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Original Article

Closure of Skull Base Defects after Endonasal Endoscopic Resection of Planum Sphenoidale and Tuberculum Sellae Meningiomas

Abstract

Background: The expanded endoscopic endonasal transplanum transtuberculum approach allows tumor removal by minimally invasive procedures. A large dural and bone defect is created during the surgical procedure, increasing the risk of postoperative cerebrospinal fluid (CSF) leakage. **Objective:** The aim of this study is to describe a surgical technique and complications observed in patients undergoing endonasal resection of planum sphenoidale and/or tuberculum sellae meningiomas. **Methods:** A retrospective analysis was performed of patients with planum sphenoidale and/or tuberculum sellae meningiomas after expanded endoscopic endonasal resection between June 2013 and August 2018, in which autologous grafts, fascia lata inlay, and nasoseptal flap onlay were used for closure of skull base defects. **Results:** Ten patients were included in the analysis. No cases of postoperative CSF leakages or meningitis were reported, whereas two patients evolved with postoperative infectious complications (fungal ball in right frontal sinus and brain abscess). The skull base defect created for resection measured, on average, 3.58 cm^2. **Conclusion:** Our experience suggests that closure of skull base defects using combined fascia lata inlay and nasoseptal flap onlay is effective for preventing postoperative CSF leakage in resection of planum sphenoidale and/or tuberculum sellae meningiomas, and offers high reproducibility due to its low cost.

Keywords: *Cerebrospinal fluid leak, meningioma, skull base, surgical flaps*

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Introduction

Skull base tumors are challenging, hard to access, and associated with high morbimortality. Endonasal endoscopic approaches, in selected cases, offer advantages over transcranial access, such as direct lesion access without the need for brain retraction, early devascularization of the tumor, removal of invaded bone and dura-mater, and better illumination and visualization of the surgical field.[1-6]

The rise in popularity of endoscopic skull base surgery, together with the advent of the nasoseptal flap, has drastically reduced rates of cerebrospinal fluid (CSF) leakage, characterizing this surgical technique as revolutionary.[7,8] Kassam *et al*.[2-4] carried out a systematization of the endoscopic expanded endonasal approach (EEA) [Figure 1].

Transplanum and transtuberculum EEAs allow minimally-invasive, highly effective tumor resection. However, a large bone and dural defect is created during the surgical procedure, often associated with high-flow intraoperative CSF leaks[9] while posing a risk of postoperative CSF leakage.

Closure of the endoscopic craniectomy must be performed with care by isolating the intracranial compartment from the sinonasal compartment, where the nasoseptal flap plays a key role in this separation.[7,10,11] Closure can be carried out in multiple layers, using heterologous materials (dura-mater substitutes, bovine collagen sponges, oxidized cellulose meshes, fibrin sealant) or autologous materials (fat, nonvascularized flaps, microsurgical flaps with vascular anastomosis, pedicled flaps or muscle tissue).[10,12,13]

In the present study, we describe the surgical technique employing autologous material in two layers for skull base repair in patients submitted to endonasal endoscopic resection of planum sphenoidale or tuberculum sellae meningiomas using

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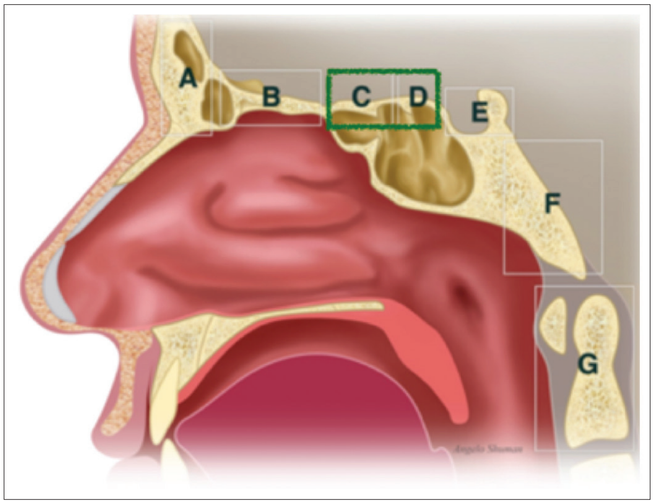

Figure 1: Illustration depicting sagital plane of skull base, divided into areas of endoscopic approach. (A) transfrontal; (B) transcribriform; (C) transplanal; (D) transtuberculum; (E) transellar; (F) transclival; (G) transodontoid. Transplanal and transtuberculum region highlighted in Green. Source: Angelo Shuman/Ricardo Dolci (2018)

nasoseptal flap (onlay) and fascia lata (inlay). Associated complications were also investigated.

Methods

A retrospective study was conducted based on the review of patient medical records and data collection after approval of the local Research Ethics Committee (permit CAEE-08113819.7.0000.5479). The study inclusion criteria were:

1. Patients aged >18 years of both genders;
2. Magnetic resonance imaging (MRI)-confirmed diagnosis of planum sphenoidal or tuberculum sela meningioma;
3. Patients submitted to endoscopic endonasal resection as a sole or initial treatment between June 2013 and August 2018;
4. Intraoperative closure of skull base with the combined use of fáscia lata inlay and nasoseptal flap onlay.

The study exclusion criteria were:

1. Patients classed as vulnerable (prisoners and pregnant women);
2. Pediatric patients.

All patients were submitted to the surgical procedure by the institution's skull base team. All complications described in medical records were collected for up to 1 year after the surgery.

Within the first 24 h of surgery, patients underwent computed tomography (CT) scan of the head, sinuses, and face. The resultant images were retrieved from the institution's digital archive system (when available) and analyzed using the Osirix software program (Pixmeo, Switzerland) to calculate the area of the skull base defect.

Surgical technique

All cases were performed under general anesthetic, without the use of lumbar drain during the intra or postoperative periods, and prophylactic antibiotics were given in accordance with prevailing guidelines of the local hospital infection advisory committee.

After general anesthesia, patients were placed in the dorsal decubitus position with head clamped in a 3-pin fixation device. The head segment was positioned, relative to the body, with slight flexion, rotated to the right, and inclined to the left. The nasal cavity was prepared using asepsis followed by the application of a topical vasoconstrictor (adrenalin diluted in distilled water 1:1000). High-definition video and camera (Stryker 1488, Kalamazoo, MI, USA) were employed for the operation together with a 0, 30° and 45° Karl-Storz Hopkins II endoscope (Tuttlingen, Germany). All extended endoscopic endonasal approaches in the institution are performed jointly by the neurosurgery and otorhinolaryngology teams using the "4 hands" technique.

The procedure commenced with middle turbinectomy to the right with preservation of the upper third, followed by ipsilateral anterior and posterior ethmoidectomy. Except in cases with specific surgical indications or anatomical abnormalities, routine nasoseptal flap in the right nasal fossa was performed.[7,8,11,14]

The nasoseptal flap is produced by making a superior incision just below the sphenoid ostium, continuing anteriorly toward the nasal septum, preserving approximately 1.5 cm of the superior portion of the septal mucosa to prevent olfactory injury, and extending to the columella region. The inferior incision is made just above the choana arch, creating a pedicle around 1.5 cm wide, where this must be preserved because it contains branches of the sphenopalatine artery which irrigates the septal mucosa. To achieve a large pedicled flap, in all cases, the incision was extended anteriorly along the nasal fossa floor below the inferior concha.

After producing the nasoseptal flap, the vomer and perpendicular plate of the ethmoid were removed, preserving 1.5 cm superiorly at the bone-cartilage transition point (posterior chondrotomy), creating a single posterior cavity to access both nostrils concomitantly. After chondrotomy, the posterior portion of the mucosa contralateral to the nasoseptal flap was used to patch the exposed cartilage of the nasal septum after producing the nasoseptal flap, as described by Caicedo-Granados *et al*. and denoted the reverse flap,[15] followed by placement of the nasal splint.

A large sphenoidectomy was performed to allow good visualization of the target area and facilitate handling of the surgical instruments, entailing complete exposure of the tuberculum sellae and planum sphenoidale

[Figures 2 and 3a]. After creating the nasoseptal flap and due preparation and exposure of the nasosinus cavity, the planum sphenoidale, tuberculum sellae and sella can be carefully drilled to the depth required for tumor resection [Figure 3b and c].

This stage constitutes the endoscopic craniectomy in an inverted trapezoid shape; the lower boundary is the upper region of the sella (superior intercavernous sinus); the lateral boundaries are the optic canals, and the upper border depends on the anterior extension of the tumor, where very anterior planum sphenoidale tumors can reach as far as the region of the cribriform plate [Figure 2].[12]

To improve control of bleeding during the operation, dural veins should be coagulated beforehand, as well as the ipsilateral McConnell capsular artery (or both in larger tumors), which is often hypertrophied and predominantly responsible for irrigating the tumor.[16,17]

The dural opening is made close to the midline, and the lesion thus identified. For larger tumors, tumor debulking is first carried out by removing intratumor fragments to aid manipulation. Subsequently, extracapsular dissection is commenced, observing the arachnoid planes surrounding the tumor to prevent damage to adjacent vascular or nerve structures [Figure 4a].[6,18]

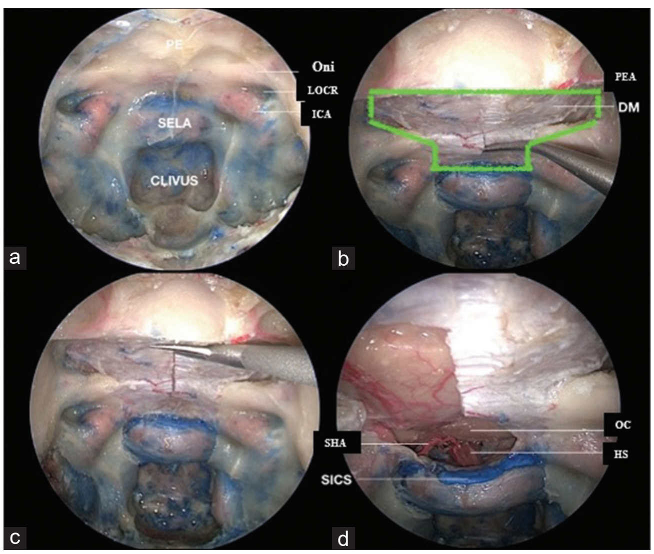

Figure 2: Imaging in cadaver using 0o optic. (a) Exposure of whole posterior wall of sphenoid sinus, for performing craniectomy using endoscopic approach. (b) Green highlights showing whole region of bone opening for access to tuberculum and planum sphenoidale region, exposing dura-mater. (c) Opening of dura-mater in region of upper boundary. (d) Opening of dura mater allows visualization of hypophyseal stalk, superior hypophyseal artery, optic chiasm and superior intercavernous sinus

Traction and movement of the tumor must be done delicately in a bid to identify adherence. Only when all adherences have been detached by direct visualization can the tumor be removed. The tumor must not be removed aggressively, tractioning it downward, without first using the standard microsurgical traction and contra-traction techniques, while protecting key structures. The tumor can then be dissected from adjacent structures [Figure 4b]. After resection, copious irrigation of the surgical cavity is mandatory, along with thorough hemostasis [Figure 4c].[6,18]

The next stage is to harvest the fascia lata, where the lower limb has been placed in the position since the outset of surgery and aseptic preparation of the skin previously carried out. In general, slight bending of the knee and inner rotation of the hip aids the removal process.

A straight 3–4 cm incision is made into the anterolateral surface of the thigh with its axis parallel to the crural fascia. When necessary, the incision can be extended to 10–12 cm according to the size of the graft needed. In the present study, grafts measuring approximately 5 cm^2 sufficed.[19,20]

After the thigh incision, fat can be collected if necessary. The dissection is deepened until identifying the fascia lata. The size of the graft to be removed can be slightly larger than the dural defect and after removal is preserved in saline until use. Hemostasis is checked to ensure no coagulations or hematomas within the incision and closure is layered using 2.0 nylon suture to draw together the removed fascia, followed by monocryl 3.0. Nylon suture 3.0 or 4.0 is used for skin closure and stitches are removed 10–15 days later depending on wound healing.

After tumor removal, irrigation and hemostasis are performed and the graft is inlayed into the skull base defect [Figure 5a]. This step must be done without folding, and the endonasal craniectomy region must be covered fully [Figure 5b]. The onlay nasoseptal flap must then be placed, with the perichondrial surface position onto the osseous part of the skull base [Figure 5c]. When positioning the flap, the surgeon must ensure the pedicle does not become

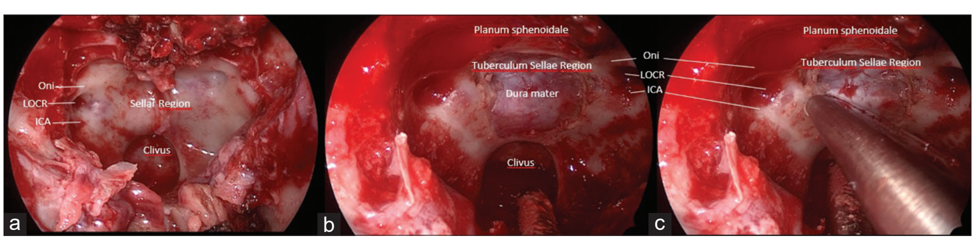

Figure 3: Intraoperative view. Step by step of endoscopic surgical field using 0°, 30° and 45° optics respectively. (a) Panoramic view of the posterior wall of the sphenoidal sinus. A large sphenoidectomy was performed to allow good visualization of the target area. (b) Dura mater after the opening of the sellar floor and suprasellar region (craniectomy). (c) Enlargement of the initial craniectomy using a Kerrison Roungeur

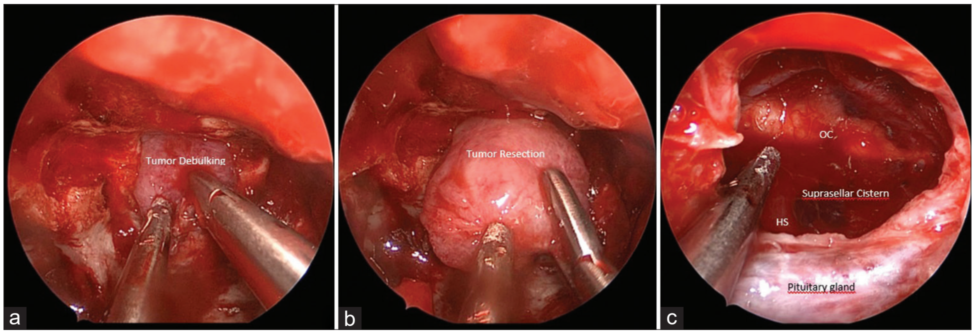

Figure 4: (a) The dural opening is made close to the midline and the lesion is thus identified, tumor debulking is first carried out by removing intratumor fragments to aid manipulation. (b) Removing the entire tumor after be dissected from adjacent structures. (c) After tumor resection, copious irrigation of the surgical cavity is mandatory, along with thorough hemostasis

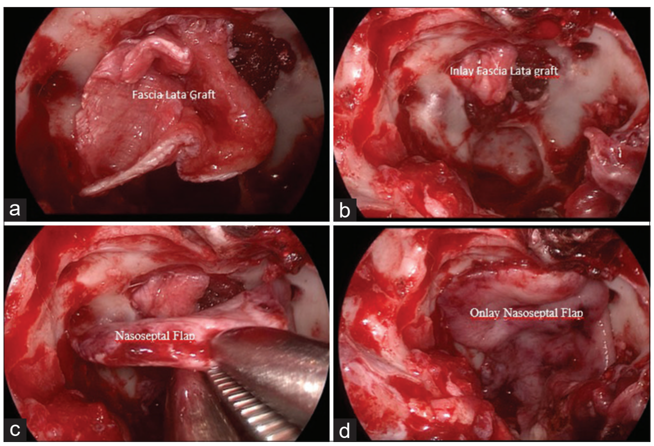

Figure 5: (a) After harvested the fascia lata graft is placemented within of craniectomy. (b) Dural reconstruction was performed with an inlay fascia lata graft. (c) The onlay nasoseptal flap must then be placed with the perichondrial surface position onto the osseous part of the skull base and the pedicle does not become twisted as this will compromise irrigation of the flap and lead to necrosis. (d) The craniectomy region must be covered fully

twisted as this will compromise the irrigation of the flap and lead to necrosis [Figure 5d].[21,22]

To prevent displacement during patient movement, a number 16–18 Foley catheter is placed and inflated with direct visualization to guarantee mechanical support for the skull base reconstruction. Both nostrils are plugged with gauze pads soaked in antibiotic cream.

During the first 24 h after the surgery, patients must be rested. Walking is commenced 24 h after the surgical procedure. Patients must refrain from physical exertion and other activities which may increase intracranial pressure, for 4 weeks after the procedure. The nasal plug is removed on the 3rd–5th postoperative day.

Results

A total of 10 patients (1 male: 9 female) satisfying the inclusion and exclusion criteria were selected, of whom 8 had tuberculum sellae meningiomas. Preoperative tumor size was also measured for 6 patients revealing an average volume of 13.42 cm^2. Analysis of the postoperative skull base dural defect was carried out, having a mean area of 3.5 cm^2. No intraoperative complications were reported. Results of the analysis of demographics and tumor for each case are given in Table 1 and Figure 6.

At the 1-year postoperative follow-up, no patients had developed meningitis or CSF leak.

One patient had an infectious complication indirectly related to the surgical procedure (fungal ball in right frontal sinus) 6 months after surgical meningioma resection. The condition evolved with moderate-to-severe headache in the right frontal sinus region and was diagnosed using CT face sinus scan. Combined Draf IIb surgery via an external approach (lynch incision) was performed with complete resolution of the clinical picture.

Another patient, on the 15th postoperative day, developed amaurosis and paresis of the abducens nerve (CN VI), whose investigation using head MRI disclosed a brain abscess which required external surgical intervention and endovenous antibiotic therapy for 6 weeks. The patient made a full recovery after the treatment. The information on patients included in this series is summarized in Table 1.

Discussion

A host of complications have been reported after endoscopic skull base surgery, such as hyposmia, nasal synechiae, nasal obstruction, transient or permanent hormone changes, and face paresthesia. However, CSF leakage and meningitis are relatively common complications that have a major impact on patient satisfaction and postoperative outcome.[14,23,24]

These complications are more common in EEA because of high-flow CSF leakage, given that breaching of the arachnoid plane, opening of the high-flow CSF cisterns or the ventricular system and large dural skull base defect occur with this approach, where these events were seen for all the cases in the present study. High rates of CSF leakage have been previously described (40%–50%) in EEAs. However, following the description and dissemination of multi-layer reconstruction in association with the nasoseptal flap, this rate has declined dramatically <3%.[7,10,23-25]

Table 1: Results obtained in the case series

Patients	Gender	Age	Area (cm²)	Tumor dimension volume (cm²)	Location of meningioma	Meningitis	Cerebrospinal fluid	Complication
Patient 1	Female	42	-	-	Tuberculum sellae	None	None	None
Patient 2	Female	39	1.737	2.6 cm × 2.3 cm × 1.5 cm (8.97 cm²)	Tuberculum sellae	None	None	None
Patient 3	Female	51	1.695	-	Tuberculum sellae	None	None	Fungal ball in right frontal sinus
Patient 4	Female	50	2.451	2.5 cm × 1.4 cm × 2 cm (7 cm²)	Tuberculum sellae	None	None	Brain abscess/right sixth nerve palsy
Patient 5	Male	48	6.479	4.2 cm × 2.8 cm × 3.6 cm (42.33 cm²)	Planum sphenoidale	None	None	None
Patient 6	Female	55	-	-	Tuberculum sellae	None	None	None
Patient 7	Female	62	-	-	Tuberculum sellae	None	None	None
Patient 8	Female	43	7.108	2.4 cm × 1.5 cm × 2 cm (7.2 cm²)	Planum sphenoidale	None	None	None
Patient 9	Female	59	2.061	1.9 cm × 1.5 cm × 1.9 cm (4.56 cm²)	Tuberculum sellae	None	None	None
Patient 10	Female	42	-	2.8 cm × 2.2 cm × 1.7 cm (10.47 cm²)	Tuberculum sellae	None	None	None
Average	-	49.1	3.58	2.7 cm × 1.9 cm × 2.1 cm (13.42 cm²)	Tuberculum sellae	No cases	No cases	Two complications

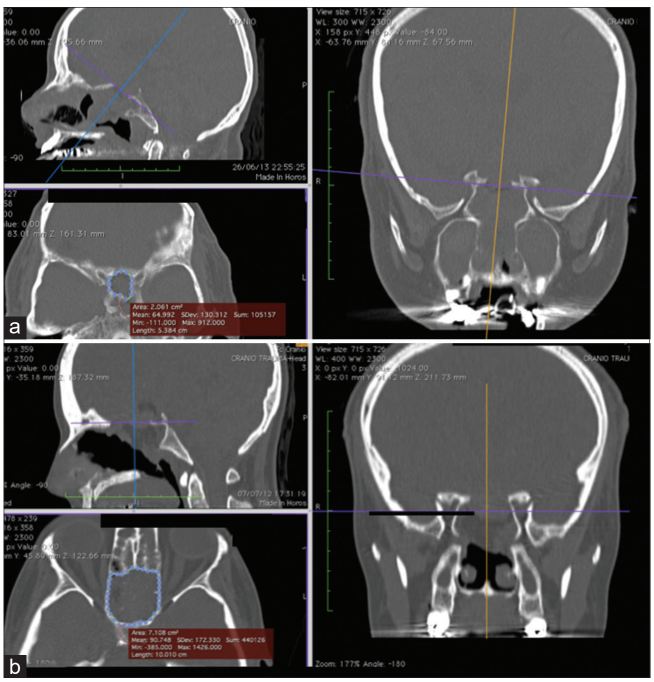

Figure 6: Computed tomography image of head performed in first 24 hours postoperatively using Osirix software (Pixmeo, Switzerland) showing area and size of craniectomy. Image reconstruction on sagital, coronal and axial planes. (a) Image showing tuberculum sellae; and (b) planum sphenoidale meningioma craniectomy

Harvey *et al*.[26] performed a systematic review analyzing endoscopic skull base surgery procedures with large dural defects (>3 cm²) and intraoperative CFS leakage, and concluded that the use of vascularized flaps in the reconstruction of these large defects resulted in a postoperative CSF leak rate of 6.7%. This difference was statistically significant compared with a series using free grafts only. Other advantages of vascularized flaps are early epithelization, allowing earlier introduction of complementary therapy (radiotherapy) with lower rates of late leaks secondary to these treatments.[7,10,13,14,24,27]

Some nuances regarding nasoseptal flaps are noteworthy, including the fact that the mucosa around the dural defect should be fully removed to allow the flap to make direct contact with the bone, else there is poor adherence of the vascularized flap, increasing the rate of CSF leakage. Nonremoval of the mucosa can also increase the risk of mucocele formation under the flap.[28-30]

Another important nuance for the closure of large skull base defects is that, when producing the nasoseptal flap, to make the more lateral inferior and superior incision and lower close to the sphenopalatine foramen, thereby allowing greater rotation and anteriorization of the resultant flap.[7-9]

In cases where the sphenoid sinus presents postsella pneumatization, fat from the abdomen or lower limb can be used to support the pedicle and its more posterior portion, thereby increasing its anterior reach.[27] In the present casuistic, use of fat in the reconstruction was not necessary. Finally, the flap should be fully supported against the skull base, with no dead space between the flap and skull base, as this also increases the risk of postoperative CSF leak [Figure 7].[7-9]

Large skull base defects with high-flow CSF leaks, require careful multi-layer reconstruction using both autologous and heterologous materials.[10,12,23,27,31-34] The technique employed in the present study, akin to that in Eloy *et al*.,[12] involved two-layer closure with autologous material, being an inlay fascia lata graft and an overlay vascularized flap, without use stitches or fibrin glue. This promoted a high level of efficacy, with no cases of CSF leakage or meningitis or complications involving the donor site (lower right limb).

The results suggest this is an effective and low-cost repair technique, in which only autologous material (fascia lata and nasoseptal flap) was used in the present study for defect reconstruction, dispensing with the need for dural substitutes, a rare situation in the literature.[8,33,34] The nonuse of heterologous materials for dural closure, its high efficacy and low cost makes this technique replicable in many centers.

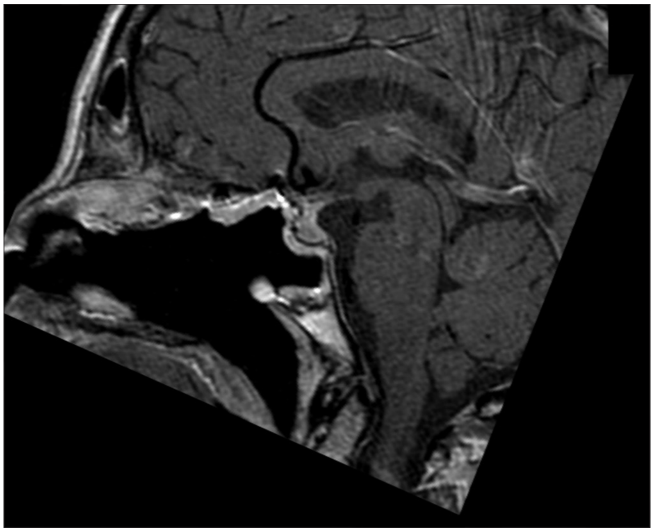

Figure 7: Magnetic resonance imaging at 6 months postoperatively showing well-lodged fascia lata inlay and nasoseptal flap and absence of "dead space" between nasoseptal flap and sphenoid sinuses, important for preventing post-operative cerebrospinal fluid leakage

Two cases of infectious complications were observed in the present series, although the fungal ball was not directly related to the surgery. By contrast, the second case with brain abscess was directly associated with the surgery. The use of fascia lata has been routine in neurosurgery since the 1990s and has proven safe with low infection rates (2.3%).[35,36] However, we do not attribute the infectious complications in the present series to the materials used, given the autologous materials were harvested from the donor site at the time of use.

The use of fat for defect closure, particularly in the skull base, is also routine. Despite publications reporting the safety of fat use,[37] there have been some reports of complications related to its intradural use, such as aseptic meningitis, lipoid dissemination by the meninges, and local inflammatory reaction.[38-41] In view of these problems, the proximity to delicate nerve structures, such as the optic apparatus and vascular structures, together with the team's experience at our institution, we avoid intradural fat, reserving its use for the sinonasal cavity when the flap requires mechanical support. This use was not needed in any of the cases reported.

The area of the endonasal craniectomy was 3.58 cm^2 in the present study, lower than the average reported by Eloy *et al*. of 5.6 cm^2.[12] The craniotomy area directly correlates with tumor location and size and tends to be greater in planum sphenoidale meningiomas. With the accrual of more years of experience, our team is now using increasingly larger dural openings, owing to the higher surgical safety for tumor removal and dural defect repair.

Conclusion

EEA constitutes an effective low-cost surgical technique involving two layers of autologous material (fascia lata inlay and nasoseptal flap onlay) for resection of planum sphenoidale and tuberculum sellae meningiomas using extended approaches to the skull base. The technique is highly replicable in many different institutions and does not negatively impact the quality of patient treatment.

Declaration of patient consent

The authors certify that they have obtained all appropriate patient consent forms. In the form the patients have given their consent for their images and other clinical information to be reported in the journal. The patients understand that their names and initials will not be published and due efforts will be made to conceal their identity, but anonymity cannot be guaranteed.

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Nil.

Conflicts of interest

There are no conflicts of interest.

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