Endoscopic Endonasal Resection of Anterior Skull Base Meningiomas
Otolaryngology -- Head and Neck Surgery 2012 147: 575 originally published online 30 April 2012
DOI: 10.1177/0194599812446565

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What is This?
Endoscopic Endonasal Resection of Anterior Skull Base Meningiomas

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Abstract

Objective. Anterior cranial fossa (ACF) meningiomas are difficult to surgically manage. Endoscopic transnasal approaches have increasingly been used as a minimally invasive route and thus offer significant advantages. However, a paucity of literature describing the intraoperative challenges and postoperative outcomes of this technique still exists.

Study Design. Case series with chart review.

Setting. The Royal Adelaide Hospital, Flinders Medical Centre, Wellington Hospital.

Subjects and Methods. Fifteen consecutive patients who underwent endoscopic resection of ACF meningiomas between 2004 and 2010 by the South Australian and Wellington Skull Base Units. Demographic and clinical information was compiled by reviewing patient charts and operation notes. Safety and efficacy of the procedure, role of a team approach, and areas for further improvement were analyzed.

Results. Of the patients, 87% were women. Tumor locations: 8 olfactory groove, 2 tuberculum sellae, 1 clinoidal, 1 jugum sphenoidale, 1 planum sphenoidale, 1 subfrontal, and 1 midline ACF floor. Commonest presenting symptom was visual change. Mean volume of tumor was 25.69 cm³, with a size area of 7.28 cm². Five were revision cases. None had previous endonasal surgery. Average operating times decreased over time. Gross total removal was achieved in 14, with no deaths. Four patients had postoperative cerebrospinal fluid (CSF) leak. Rate of CSF leak decreased over time. Sixty percent of patients reported visual improvement. Two patients had radiological evidence of recurrence.

Conclusion. ACF meningiomas can be safely removed endonasally, offering significant advantages over the traditional transcranial approach for suitable tumors. Early audit of this approach shows results achieved by this unit are comparable with the published literature.

Keywords
dendoscopic meningioma, skull base meningioma, endonasal meningioma

Received October 31, 2011; revised March 13, 2012; accepted April 5, 2012.
The traditional transcranial approach necessitates brain retraction, and acceptable morbidity rates are sometimes difficult to achieve, particularly when the tumors are intimately related to important neurovascular structures. The endoscopic transnasal method of approaching these tumors has been increasingly used as a minimally invasive route to the anterior skull base. Brain retraction is avoided, and the manipulation of large vessels and neurological structures is reduced. It has also been directly shown to hasten postoperative recovery.

A paucity of literature describing the intraoperative challenges and postoperative outcomes of endoscopic approaches, however, still remains.

This study aims to evaluate the management of ACF meningiomas surgically resected via an endoscopic transnasal approach by the South Australian Endoscopic Skull Base Unit (SAES) and Wellington Skull Base Unit since 2004. Safety and efficacy of the procedure, role of the multidisciplinary team approach, and areas for further technical refinement are analyzed.

**Methods**

This case series with chart review included 15 consecutive patients who underwent endoscopic transnasal resection of ACF meningiomas between 2004 and 2010. Ethics approval was obtained from the Central Northern Adelaide Health Service Ethics of Human Research Committee.

Patients with tumor types other than meningioma as confirmed by histology were excluded, as were tumors approached with alternative surgical methods.

Demographic and clinical information was compiled by reviewing patient charts and operation notes. Tumor size and extension were estimated by measuring the anteroposterior, vertical, and horizontal diameters on preoperative magnetic resonance imaging (MRI) scans. Tumors were graded according to the Snyderman degree of difficulty, which describes whether a tumor has a cortical cuff, vascular attachment, or vascular encasement. Associated brain edema was also noted. The extent of resection was obtained from the operative report and correlated with review of intraoperative videos and postoperative histopathology reports.

Patients were reviewed at 3 months postoperation with clinical assessment and MRI scan. Magnetic resonance imaging scans were repeated yearly thereafter.

The literature was then reviewed to compare our results with other published series.

**Surgical Method**

Each case was approached via an endoscopic transnasal method by an experienced rhinologist and neurosurgeon. Image guidance (StealthStation Medtronic Surgical Technologies, Jacksonville, Florida) was used in all cases using both MRI and computed tomography (CT) sequences obtained immediately prior to surgery.

Following review of the surgical plan, the nose was prepared topically with 2 mL of 10% cocaine, 2 mL of 1:1000 adrenaline, and 2 mL of saline soaked onto neuropaties. The septum and lateral nasal wall were injected with 2 mL of 2% lignocaine and 1:80,000 adrenaline. The patient was placed in a reverse Trendelburg position at an approximate angulation of 30 degrees. The anterolateral thigh or abdomen was prepared for harvesting of fat and fascia to repair the dural defect. An indwelling catheter, invasive blood pressure monitoring, prophylactic antibiotics, and deep venous thrombosis (DVT) prophylaxis were used. There was no use of prophylactic lumbar drains.

The first step is raising a septal flap, as described by Hadad et al. This is used for reconstruction and is temporarily placed into the nasopharynx while the remainder of the resection occurs. Endoscopic sinus surgery (ESS) is then performed with the aim being to

1. provide access for a 2-surgeon, 4-handed operation;
2. identify key landmarks such as the skull base, orbit, orbital apex, carotico-optic recess, optic nerve, and internal carotid artery; and
3. expose the skull base overlying the area to be resected.

In general, a wide middle meatal antrostomy, frontal sinusotomy, and complete sphenoethmoidectomy are performed. An endoscopic modified Lothrop procedure (EMLP) is performed if the tumor extends anterior to the anterior ethmoidal artery (AEA). The AEA and posterior ethmoidal arteries (PEA) supply the meninges of the ACF and can be considerably enlarged in meningiomas and other tumors arising in this region. They are identified and ligated. We achieve control of the AEA as it crosses the midpoint of the ethmoid roof when performing skull base surgery, rather than as it exits the anterior ethmoidal foramen. Loss of control of the AEA at this point is more likely to cause retraction of the AEA within the orbit and subsequent hematoma. If the technique to ligate the artery as it exits the orbit is used, a small amount of the lamina papyracea needs to be removed, which often results in fat prolapse into and around the AEA foramen. This dehiscent fat may hinder further ethmoid dissection and dissection of the intracranial tumor.

The bone overlying the meningioma is then carefully removed to expose the dura. Cautery is applied to the dura before resection. The middle of the tumor is debulked, allowing the edges of the tumor to collapse into the created space. This allows the arachnoid plane to be identified and facilitates careful dissection of the tumor from the surrounding tissue and neurovascular structures using traditional neurosurgical techniques. The ear, nose, and throat (ENT) surgeon provides the necessary visualization as well as suction and traction when required.

After tumor removal, a multilayered closure of the dural defect is performed. This has evolved over time to include intradural fat, underlay fascia (rectus or tensor lata), overlay fascia, and finally the vascularized septal flap. The septal flap is placed without tension over the defect and onto the bony defect edges rather than onto mucosa. Surgicel (Ethicon, Somerville, New Jersey) is used to hold the edges of the septal...
flap in position prior to the application of DuraSeal (Confluent Surgical, Waltham, Massachusetts). We have found that the use of Gelfoam (Pfizer, New York, New York) is important to prevent the DuraSeal insinuating between the septal flap and the bone and therefore preventing neo-angiogenesis and healing by primary intention. The flap and dural repair is supported with Gelfoam, followed by Bismuth Iodoform, Paraffin Paste (B.I.P.P.; Orion Laboratories, Balcatta, Australia)—soaked ribbon gauze. It is removed after 5 to 7 days.

Results

Patients

Between 2004 and 2010, 15 patients underwent transnasal resection of ACF meningioma by the SAES and the Wellington Skull Base Unit. More cases were attempted endoscopically in the latter years as our experience with the endonasal approach grew.

Eighty-seven percent of patients were women (13 of 15) with a mean age of 55 years (range, 28-74 years). Tumor locations were as follows: 8 olfactory groove, 2 tuberculum sellae, 1 clinoidal, 1 jugum sphenoidale, 1 planum sphenoidale, 1 subfrontal, and 1 midline anterior cranial fossa floor.

The most common presenting symptom was visual change or loss. This was present in 10 patients (67%) who had clinical evidence of optic chiasmal or tract compression. Anosmia was the second most common presenting symptom, experienced in 4 of 15 (27%) patients, often in combination with visual change/loss. Five (31%) patients had experienced headaches. One patient presented with epistaxis and another with first-onset seizures. One patient had a preoperative hyponatremia thought to be secondary to syndrome of inappropriate anti-diuretic hormone secretion.

The smallest tumor operated on was 1.26 \( (1.5 \times 1.2 \times 0.7) \) cm\(^3\) in volume, whereas the largest was 130.5 \( (5.8 \times 5.0 \times 4.5) \) cm\(^3\). The mean volume of the tumor was 25.69 cm\(^3\), with a size area of 7.28 \( (2.8 \times 2.6) \) cm\(^2\).

Five (33%) were revision cases. All had previously undergone craniotomy for excision of their meningioma. None had previous endonasal surgery. Operative times ranged from 3 hours 15 minutes to 12 hours 11 minutes. The 2 cases with the longest operating times also had the largest sized tumors. Average operating times in the first years of practice were higher than in the latter years (Figure 1). Patient characteristics are displayed in Table 1.

Extent of Resection

Of the 15 patients, gross total removal was achieved in 14 (93.3%). Subtotal resection was performed in a case where the tumor was intimately related to the anterior cerebral artery and internal carotid artery (ICA) and extending into the pituitary fossa. The right cavernous ICA was encased for approximately 70% of its circumference. During the procedure, the anterior cerebral arteries were identified and preserved and adherent tumor dissected free. Tumor also encased the frontopolar arteries bilaterally, and these were sacrificed. Residual tumor was left on dura only.

Only 1 patient experienced an intraoperative complication. This patient had recurrence of an olfactory groove meningioma, having previously undergone transcranial surgery. Pus was noted in the frontal sinus after performing the frontal sinusotomy. The surgical team decided that a staged approach would be the safest option. The access part of the procedure was completed, but the intracranial work was postponed. The patient was placed on antibiotic therapy, and surgery was rescheduled for a week later.

At the second stage of this procedure, the left AEA retracted into the orbit with a resultant retro-orbital hematoma and proptosis. The medial orbital wall was decompressed endoscopically. Surgery continued uneventfully after the decompression. There were no orbital sequelae noted postoperatively other than mild periorbital bruising.

Morbidity and Mortality

There were no deaths in this series. There were 4 patients (27%) with postoperative cerebrospinal fluid (CSF) leak. One resolved spontaneously and 1 with lumbar drainage. Two required further surgery.

The first of these patients was an obese, chronic smoker, with chronic cough, who continued to smoke before and after surgery. In the postoperative period, she developed a prolapse of ACF contents into the nasal cavity. A small leak between 2 layers of fascia lata was noted, but there were no leaks seen around the periphery of the skull base reconstruction. The CSF leak was identified and plugged with abdominal fat, harvested from a paramedian incision with an overlay of abdominal rectus muscle fascia and BioGlue (CryoLife, Atlanta, Georgia).

This patient re-presented to the hospital 6 months later with a recurrence of a CSF leak and meningitis, requiring an endoscopic leak repair, as well as intravenous antibiotics. She initially recovered well but at a regular follow-up 2 years later was noted to have a meningoencephalocele at the site of the previous skull base repair. She subsequently had this repaired and has since encountered no further complications.

The second patient developed a CSF leak on postoperative day 6. This was repaired endonasally without further complication.
The rate of CSF leak decreased over time. In the first 4 years of practice, 3 CSF leaks were encountered out of 5 cases. However, in the subsequent 3-year period, there was only 1 instance of CSF leak out of 10 cases (Figure 2).

Three of the CSF leaks occurred in primary endonasal cases, with 1 leak in a revision case.

The other complication of note was that of an intracranial bleed, which occurred in a patient on postoperative day 1. This required return to the operating theater for craniotomy and evacuation of the clot. There were no further complications in this patient’s recovery.

Specific nasal morbidity included nasal cavity crusting, which was present in the first month postoperatively in 3 patients. This resolved with toileting and regular saline douching. Toileting and douching regimens were the same as those used in routine postoperative ESS follow-up.

### Clinical Outcomes

Each patient had a 3-month follow-up and yearly thereafter. Ten patients had visual loss as a presenting symptom. Six (60%) of these patients reported improvement in visual function postoperatively. Anosmia, however, persisted in the 4 patients who experienced this symptom. Those who experienced headaches found a marked reduction in their incidence and intensity. Patients who had experienced endocrine disturbances, epistaxis, and seizures had no further episodes of these.

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**Table 1. Patient Characteristics**

<table>
<thead>
<tr>
<th>Patient</th>
<th>Age, y</th>
<th>Sex</th>
<th>Previous Treatment</th>
<th>Presenting Symptoms</th>
<th>Preoperative Endocrine Status</th>
<th>Tumor Site</th>
<th>Tumor Size, cm, ( \text{AP} \times \text{TV} \times \text{CC} ) (Area cm(^3))</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>40</td>
<td>F</td>
<td>Craniotomy</td>
<td>Vision loss</td>
<td>Normal</td>
<td>Clinoidal/posterior ethmoid</td>
<td>(1.5 \times 1.2 \times 0.7) (1.26)</td>
</tr>
<tr>
<td>2</td>
<td>28</td>
<td>F</td>
<td>None</td>
<td>Vision loss</td>
<td>Normal</td>
<td>Olfactory groove</td>
<td>(1.5 \times 1.6 \times 0.9) (2.16)</td>
</tr>
<tr>
<td>3</td>
<td>46</td>
<td>M</td>
<td>None</td>
<td>Vision loss</td>
<td>Normal</td>
<td>Olfactory groove</td>
<td>(5.8 \times 5.0 \times 4.5) (130.50)</td>
</tr>
<tr>
<td>4</td>
<td>55</td>
<td>F</td>
<td>None</td>
<td>Headaches</td>
<td>Normal</td>
<td>Midline floor of anterior cranial fossa</td>
<td>(4.3 \times 4.2 \times 3.0) (54.18)</td>
</tr>
<tr>
<td>5</td>
<td>41</td>
<td>F</td>
<td>Craniotomy</td>
<td>Vision loss</td>
<td>Normal</td>
<td>Olfactory groove</td>
<td>NA</td>
</tr>
<tr>
<td>6</td>
<td>70</td>
<td>F</td>
<td>None</td>
<td>Anosmia</td>
<td>Normal</td>
<td>Olfactory groove</td>
<td>(4.0 \times 3.6 \times 2.7) (38.88)</td>
</tr>
<tr>
<td>7</td>
<td>60</td>
<td>F</td>
<td>None</td>
<td>Headache</td>
<td>Normal</td>
<td>Jugum sphenoidale</td>
<td>(2.0 \times 3.0 \times 1.0) (6.00)</td>
</tr>
<tr>
<td>8</td>
<td>74</td>
<td>F</td>
<td>None</td>
<td>Headaches</td>
<td>Normal</td>
<td>Olfactory groove</td>
<td>(4.9 \times 4.2 \times 4.4) (90.55)</td>
</tr>
<tr>
<td>9</td>
<td>62</td>
<td>F</td>
<td>Craniotomy</td>
<td>Seizures</td>
<td>Normal</td>
<td>Subfrontal</td>
<td>(2.1 \times 1.7 \times 2.0) (7.14)</td>
</tr>
<tr>
<td>10</td>
<td>65</td>
<td>F</td>
<td>None</td>
<td>Headache</td>
<td>Normal</td>
<td>Turbercullum sellae</td>
<td>(1.3 \times 1.4 \times 1.2) (2.55)</td>
</tr>
<tr>
<td>11</td>
<td>54</td>
<td>F</td>
<td>None</td>
<td>Headache</td>
<td>Normal</td>
<td>Olfactory groove</td>
<td>(2.3 \times 2.0 \times 2.0) (9.30)</td>
</tr>
<tr>
<td>12</td>
<td>66</td>
<td>F</td>
<td>None</td>
<td>Visual loss</td>
<td>Hyponatremia</td>
<td>Turbercullum sellae</td>
<td>(2.0 \times 1.3 \times 1.7) (4.42)</td>
</tr>
<tr>
<td>13</td>
<td>61</td>
<td>M</td>
<td>Craniotomy</td>
<td>Epistaxis</td>
<td>None</td>
<td>Olfactory groove</td>
<td>(2.3 \times 1.7 \times 2.3) (8.99)</td>
</tr>
<tr>
<td>14</td>
<td>43</td>
<td>F</td>
<td>Craniotomy</td>
<td>None</td>
<td>Normal</td>
<td>Olfactory groove</td>
<td>(2.3 \times 2.3 \times 1.6) (8.46)</td>
</tr>
<tr>
<td>15</td>
<td>66</td>
<td>F</td>
<td>None</td>
<td>Vision loss</td>
<td>Normal</td>
<td>Planum sphenoidale</td>
<td>(2.7 \times 3.1 \times 2.5) (20.96)</td>
</tr>
</tbody>
</table>

Abbreviations: AP, anteroposterior; CC, craniocaudal; NA, not available; TV, transverse.

**Figure 2.** Incidence of cerebrospinal fluid (CSF) leak over years of practice.
Only 2 patients had radiological evidence of recurrence on follow-up MRI. One patient had follow-up surgery via a supraorbital route. The other was judged unsafe for further surgery because of medical comorbidities and underwent radiotherapy.

Intraoperative and postoperative results are displayed in Table 2.

### Discussion

This is the second largest series of ACF meningiomas removed with an endoscopic endonasal technique and shows that ACF meningiomas can be safely removed endonasally. The outcomes achieved by this unit are comparable with published literature. Excellent objective and subjective measures of success have been achieved. Symptomatic improvement was achieved in 73% and complete tumor resection in 93%. The morbidity rate was low, and the initial high CSF leak rate has improved with usage of the vascularized pedicled septal flap.

Limitations of traditional craniotomy techniques include brain retraction, manipulation of neurovascular structures, and limited access to the sellar, suprasellar and retrochiasmal regions. The open technique can therefore often lead to high morbidity rates and prolonged length of hospital stay. Over the past 2 decades, lessons learned from ESS have been applied to the treatment of challenging skull base lesions and in turn posed realistic alternatives for their treatment. The technique avoids brain retraction and also carries with it superior ophthalmological outcomes with a decreased incidence of neurological complications.

The 2-surgeon binostril bimanual technique allows enhanced instrument manipulation and excellent visualization of the skull base. Early identification and coagulation of the dural attachment of the tumor is also permitted, so debulking and resection can occur in a near-bloodless field. The technique also allows for an optimal cosmetic outcome while minimizing postoperative pain.

It does, however, have some limitations. Longer operative times are required, and intraoperative bleeding may compromise the safety and completeness of the resection. Reconstruction is a challenging and critical step of the procedure with the optimal solution not yet found. The use of a vascularized septal flap, however, has been a significant advance in reducing CSF leak rates. Specific nasal morbidity may also be a problem, with nasal crusting and discharge being the most commonly reported symptoms.

Tumor characteristics less suitable for endoscopic resection have also been described. Significant optic canal tumor extension, often laterally, may be deemed a contraindication.

### Table 2. Intraoperative and Postoperative Results

<table>
<thead>
<tr>
<th>Patient</th>
<th>Resection</th>
<th>Operative Time, h:min</th>
<th>Intraoperative Complications</th>
<th>Postoperative Complications</th>
<th>Postoperative Complications</th>
<th>WHO Grade</th>
<th>Symptoms</th>
<th>Resolved</th>
<th>Recurrence</th>
<th>Follow-Up, mo</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Complete</td>
<td>9:39</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>9</td>
<td>I</td>
<td>N</td>
<td>N</td>
<td>72</td>
</tr>
<tr>
<td>2</td>
<td>Complete</td>
<td>6:37</td>
<td>None</td>
<td>CSF leak</td>
<td>No intervention</td>
<td>5</td>
<td>I</td>
<td>Y</td>
<td>N</td>
<td>60</td>
</tr>
<tr>
<td>3</td>
<td>Complete</td>
<td>10:45</td>
<td>None</td>
<td>CSF leak</td>
<td>Lumbar drain</td>
<td>15</td>
<td>I</td>
<td>N</td>
<td>N</td>
<td>48</td>
</tr>
<tr>
<td>4</td>
<td>Complete</td>
<td>6:17</td>
<td>None</td>
<td>CSF leak</td>
<td>Lumbar drain</td>
<td>22</td>
<td>I</td>
<td>Y</td>
<td>N</td>
<td>36</td>
</tr>
<tr>
<td>5</td>
<td>Complete</td>
<td>8:38</td>
<td>None</td>
<td>CSF leak</td>
<td>Lumbar drain</td>
<td>5</td>
<td>I</td>
<td>N</td>
<td>Y</td>
<td>36</td>
</tr>
<tr>
<td>6</td>
<td>Complete</td>
<td>8:20</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>6</td>
<td>I</td>
<td>N</td>
<td>N</td>
<td>24</td>
</tr>
<tr>
<td>7</td>
<td>Complete</td>
<td>4:01</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>5</td>
<td>I</td>
<td>Y</td>
<td>N</td>
<td>12</td>
</tr>
<tr>
<td>8</td>
<td>Near complete</td>
<td>12:11</td>
<td>None</td>
<td>Intracranial bleed requiring craniotomy</td>
<td>27</td>
<td>I</td>
<td>N</td>
<td>N</td>
<td>12</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Complete</td>
<td>5:15</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>13</td>
<td>I</td>
<td>Y</td>
<td>N</td>
<td>12</td>
</tr>
<tr>
<td>10</td>
<td>Complete</td>
<td>3:15</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>9</td>
<td>I</td>
<td>Y</td>
<td>N</td>
<td>3</td>
</tr>
<tr>
<td>11</td>
<td>Complete</td>
<td>4:09</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>10</td>
<td>I</td>
<td>Y</td>
<td>N</td>
<td>3</td>
</tr>
<tr>
<td>12</td>
<td>Complete</td>
<td>4:50</td>
<td>None</td>
<td>Hyponatremia</td>
<td>None</td>
<td>9</td>
<td>I</td>
<td>Y</td>
<td>N</td>
<td>3</td>
</tr>
<tr>
<td>13</td>
<td>Complete</td>
<td>3:34</td>
<td>None</td>
<td>CSF leak</td>
<td>Lumbar drain</td>
<td>19</td>
<td>I</td>
<td>Y</td>
<td>N</td>
<td>3</td>
</tr>
<tr>
<td>14</td>
<td>Complete</td>
<td>5:08</td>
<td>Acute left orbital hematoma required decompression</td>
<td>None</td>
<td>15</td>
<td>I</td>
<td>Y</td>
<td>N</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>Complete</td>
<td>6:58</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>9</td>
<td>I</td>
<td>Y</td>
<td>N</td>
<td>3</td>
</tr>
</tbody>
</table>

Abbreviations: CSF, cerebrospinal fluid; LOS, length of stay; N, no; RTT, return to theater; WHO, World Health Organization; Y, yes.
as would extension lateral to a major neurovascular structure. If the surgical goal is complete removal, limitations may include encasement of either internal carotid or anterior communicating arteries. Relative factors such as tumor size over 4 cm and significant peritumor edema on MRI may make the approach less agreeable.9,15,16,21

Our experience, however, has highlighted 2 main rules. First, the surgeons involved require sufficient operative experience with a well-established skill set. Second, neurovascular structures should never be crossed.

Preoperative planning is of upmost importance for appropriate patient selection. The SAES comprises ENT surgeons, neurosurgeons, radiologists, endocrinologists, and allied health staff, meeting regularly to discuss which operative plan is most appropriate. In some instances, a combined open and endonasal approach may ensure greater patient safety and avoid damage to critical neurovascular structures. No case is approached endonasally without a consensus agreement.

The SAES team has developed and evolved skills through years of endoscopic pituitary resection surgeries, coupled with backgrounds in ESS and neurological microsurgery. Skill sets have been broadened by regular conference, course, and workshop attendance as well as practical cadaver dissections.

To justify the use of the endonasal approach, outcomes and complication rates should be comparable with those of a transcranial method. Our results are equivalent in achieving gross total resection, as well as improvement in visual outcomes and mortality rates (Table 3). Cerebrospinal fluid leak has remained the greatest point of difference between the 2 methods, with rates of CSF leak for transcranial series documented as being rare. Our rates of CSF leak have been comparable to other endonasal series (Table 4).

<table>
<thead>
<tr>
<th>Table 3. Other Transcranial Series Outcomes Compared with Current Series Outcomes19</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Series</strong></td>
</tr>
<tr>
<td>Current series</td>
</tr>
<tr>
<td>Al-Mefty and Smith 199122</td>
</tr>
<tr>
<td>Yasargil 199623</td>
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Dashes indicate data not available.

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<th>Table 4. Other Endonasal Series Compared with Current Series19</th>
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<td><strong>Series</strong></td>
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<td>Jho 200135</td>
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<td>Gardner et al 20085</td>
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Abbreviation: CSF, cerebrospinal fluid. Dashes indicate data not available.
After reviewing the causes of intraoperative orbital hematoma, the method of ligation of the AEA and PEA has changed. These arteries are now ligated where they cross the skull base at its midpoint. This way, inadvertent trauma is unlikely to cause intraorbital retraction of the artery.

It can be seen that each operation indeed promotes further refinement of the endonasal technique.

**Conclusion**

Anterior cranial fossa meningiomas can be safely removed endonasally and offer significant advantages over the traditional transcranial approach for suitable tumors. Early audit of this approach shows that results achieved by this unit are comparable with the published literature. However, patient selection and team approach are critical. Reasons for failure must be carefully examined and refinements in technique made to improve outcomes.

**Author Contributions**

Vikram Padhye, design, data acquisition, analysis, interpretation, article writing; Yuresh Naidoo, design, data analysis, article writing/editing; Hamish Alexander, data acquisition; Stephen Floreani, patient care, article edit; Simon Robinson, patient care, article edit; Stephen Santorenoes, patient care, article edit; Agadha Wickremesekera, patient care, data acquisition, article edit; Brian Brophy, patient care, article edit; Margaretue Harding, patient care, article edit; Nick Vrodos, patient care, article edit; Peter-John Wormald, supervisor, design, analysis, interpretation, article edit.

**Disclosures**

**Competing interests:** Peter-John Wormald has provided consultancy to Neilmed and has received royalties for the design of a surgical instrument from Medtronic (the instrument is not related to this study in any way).

**Sponsorships:** None.

**Funding source:** None.

**References**


