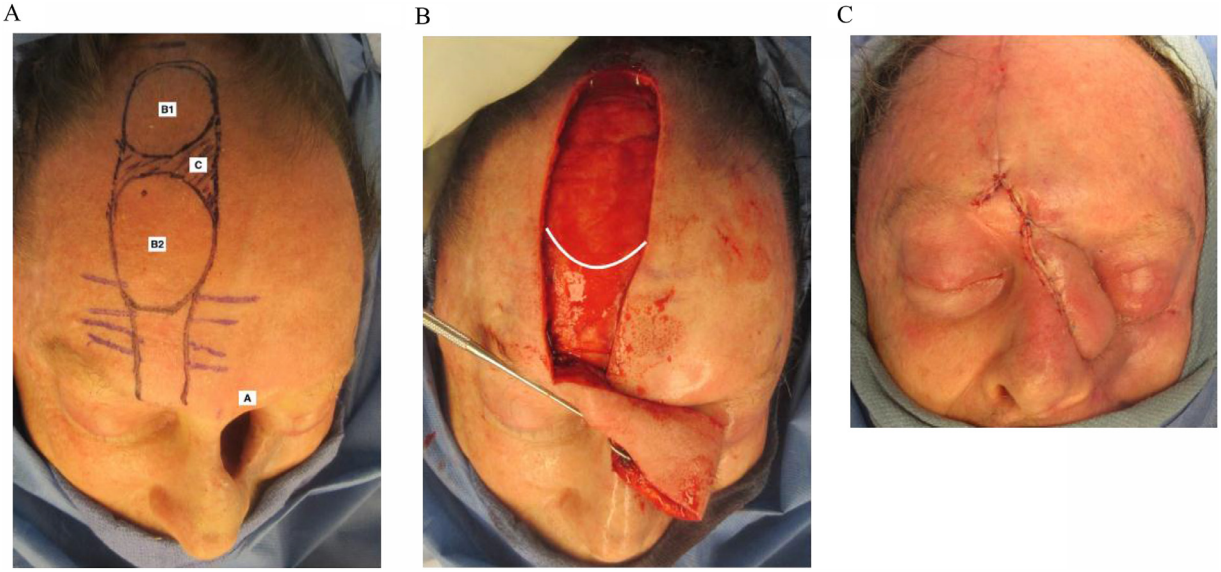

Figure 5 Tunneled paramedian forehead flap. (A) A paramedian forehead flap used to close a sinocutaneous fistula. A template based on the defect (A) was traced onto the forehead at the paramedian position (B1, intranasal portion, B2 extranasal portion). Portion C was de-epithelialized . (B) Raising the paramedian forehead flap. Inferior to the white line, dissection proceeds in a subperiosteal plane in order to protect the vascular pedicle. (C) Primary closure of the defect results in an acceptable scar.

increased mobility. This is a versatile flap that may tunnel or interpolate over an intact skin bridge with later division and inset. It may also be used with 2 skin paddles if a skin defect is also present and folded, or it may incorporate a de-epithelialized portion to avoid intranasal hair growth.

Prepare a template based on the size of the skull base defect. Aluminum from suture packaging or nasal pledgets can be used to size the defect. Trace the template onto the forehead at the paramedian position, at a height above the brow equal to the distance from the medial aspect of the brow to the defect (Figure 5). Gauze can be rotated from the medial brow as its pivot point in order to assess this distance. A midline skin paddle is preferred in children as the scar will preserve forehead rhytids that typically do not cross midline. A low midline hairline may not be amenable to this approach. Basing the pedicle off of the supratrochlear artery contralateral to the defect decreases the arc of rotation needed to reach the defect. Additionally, a contralateral-based pedicle decreases visual obstruction until division and inset for interpolated flap designs.

Incisions at the distal end of the flap may be made superficial to the frontalis muscle, in a subgaleal plane, or a subpericranial plane based on the defect characteristics and surgeon preference. If one raises the distal end of the flap in the subcutaneous plane, leaving the galea and frontalis down, the proximal half of the flap may be elevated in the subgaleal plane, leaving periosteum down until 1.5 cm superior to the level of the eyebrow. After this point, dissection proceeds in a subperiosteal plane in order to protect the vascular supply. Additional flap length can be obtained by extending the proximal end of the flap below the supraorbital rim.

Create a bony nasion defect with a diamond-burr in a similar fashion as described above. Pass the flap through the defect with the skin side of the flap facing the nasal cavity. A layered closure is used with the dura typically closed via a collagen matrix followed by dural sealant, flap, and nasal packing as described above.

The donor site is closed by widely undermining in a subgaleal plane with deep sutures in the galea and deep dermis to ensure adequate strength. A layered closure is used for the vertical portion of the donor site. Gaps at the distal end of the donor site that cannot be closed primarily may be left to heal by secondary intention.

While the paramedian forehead flap is a well-vascularized and robust flap, there is a minute risk of flap necrosis due to torsion or tension on the pedicle or vascular injury by a too-narrow pedicle. Additionally, because forehead flaps need extensive lengths to reach the skull base, hair bearing scalp may be present in the nasal cavity following flap inset. Revision procedures, laser hair removal, or regular office visits to trim intranasal hair may be required. Alternatively, the skin paddle may be de-epithelialized to minimize hair growth at the primary surgery or as a secondary procedure.

Temporoparietal fascia flap

The TPF flap provides a thin layer of well-vascularized tissue that is excellent for a variety of defects given its length and pliability.[8] It can be used for anterior and lateral skull base defects, orbital roof, and middle fossa defects, as well a sling for orbital floor reconstruction.[9] The flap can be transposed via a transpterygoid corridor in order to reconstruct anterior skull base defects without the need for maxillofacial osteotomies. As such, this flap is ideal for reconstruction of clival, sellar, and planum sphenoidale

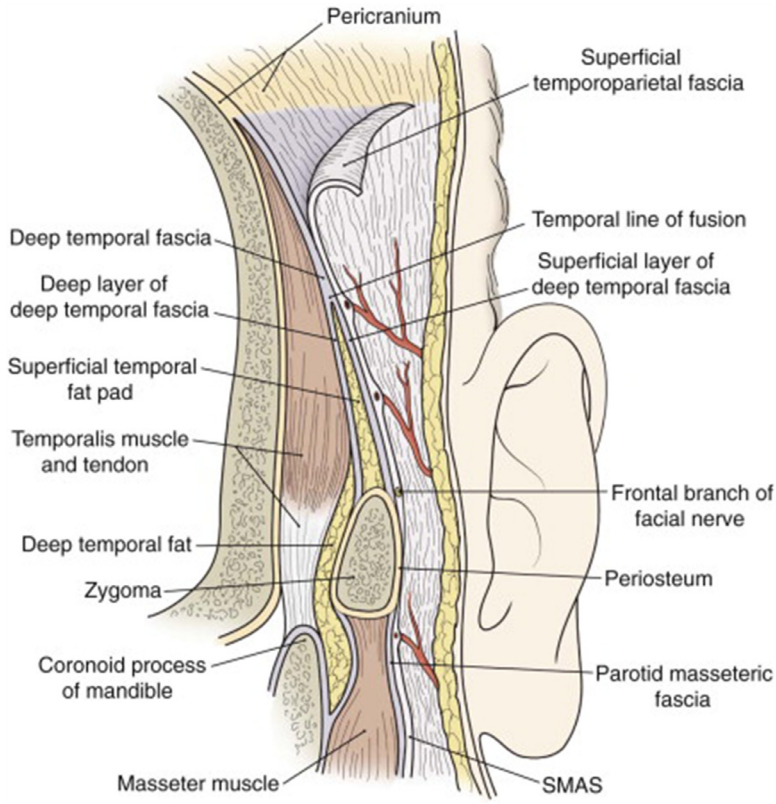

Figure 6 Layers of the scalp at the zygomatic arch.

defects because of its position as it enters the nasal cavity via the pterygopalatine corridor. The flap is long and large enough to cover clival defects that extend to the foramen magnum.

Surgical anatomy

At the level of the TPF, the scalp consists of 5 soft tissue layers: skin, subcutaneous connective tissue, TPF (superficial temporal fascia), temporalis fascia (deep temporal fascia), and temporalis muscle (Figure 6). The TPF is a continuation of the superficial musculoaponeurotic system inferiorly and the galea aponeurosis superomedially. The deep temporal fascia contains a deep and superficial layer, which attach to their respective layers on the zygomatic arch. The flap is supplied by the superficial temporal artery (STA), a terminal branch of the external carotid artery. The STA courses through the parotid gland and traverses the zygomatic process of the temporal bone after which it becomes incorporated into the TPF.[9] In most instances, the STA bifurcates into anterior and posterior parietal branches at the level of the zygomatic arch.[10] A line drawn from a point 5 mm below the tragus, passing 1.5 cm above the lateral extremity of the eyebrow estimates the path of the frontal branch of the facial nerve.[11] The surgeon should be mindful of the frontal branch's location when operating in the temporal aspect of the scalp and skull.

Operative technique

First, create the transpterygoid corridor. Perform a total ethmoidectomy and a wide medial maxillectomy followed by ligation of the sphenopalatine artery (SPA). In brief, the lateral mucosa of the nasal cavity is elevated over the crista ethmoidalis to expose the SPA. Ligate the SPA at its foramen with endoscopic hemoclips and proceed with dissection into the pterygopalatine fossa (PPF) to the internal maxillary artery. Expose the pterygopalatine ganglion posterior to the SPA by removing the lateral wall of the maxillary antrum and the posterior maxillary wall with Kerrison rongeurs. A wide maxillary antrostomy allows for maximal exposure. Follow the ganglion medially to identify the Vidian nerve and the pterygoid canal. Transect the Vidian nerve and dissect the descending palatine vessels and nerve from the greater palatine canal to displace the contents of the PPF inferiorly. Prior to surgery, the patient should understand that Vidian neurectomy can result in nasal and lacrimal dryness. Next, expose the root of the pterygoid plate. Using a high-speed drill, remove the anterior aspect of the pterygoid plates and create the transpterygoid corridor. This dissection can be done entirely endoscopically using 0° endoscopes. However, Theodosopoulos et al have described the use of transnasal and Caldwell-Luc approaches to increase visualization of the PPF.[12] Furthermore, inferior turbinectomy or anterior septal window can allow for more superior and lateral views respectively.

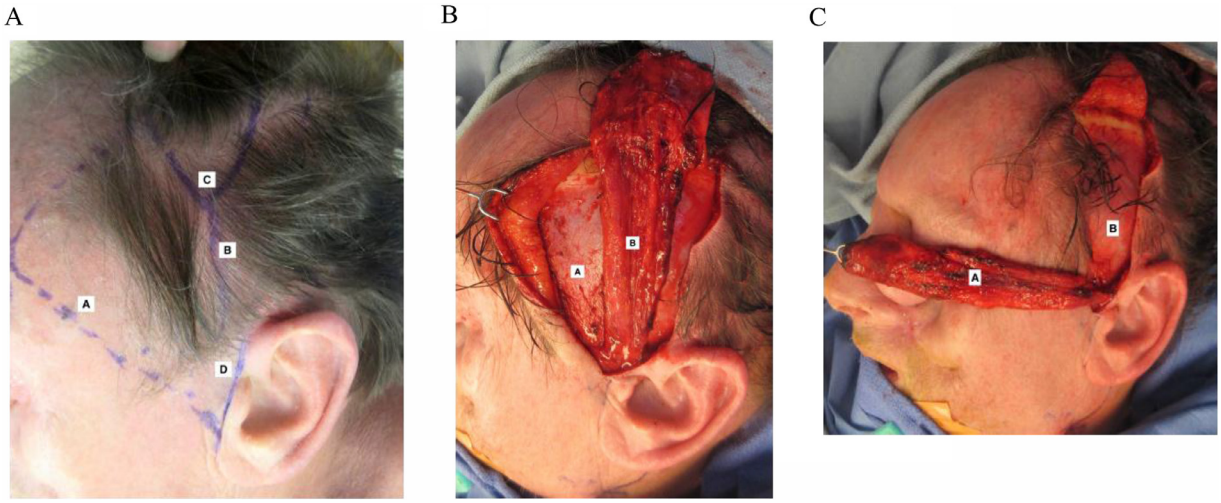

Figure 7 Temporoparietal fascia flap harvest. (A) A; Ptanguy's line, B; Doppler signal of the superficial temporal artery (STA). C; branching of the STA. D; Preauricular crease. (B) A hemicoronal flap incision integrates into a preauricular crease. Skin is elevated in a subdermal plane. For the portion of the flap over the skull, incisions are taken down through the pericranium and all 4 layers of the scalp (except skin) are incorporated into the flap. Over the temporalis muscle A; a plane is developed superficial to the deep temporal fascia. B; The temporoparietal fascia flap. (C) Length of the TPF flap; A. The donor site; B is undermined as needed and closed primarily. A drain is left in place.

A Doppler may be useful in identifying the STA before the flap is harvested. The flap may be harvested with a hemicoronal scalp incision that integrates into a preauricular crease or via a Y-shaped incision in the temple extending inferior to the preauricular crease. The incision should be superficial and not extend deeper than the hair follicles. Dissection proceeds in the subfollicular plane anterior and posterior to the incision. The anterior limit of the flap should not extend beyond the hairline to minimize the risk to the frontal branch. Subfollicular dissection reduces the risk of postoperative alopecia. After adequate exposure, margins of the fascial flap are incised and the flap is dissected from the cranium superiorly to the superior temporal line and the deep temporal fascia in the temple. The flap narrows at the pedicle with special attention to preserve the STA and allow adequate flap rotation (Figure 7).

Next, connect the TPF dissection site with the PPF. Incise the superficial layer of the deep temporal fascia several centimeters above the zygomatic arch so as to safely elevate the periosteum off of the arch and minimize risk to the frontal branch of the facial nerve. Additionally, the anterior edge of the temporalis muscle can be elevated off of the lateral orbital wall and pterygomaxillary fissure in order to further develop a soft tissue tunnel (Figure 8).

Dilate the soft tissue tunnel bluntly by passing percutaneous tracheostomy or vaginal dilators over a guidewire or through a 1 inch penrose drain deep to the zygomatic arch, lateral to the orbit, and through the maxillary defect. Grasp the tip of the wire or penrose endoscopically. Following adequate dilation, pull the flap through via Seldinger technique by securing the flap to the wire or drain with sutures. Pull the nasal end of the wire or drain and with it, the TPF flap. The internal maxillary artery should be freely mobile within the PPF in order to safely perform this maneuver. A suction drain can be placed in the scalp before it is closed. Once the flap is transposed, it can be used in a layered reconstruction of the skull base defect as described above. The flap is ideally harvested ipsilaterally; however, it can be harvested from the side contralateral to the defect if the patient has had prior violation of the PPF.

Temporalis muscle flap

Surgical anatomy

Although harvested from the same region as the TPF flap, the TMF is based off of a different blood supply and provides more bulk than the TPF flap although it is still relatively thin and pliable. TPF can be included on the superficial surface of the TMF if needed. The TMF is based off of the anterior and posterior deep temporal arteries which are located on the deep aspect of the muscle and originate medial to the coronoid process of the mandible. Again, one should be mindful of the course of the frontal branch of the facial nerve when raising this flap. This flap provides excellent coverage for lateral skull base defects but can also be used for anterior skull base defects extending as far medially as the clivus.

Operative technique

Similar to the TPF flap, make a hemicoronoal or Y-shaped incision in the temple extending into a preauricular skin crease and extend it down to the temporalis fascia. Dissect in a plane superficial to the superficial layer of the deep temporal fascia anteriorly toward the temporal fat pad. At this point, incise the superficial layer of the deep

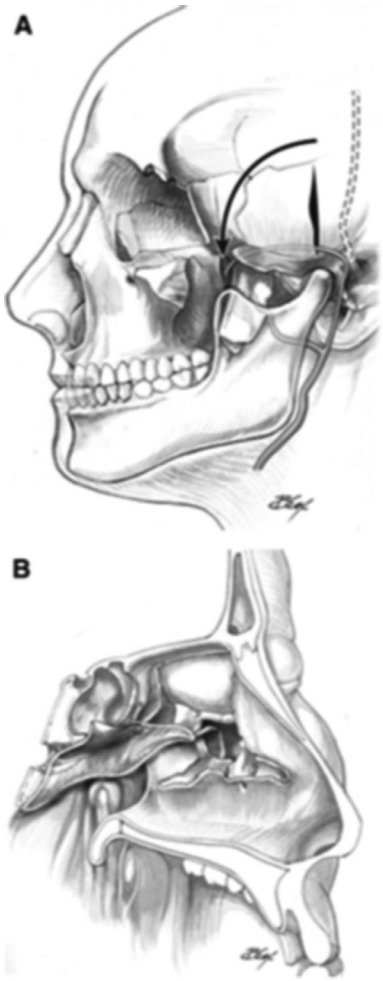

Figure 8 Transposition of the temporoparietal fascia flap. (A) A transpterygoid tunnel is created by elevating tissue off of the zygomatic arch, the lateral orbital wall, and the pterygomaxillary fissure. Endoscopically, the posterior wall of the maxilla is removed and the medial and lateral pterygoid plates are drilled away. The contents of the pterygopalatine fossa are displaced inferiorly. (B) The tunnel is dilated and the flap is transposed endoscopically via Seldinger technique. This image shows the length of the flap as it covers a clival defect.
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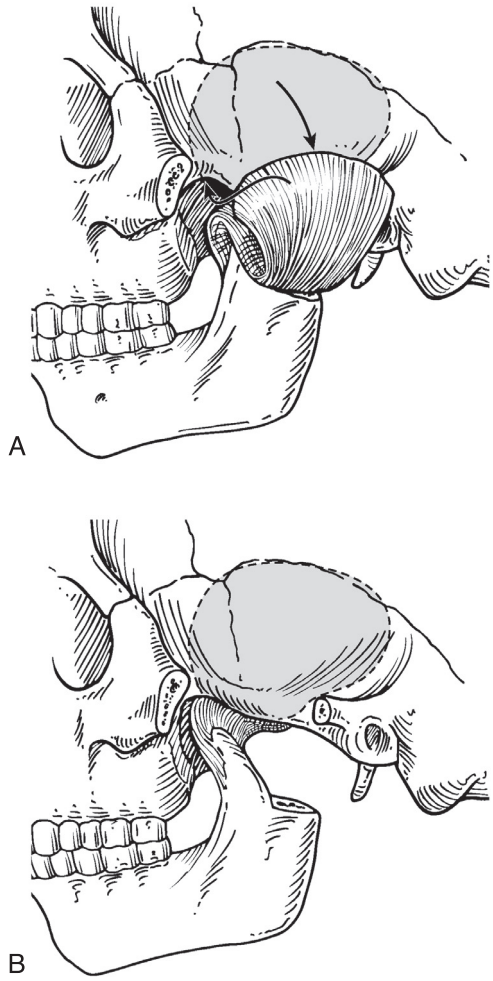

Figure 9 Transposition of the temporalis muscle flap. After the flap has been raised, it is passed medial to the coronoid process into the nasopharynx.

temporalis fascia to expose the temporalis muscle. Dissection proceeds anteriorly in a subfascial plane, deep to the fat pad, to the lateral orbital bony rim. Incise the temporalis fascia down to bone along the superior temporal line and posterior margin of the muscle. Next, raise the temporalis muscle off of bone in an inferior direction with the use of a periosteal elevator or diathermy. Over the zygomatic arch, subperiosteal elevation with Lempert elevators avoids damage to the anterior and posterior temporal arteries which lie on the deep surface of the muscle. Langenbeck retractors are helpful in visualizing the full length of the zygomatic arch. The dissection is carried inferomedially toward the coronoid process. Some authors describe removing the zygoma via osteotomies after predrilling holes in order to reduce trauma to the flap during rotation, improve flap length, and facilitate coronoid resection.[13] The flap is then passed medial to the coronoid process (Figure 9). The coronoid may be removed if additional length is needed to reach medial skull base defects as the temporalis muscle insertion is on the medial aspect of the coronoid process. Employ a layered closure and buttress as described earlier.

One of the major drawbacks of the TMF is temporal fossa concavity. This can be mitigated by splitting the flap coronally, between the anterior and posterior deep temporal arteries. The portion of the flap that is not needed for reconstruction is sutured back into its origin to recreate normal contour. Additionally, fat grafts, hydroxyapatite, or prosthetic implants may be used. Physical therapy is needed after coronoid resection as limitation of jaw movement following removal is common.[13] While complete paralysis of the frontal branch of the facial nerve is rare, reports of up to 10% of temporary paresis have been described.[13]

Conclusion

Anterior skull base defects present unique reconstructive challenges. Extranasal flaps such as the pericranial flap, the TPF flap, the TMF, and the paramedian forehead flap provide excellent alternatives or adjuncts to intranasal flaps with robust vascular supplies, excellent coverage, and relative ease of harvest. In the pediatric population, the pericranial and TPF flaps can be performed with high reliability and minimal morbidity or noticeable scarring. The temporalis muscle and PMFF flaps also offer reasonable options yet with higher cosmetic visibility. Free flaps are another viable option for reconstruction of anterior skull base defects that are outside the scope of this article.

Disclosure

The authors reported no proprietary or commercial interest in any product mentioned or concept discussed in this article.

Conflict of interest

None.

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