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ORIGINAL RESEARCH

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Endonasal skull base repair with a vascularised pedicled temporo-parietal myo-fascial flap

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Abstract

Objective: Expanded endonasal approaches (EEAs) to the skull base have increased the scope and extent of pathologies that can be treated endoscopically. The trade-off is creation of large skull base bone defects requiring reconstruction to re-establish barriers between the sino-nasal mucosa and subarachnoid space to prevent CSF leak and infection. A popular reconstructive technique is the local vascularized pedicled naso-septal flap, an option that may not always be possible when there is disruption of the vascular pedicle from multiple previous surgeries, adjuvant radiotherapy or extensive tumor infiltration. An alternative is the regional temporo-parietal fascial flap (TPFF) transposed via the trans-pterygoid route. We implemented a modification of this technique incorporating contralateral temporalis muscle at the tip of this flap and deeper vascularised pericranial layers within the pedicle to provide a more robust flap in selected cases.

Study design/methods: A retrospective review of two cases is presented with both patients having undergone multiple EEAs to resect skull base tumors with adjuvant radiotherapy, their postoperative courses complicated by recalcitrant CSF leaks resistant to multiple surgeries.

Results: Our patients had their persistent CSF fistulae repaired using infra-temporal transposition of the TPFF modified to include some of the contralateral temporalis muscle with optimisation of a vascular pedicle: a temporo-parietal temporalis myo-fascial flap (TPTMFF). Both CSF leaks resolved without further complication.

Conclusion: In situations where local flap repair to reconstruct skull-base defects following EEA may not be viable or has failed, a modified regional flap incorporating temporo-parietal fascia with a preserved vascular pedicle along with attached temporalis muscle plug may provide a robust alternative option.

KEYWORDS
endoscopic, persistent CSF leak, scholarly database, skull base reconstruction, temporalis temporoparietal myo-fascial flap

Level of evidence: 4.

1 | INTRODUCTION

The scope of skull base surgery that can be performed endoscopically has greatly increased with the advent of expanded endonasal approaches (EEAs) with specific advantages including minimal manipulation of neural and vascular structures, direct access to pathology and improved cosmesis. Both the frequency of EEAs to the skull base and the physical size of lesions that can be resected is increasing.[1,2] The trade-off is the need for increased operative exposure with creation of larger bone and dural defects. CSF leak is the major recognized complication in endoscopic skull base surgery whenever dural breach occurs, and prompt reconstruction of the defect with restoration of a barrier between the sino-nasal mucosa and subarachnoid space is critical to minimize risk of ascending infection.[3–5]

Smaller defects of the skull base (<1 cm) hold a number of options for reconstruction. Typically repair of these small defects using multilayered free grafts is successful in 90%–95% of cases.[6] Reconstruction of larger defects following EEAs or where there is a risk of high flow CSF leak (e.g., surgery for craniopharyngioma with 3rd ventricular breach) can be more challenging especially when revision surgery is performed, or where quality of the surrounding tissue is compromised (e.g., previous radiotherapy, tumor infiltration). In these difficult cases where defect coverage or tissue healing is of concern, the use of vascularised tissue and flaps–with their potential for enhanced healing–as a substrate for the repair is standard practice.

In the first instance local vascularised flaps are the preferred mode of repair. There are a number of intranasal vascularised flaps of which the pedicled naso-septal flap, based upon the naso-septal branch of the spheno-palatine artery–the Hadad-Bassagasteguy flap[7] is the first line choice as a versatile and robust local flap which is relatively easy to harvest and apply. Other options include the inferior turbinate and lateral nasal wall flap, which takes its supply from the inferior turbinate branch of the posterior lateral nasal artery (itself a branch of the spheno-palatine artery),[8] and the middle turbinate flap arising from the middle turbinate artery.[9,10] These local flaps are advantageous owing to their relatively simple harvesting via endonasal visualization and low-donor site morbidity.[11] A number of authors have described algorithms for flap selection based on size and anatomical region of the defect.[12,13] The middle turbinate flap may be used for small defects of the anterior cranial fossa or sphenoid but is limited by its small size and thin mucosa. The inferior turbinate and lateral nasal wall flap can be used for small clival defects but will often not reach the anterior cranial fossa easily. The naso-septal flap therefore is often the option of choice of all the intra-nasal flaps due to its ease of harvesting, versatility and reach.

However, in some situations it may not be available or appropriate. For example, a naso-septal flap may have been used previously and failed or the donor nasal mucosa, or its vascular pedicle, may have been damaged by radiotherapy, previous surgery or tumor infiltration. In such cases an alternative mode of reconstruction is needed such as a regional vascularised flap, the options of which include pericranial flaps (pedicled on the supra-orbital and supra-trochlear vessels), palatal flaps and temporo-parietal fascial flaps.

The temporo-parietal fascia has been well described including its potential uses for reconstruction around the head and neck region.[14,15] Fortes and colleagues describe a technique of transpterygoid transposition of a temporo-parietal fascia flap (TPFF) for skull base reconstruction after EEA for use when the naso-septal flap is not available.[16] The principles of this technique are to use a pedicled temporo-parietal fascial flap based on the superficial temporal vessels. The flap is passed via a soft tissue tunnel under the zygomatic arch into the infra-temporal fossa and onwards though a transpterygoid window into the nasal cavity, with the advantage of negating the need for extensive osteotomies of the facial skeleton.

Within the arena of skull base surgery vascularised tissue outperforms non-vascularised tissue for repair of CSF leak.[17] For vascularised flaps, those containing muscle, as opposed to fascia alone, are also more likely to take successfully.[18] Muscle is one of the oldest and most effective sealants and has been used as a substrate for repair in emergency situations for decades.[19] We present a modification of the Fortes temporo-parietal fascial flap[16] by including the deeper fascial and pericranial layers within the pedicle and also include a strip of temporalis muscle from the contralateral side at the flap's tip for use as a more robust repair in patients with resistant CSF leaks–a temporoparietal temporalis myo-fascial flap (TPTMFF).

The anatomy of the temporalis region and temporo-parietal fascia has been well described.[20,21] The layers from skin down to bone are summarized in (Figure 1). Below the skin and subcutaneous tissue lies the temporo-parietal fascia (TPF), a musculo-aponeurotic layer continuous with the galea aponeurotica superiorly. The TPF derives is blood supply from the superficial temporal artery (STA), a branch of the external carotid artery,[20,22] the distal branches of which form extensive anastomoses across the midline with contralateral vessels.[23] Deep to the TPF is the loose areolar layer, or subgaleal fascia, comprised of multiple connective tissue sheets that glide over one another. It had been thought that this layer is relatively avascular but evidence indicates that there are multiple perforating vessels from the STA supplying the subgaleal tissues.[24–26] The subgaleal tissues, often referred to as pericranium, include the subgaleal fascia and periosteum of the skull. At the temporal line of fusion the periosteum continues laterally on the bone surface deep to the temporalis muscle but also fuses with the temporalis muscle fascia overlying the temporalis muscle lateral to the superior temporal line. Inferiorly the temporalis muscle fascia splits into the deep and superficial temporal fascia which run on the deep and superficial sides of the superficial temporal fat pad respectively. The vascular supply to the temporalis muscle includes small branches of the STA, the middle temporal artery (itself a branch of the STA traveling within or deep to the temporalis muscle fascia), and the deep temporal arteries arising from the internal maxillary artery (traveling within the temporalis muscle or deep to the muscle within the periosteum).[27] The middle temporal artery supplies the temporalis muscle fascia. Elevation of a thick flap including TPF, subgaleal fascia and periosteum with a wide base will include superficial temporal artery branches and perforating bridging vessels in the subgaleal fascia preserving optimal perfusion of the flap. Combined with the extensive anastomoses of the STA across the midline we believe

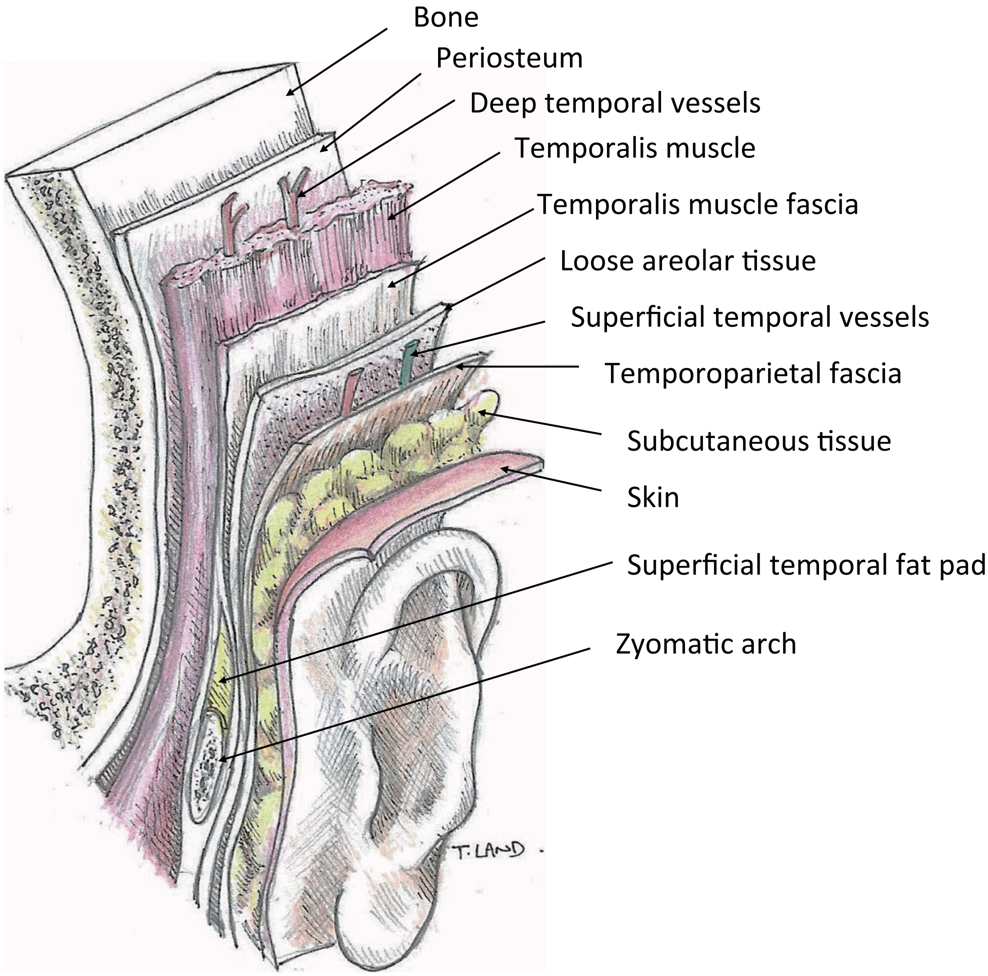

FIGURE 1 Drawing demonstrating the anatomical layers of the temporal region scalp from the skin down to the bone. Of note the temporal line of fusion (periosteum and temporalis muscle fascia) is omitted to better visualize the layers

these factors allow us to harvest a longer viable flap continuing in a coronal plane across the midline with optimized vascular supply.

2 | MATERIALS AND METHODS

Following NHS Health Research Authority assessment tool approval we undertook a retrospective review of the clinical background, surgical method and outcome for two patients who underwent repair of resistant CSF leaks following complicated trans-sphenoidal surgery and skull base radiotherapy, with transposition of a vascularised pedicled temporoparietal temporalis myo-fascial flap (TPTMFF).

2.1 | Surgical technique

A large ipsilateral maxillary antrostomy is performed allowing endoscopic access to the posterior maxillary sinus wall. The mucosa over the postero-lateral maxillary sinus is removed and the thin bone making up the posterior wall is gently fractured and removed with Kerrison's rongeurs creating a 2 cm window into the infratemporal fossa.

A bi-coronal incision is made down to the level of the TPF staying below the hair follicles. Skin and subcutaneous tissue is gently dissected away from the TPF and reflected forwards. The TPF is exposed adequately to the superior temporal line on the contralateral side (Figure 2) with enough anterior exposure to allow a pedicle width of at least 4 cm to incorporate as many deep and superficial temporal vessels as possible. An area of contralateral temporalis muscle the size of the defect is marked (approximately 4 cm $\times$ 2 cm in our cases) creating the distal limit of the flap. The margins are incised down to bone and continued over the midline in a broad band approximately 4 cm in width back towards the pedicle. A periosteal elevator is used to strip the incised portion of the contralateral temporalis muscle towards the midline with attached periosteum, overlying temporalis fascia, subgaleal layer and TPF as a single thickness sheet (see Figures 3 and 4). Care is taken not to disrupt the layers so as to preserve any perforating vessels that may cross the subgaleal layer. The flap is raised proximally to include a wide base (Figure 4B). On the ipsilateral side, the TPF is raised with all deep scalp layers including periosteum until the superior temporal line is encountered. At this point the flap is carefully freed from the bone at the temporal fusion line and proximally the plane of dissection is continued through the loose areolar layer, remaining superficial to the superficial temporal fat pad, without interrupting the temporalis muscle or its fascia. As the zygomatic arch is approached it is prudent to be aware of the temporal branch of the facial nerve within this plane and effort made to preserve it.

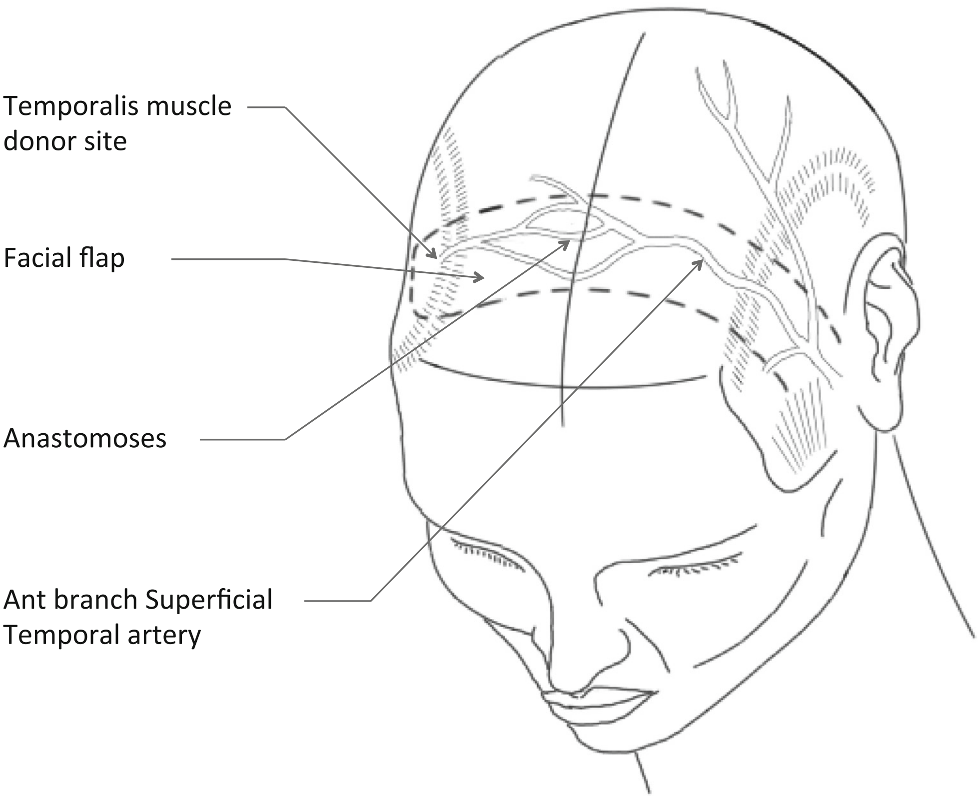

FIGURE 2 Drawing demonstrating demarcated flap based on superficial temporal artery (dotted line). The contralateral superior temporal line and temporalis muscle can be seen providing the landmarks for the distal flap margin

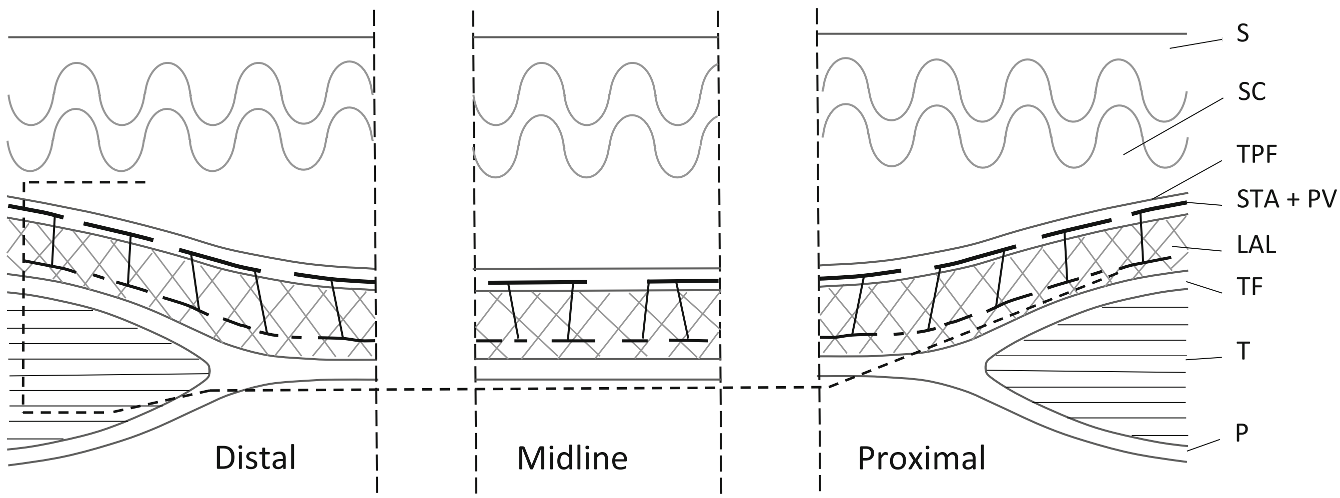

FIGURE 3 Schematic drawing demonstrating coronal cross section along axis of the flap including STA blood supply and perforating vessels at different locations along the flap (Distal / Contralateral, Midline, Proximal/Ipsilateral). The layers of the scalp are labeled: LAL, loose areolar layer; P, periosteum; S, skin; SC, subcutaneous tissue; T, temporalis muscle; TF, temporalis fascia; TPF, temporo, parietal fascia; STA + PV, superficial temporal artery and perforating vessels. The fine dotted line marks the distal flap margin and layers contained within the flap as it is raised. Of note the temporal line of fusion is where the temporalis fascia and periosteum join

On the ipsilateral side a space is created behind the zygomatic arch using blunt dissection to gain access into the infra-temporal fossa (ITF). An olive tip sucker is passed into the ITF and advanced gently through the fat of the ITF until it can be seen to enter the window created in the posterior-lateral wall of maxillary sinus under endoscopic visualization (Figure 5A). Thus a tunnel communicating the infratemporal fossa with the nasal cavity is created. The passage is made as anteriorly as possible with a blunt instrument to avoid injury to the 2nd division of the maxillary artery and its branches. A guide wire can be passed down the sucker and the tunnel gently dilated (Figure 4B) using a “Rhino percutaneous tracheostomy dilator” (Ciaglia Blue Rhino® Advanced Percutaneous Tracheostomy kit, Cook Medical). The smooth external surface of this system minimizes trauma to the structures of the ITF. A large

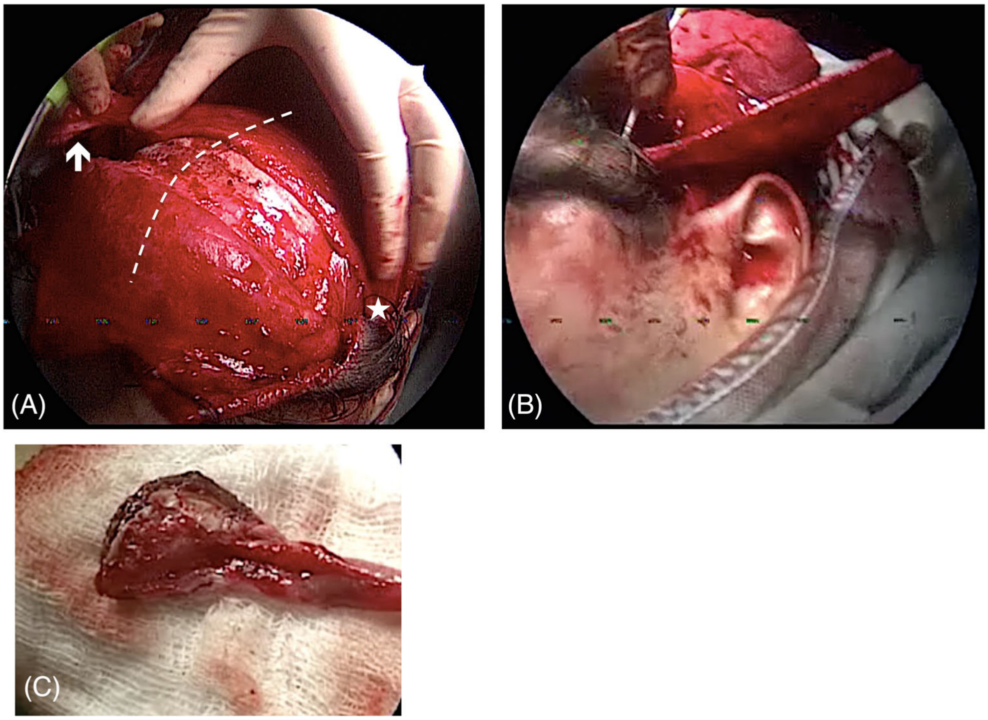

FIGURE 4 (A) The TPTMFF is harvested with the contralateral temporalis muscle tip demonstrated (arrow), the midline is marked with a dotted line and the base of the flap with an star. (B) Image demonstrating the base of the raised flap. A guide wire dilator is demonstrated during the process of tunneling via the infratemporal fossa. (C) The tip of the TPTMFF with a broad sheet of temporalis muscle. Overlying temporalis fascia and temporoparietal fascia demonstrated continuing along with the pericranium and subgaleal tissues as the proximal flap

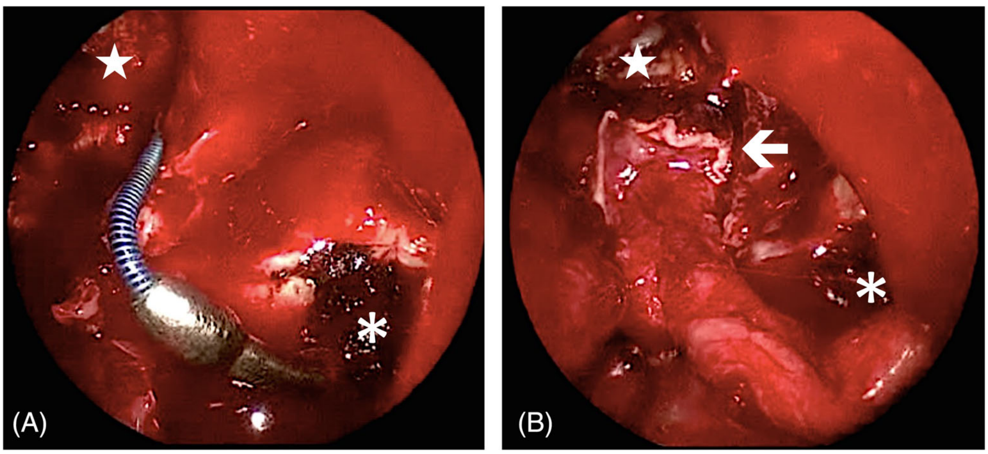

FIGURE 5 Endoscopic views of the nasal cavity on the left side demonstrating skull base defect (star) and maxillary antrostomy (asterisk). (A) The olive tip sucker has created a soft tissue tunnel from the infra-temporal fossa into the nasal cavity via a maxillary antrostomy for transposition and passage of the pedicled temporo-parietal temporalis myo-fascial flap (TPTMFF). (B) The flap can be seen with the temporalis muscle indicated by the arrow, the pedicle can be seen originating from the maxillary antrostomy

bore flexible tube can be passed over the dilators. The distal end of the flap is then sutured to the guide wire and the flap is passed through this tunneled tube into the maxillary sinus and then the nasal cavity (Figure 5B). Care should be taken so as not to twist the pedicle compromising its blood supply. Once the edges of the defect are refreshed the muscular tip of the flap is used to plug the hole and stop the CSF leak (Figure 6). The reconstruction is completed with oxidized cellulose haemostatic fabric (Surgicel) overlay and dural sealant. Nasopore and Merocel packing is used to dress the repair. The bicoronal incision is closed in the standard manner.

3 | RESULTS

3.1 | Patient A

Our first patient initially presented with Cushing's disease secondary to pituitary micro-adenoma at the age of 12-years and underwent bilateral adrenalectomy. He had trans-sphenoidal adenectomy and received pituitary radiotherapy 1 and 2 years later respectively. He was clinically well postoperatively apart from growth hormone deficiency treated medically. At the age of 33 years imaging of his pituitary gland was repeated to investigate increasing ACTH levels,

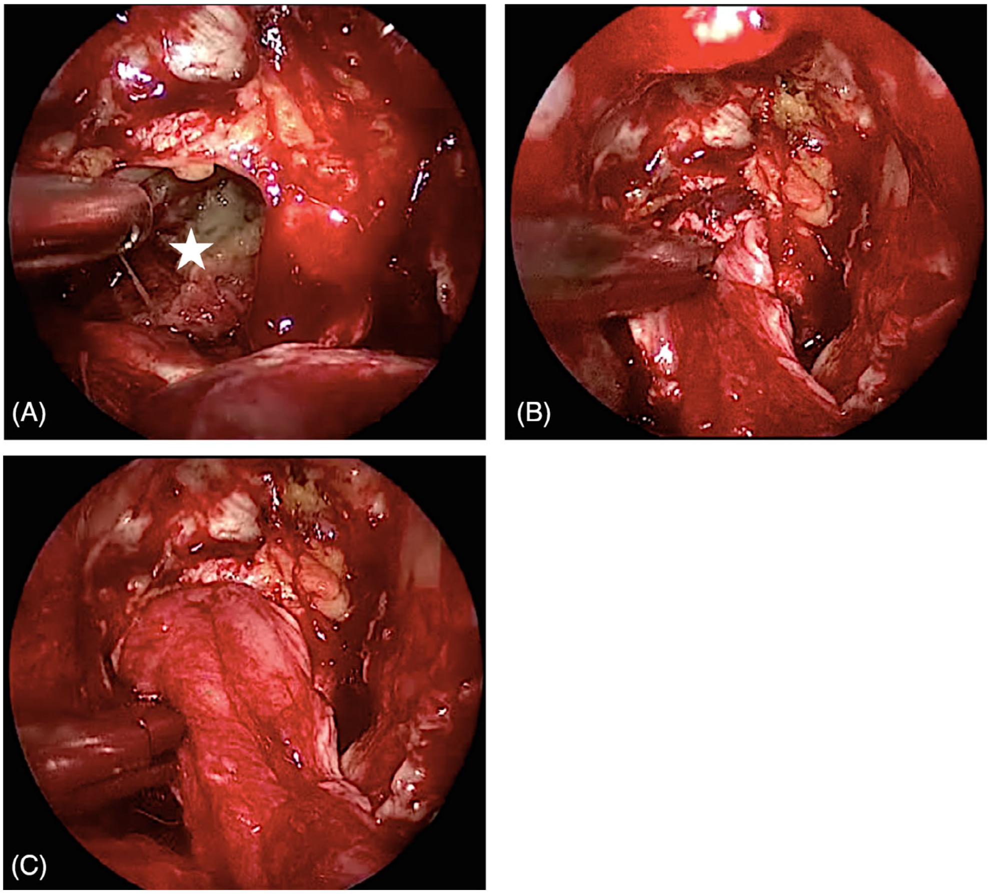

FIGURE 6 Endoscopic view of nasal cavity with (A) skull base defect visualized (star). (B) Placement of the Temporo-parietal myo-fascial flap (TPTMFF). The (contralateral) broad sheet of thick temporalis muscle at the tip of the flap together with its overlying fascial layers is visualized being sited over the defect to provide a more robust repair. C The final positioning of the flap with pedicle running towards the scope

hyperpigmentation and clinical features of Nelson's syndrome. This demonstrated recurrence of the ACTH-secreting pituitary adenoma extending into the cavernous sinus. He underwent endoscopic endonasal removal of recurrent pituitary macro-adenoma. Complete clearance along the sella floor was achieved and the defect was repaired with a combination of oxidized cellulose haemostatic fabric in the sella fossa and a pedicled naso-septal flap. A week later he presented with CSF rhinorrhoea and underwent repeat endoscopic surgery. A fat graft was harvested from the right thigh and, combined with oxidized cellulose haemostatic fabric, was placed through the defect as an inlay with further oxidized cellulose haemostatic fabric onlay. Persistence of the CSF leak prompted a further endoscopic procedure where the fat graft was removed and the naso-septal flap taken down. Then muscle graft harvested from the leg was placed in the pituitary fossa defect and a new contralateral limited naso-septal flap harvested and placed as an onlay. This was followed by a period of CSF diversion by lumbar drainage. Four weeks later, the CSF leak recurred and a third endoscopic repair was undertaken. The naso-septal flap was sacrificed due to its friable non-viable appearance. A new graft of muscle, fascia lata and fat was harvested from the thigh and a left inferior turbinate flap elevated. The closure was performed in layers with muscle plug, fat, fascia lata and inferior turbinate flap. Unfortunately the CSF leak recurred shortly after. On this occasion, endoscopic examination revealed a dusky inferior turbinate flap with continuing CSF leak prompting further repair with our new technique.

3.2 | Patient B

Our second patient was found to have a clival tumor aged 32 following investigation for transient diplopia. Four months after the initial presentation trans-sphenoidal debulking of the clival tumor confirmed this lesion to be a chordoma. Initial reconstruction was performed with a naso-septal flap. One week following the initial surgery she was returned to theater with persistent CSF leak for an endoscopic repair with abdominal fat graft in addition to careful reapplication of the naso-septal flap. Two weeks after the original surgery she was returned again for further CSF leak repair and augmentation of the naso-septal flap with muscle graft from the thigh. Subsequently the CSF leak resolved and the patient was managed with surveillance. Proton beam therapy was given as 74Gy in 37 fractions over a two-month period. Over the next 2 years MRI surveillance demonstrated reduced tumor residuum. Unfortunately after the patient described blurred vision 3 years later a further MRI showed evidence of tumor recurrence in the area of the posterior clinoid. Repeat endoscopic excision of the recurrent clival chordoma with wide bone removal including the planum sphenoidale and complete exposure of the right internal carotid artery was performed. The defect was repaired with free muscle graft and fascia lata, then a temporary lumbar drain was inserted. One month later she was readmitted with CSF leak. On this occasion further repair was performed with our new temporo-parietal temporalis myo-fascial flap.

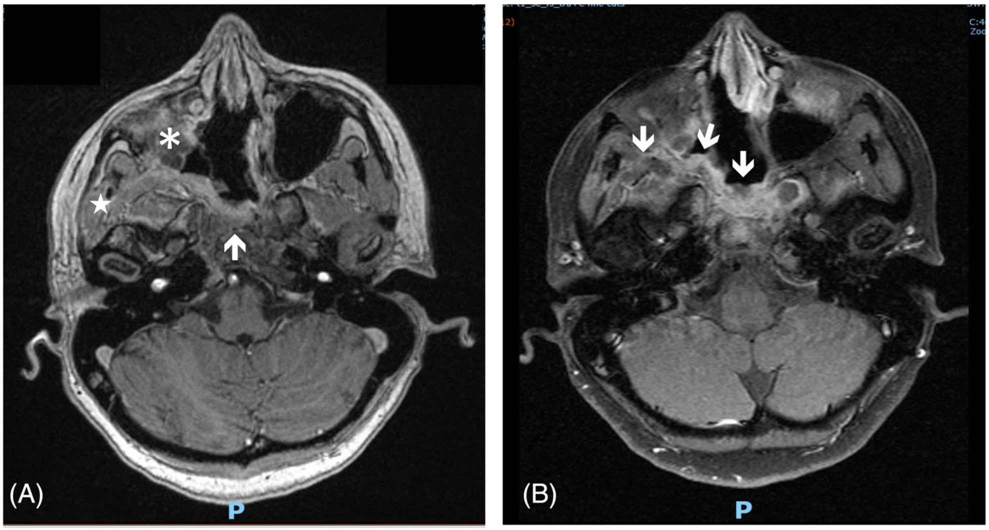

FIGURE 7 (A) Axial T1 MPR MRI image of one of our patients at 3 months post repair. Of note the pedicle of the flap can be seen originating from the right infratemporal fossa (star). The pedicle runs medially along the posterior partially opacified maxillary sinus (asterisk) and into the posterior nasal cavity to cover the skull base defect (arrow). (B) This T1 contrasted sequence shows contrast uptake along the pedicle and at the tip of the flap demonstrating persistent vascularity (arrows)

In both cases the TPTMFF healed well with no further evidence of CSF leak and no reported complication or donor site morbidity. Postoperative imaging with MRI at 3 months demonstrated contrast enhancement along the pedicle and tip of the flap suggestive of maintained vascular perfusion (Figure 7).

4 | DISCUSSION

Prompt restoration of a barrier between the sino-nasal mucosa and subarachnoid space is one of the cornerstones of reconstruction following EEAs to the skull base as the effects of an ascending infection are potentially catastrophic. The widespread use of EEAs providing greater scope for endoscopic skull base procedures has complicated the task by leaving larger defects for repair. Typically the pedicled naso-septal flap is successfully used providing a local vascularised tissue reconstruction following EEA. We maintain that the Hadad-Bassagasteguy naso-septal flap is the first line choice for reconstruction following uncomplicated EEA given its significant advantages as a highly versatile local flap encouraging rapid healing.

However, in some situations the mucosa, or blood supply from the naso-septal artery, a branch of the spheno-palatine artery, is compromised. For example the vascular pedicle may be disrupted following tumor infiltration, radiotherapy to the local mucosa or previous surgery especially when posterior septectomy has been performed. Fortes[16] describe a technique of transpterygoid transposition of a temporo-parietal fascia flap (TPFF) as a potentially large vascularised regional flap for use in skull base reconstruction when the naso-septal flap is not an option and where vascularised repair is desirable to promote better healing post radiotherapy. Regional flaps such as this utilize tissues harvested from outside the local zones potentially damaged by previous radiotherapy.

We propose a modification of the Fortes[16] technique using a pedicled temporo-parietal fascial flap based on the STA, with the inclusion of the deeper subgaleal layers creating a thicker flap with a robust blood supply from the STA and its subgaleal perforating vessels. The extensive anastomoses of the STA across the midline of the scalp and the small perforating vessels running from temporoparietal fascia to the subgaleal tissues provide an extensive vascular network. Hence we believe that the length of the flap can be extended across the midline as a fascial flap with optimized vascularity accounting for the contrast enhancement seen along the length of the flap in postoperative imaging. The muscular component included at the tip of the flap is traditionally an ideal tissue sealant and may also be applied as a thick physical plug, which we feel is superior to a thin overlay repair. Although the blood supply to the muscle at the tip is likely to be disrupted and random at best we maintain that a muscular plug remaining attached to the overlying vascularised temporoparietal fascia creates a sturdy scaffold for the fascia. We propose that our modifications to the Fortes TPFF maximizes its robust nature and healing potential providing the best chance of CSF leak repair in suboptimal conditions.

Our modified flap maintains the flexibility and pliability seen with the temporoparietal fascia allowing passage into the nasal cavity via an infra-temporal soft tissue tunnel. We have used this technique of temporo-parietal temporalis myo-fascial flap (TPTMFF) for repair following EEA on two patients. Both cases have involved complicated persistent CSF leaks resistant to other forms of repair and our modified flap has been successful on both occasions with minimal donor site morbidity at 2 year follow up.

5 | CONCLUSION

In the first instance repair of uncomplicated defects following EEA is best performed with the standard vascularised naso-septal flap. However in complicated cases where multiple surgeries have been performed, radiotherapy administered or CSF leak resistant to repair has occurred the modified temporo-parietal temporalis myo-fascial flap (TPTMFF) is a robust option for skull base repair via the infra-temporal fossa approach.

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There were no external funding sources.

CONFLICT OF INTEREST

The authors have no conflicts of interest to declare.

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