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HOW I DO IT - NEUROSURGICAL TECHNIQUES

Eyebrow craniotomy for anterior skull base lesions: how I do it

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Abstract
Background The eyebrow craniotomy is a less invasive alternative approach for accessing anterior skull base lesions, compared to traditional and more extensive exposures. We give a stepwise description of this minimally invasive technique with discussion on the indications, limitations and key aspects of perioperative management.
Methods Positioning of the head and planning the surgical corridor are dictated by the nature, site and size of the target lesion. The eyebrow incision should spare the medial and posterolateral neural structures. Microsurgical strategy is based on opening up the basal cisterns and respecting the distorted neurovascular anatomy. Selective use of brain retractor and angulation of the operative microscope enable the surgeon to make use of the "keyhole effect" for accessing a larger target. Perioperative measures are in part dictated by the nature of the pathology, involvement of the optic apparatus and changes to pituitary function.
Conclusion The eyebrow craniotomy may be safely used as a minimally invasive approach for a variety of anterior skull base lesions. There is an operative learning curve and some types of pathologies are easier to approach by this technique than others.

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Key points

- The eyebrow craniotomy is an alternative less invasive approach for accessing anterior skull base lesions
- Positioning of the head and planning the surgical corridor are dictated by the nature, site and size of the target lesion
- Microsurgical strategy is based on opening up the basal cisterns and respecting the distorted neurovascular anatomy.
- Selective use of brain retractor and angulation of the operative microscope enable the surgeon to make use of the "keyhole effect" for accessing a larger target
- Perioperative measures are in part dictated by the nature of the pathology, involvement of the optic apparatus and changes to pituitary function.
- There is an operative learning curve and some types of pathologies are easier to approach by this technique than others.

Keywords Eyebrow craniotomy · Keyhole approach · Anterior skull base

Introduction

Minimally invasive transcranial approaches have evolved along the concept of creating the smallest and least destructive surgical corridor, while maintaining optimal access to the target area. One of the most frequently used variant is the eyebrow craniotomy, which has been safely applied for accessing the anterior skull base lesions by several authors [2–8]. Benefits include smaller incision, minimal brain exposure and retraction, good visualization of key anatomical structures, reduced blood loss with lower morbidity and mortality [2, 4, 5, 8]. As a result, the eyebrow craniotomy has emerged as a viable option to more invasive skull base approaches such as the bifrontal, pterional and orbitozygomatic craniotomies.

In the current review we summarize key technical considerations and aspects of perioperative management when performing an eyebrow craniotomy for anterior skull base lesions. The surgical strategy is illustrated by a case example of a tuberculum sella meningioma.

Relevant surgical anatomy

Extradural anatomy

The key anatomical landmarks for the eyebrow craniotomy are the supraorbital notch, orbital bar and the frontal process of the zygoma (Fig. 1a and b). The supraorbital notch marks the entry site for the supraorbital branch (originating from the first division of trigeminal nerve) and the frontal process of the zygoma is 1 cm anterior to the course of the frontal branch (originating from the facial nerve) (Fig. 1b). The skin incision runs parallel to the orbital bar and it is guided by these palpable bony landmarks to spare the two nerves during exposure. The keyhole lies just posterior to the frontal process and marks the site of the burr hole for the craniotomy.

Intradural anatomy and displacement of neurovascular structures

Durotomy uncovers the frontal lobe, which often falls away aided by gravity assisted retraction, creating the corridor to the anterior skull base (Fig. 1c, d). First glance surgical view will reveal the right optic nerve as the foremost structure with the ipsilateral carotid artery laterally, emerging from behind the anterior clinoid process (Fig. 1c). Release of CSF by opening the chiasmatic and carotid cisterns, encasing the optic nerves and carotid artery respectively, facilitates brain relaxation. With further dissection the optic chiasm, the vasculature of the anterior circulation are visualized (i.e., internal carotid, ICA; anterior cerebral, ACA; middle cerebral arteries, MCA). Splitting the proximal sylvian cistern improves access to the MCA complex, the middle cerebral

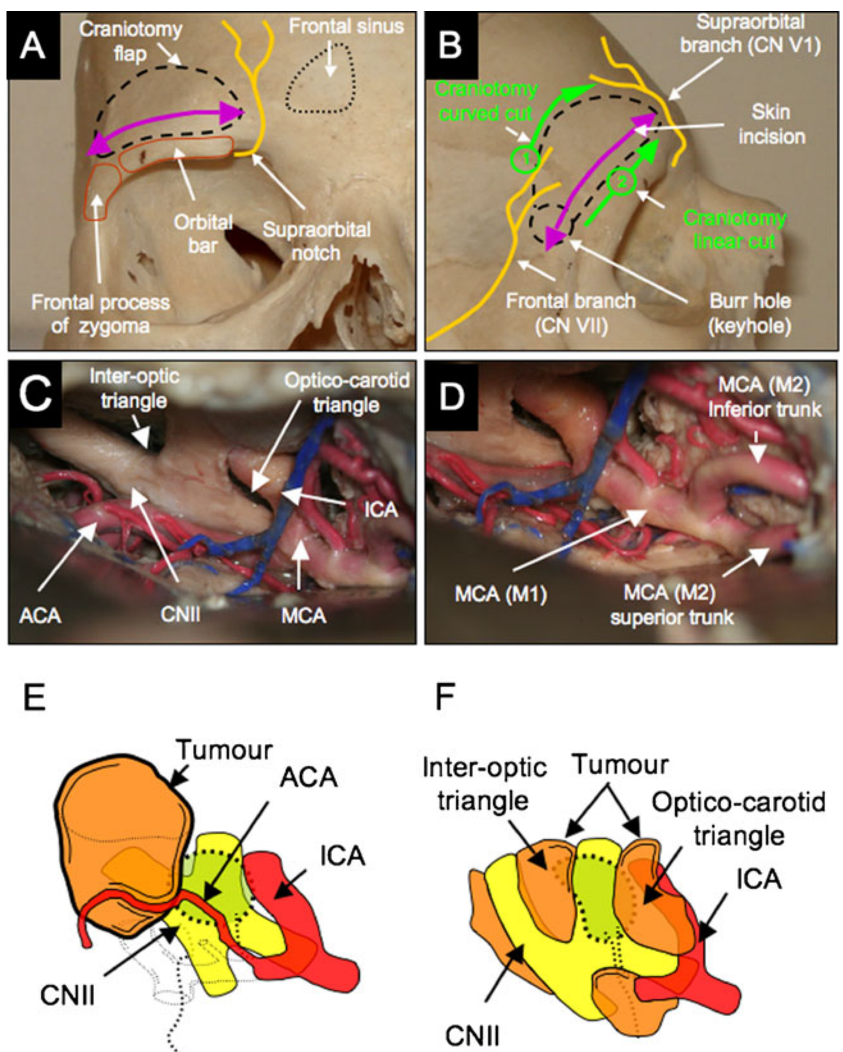

Fig. 1 Relevant surgical anatomy. Anterior (**a**) and lateral (**b**) views of skull depicts the anatomical relationships of the skin incision, adjacent nerves and bone flap of the eyebrow craniotomy. Intradural anatomy of a right sided eyebrow craniotomy, medially (**c**) and more laterally after splitting the proximal Sylvian fissure (**d**). Schematic illustration of the likely neurovascular distortion by tumours occupying the anterior skull base (**e**) and sellar region (**f**)

artery (M1), its bifurcation and the medial temporal lobe (Fig. 1d).

These neurovascular arrangements can be disrupted by tumours of the anterior skull base. The anterior cerebral arteries may be draped over large lesions arising from the anterior skull base (e.g., olfactory groove meningiomas) as illustrated by Fig. 1e. The interoptic and optico-carotid triangles may be expanded by sellar masses which stretch and displace the optic nerve and ICA (Fig. 1f).

Description of the technique

Preoperative planning and positioning of the head

Preoperative assessment of craniocerebral and neurovascular relationships are paramount. For example, in case of an olfactory groove meningioma (Fig. 2a, c, e), the lesion is situated relatively anterior along the anterior fossa floor and the surgical trajectory would fall at an angle of 40–60º relative to the neutral plane (Fig. 2c). Accessing the full height of the tumour also requires a 'taller' craniotomy (Fig. 2e). On the other hand, a tuberculum sella meningioma is more posteriorly located (Fig. 2b, d, f) and would require an approach trajectory of 20–30° (Fig. 2d) and a standard height craniotomy (Fig. 2f). Lesions larger than the craniotomy window size can be accessed by using the "keyhole-effect", a manoeuvre that involves tilting of the microscope to bring lesion edges at the depth into view.

The head is elevated above the cardiac level (approx 20°) to facilitate venous outflow and retroflexed (approx 20–30°) to optimize the surgical angle and to take advantage of gravity-assisted retraction of the frontal lobe (Fig. 3). Lateral rotation is dictated by the depth of the target lesion,

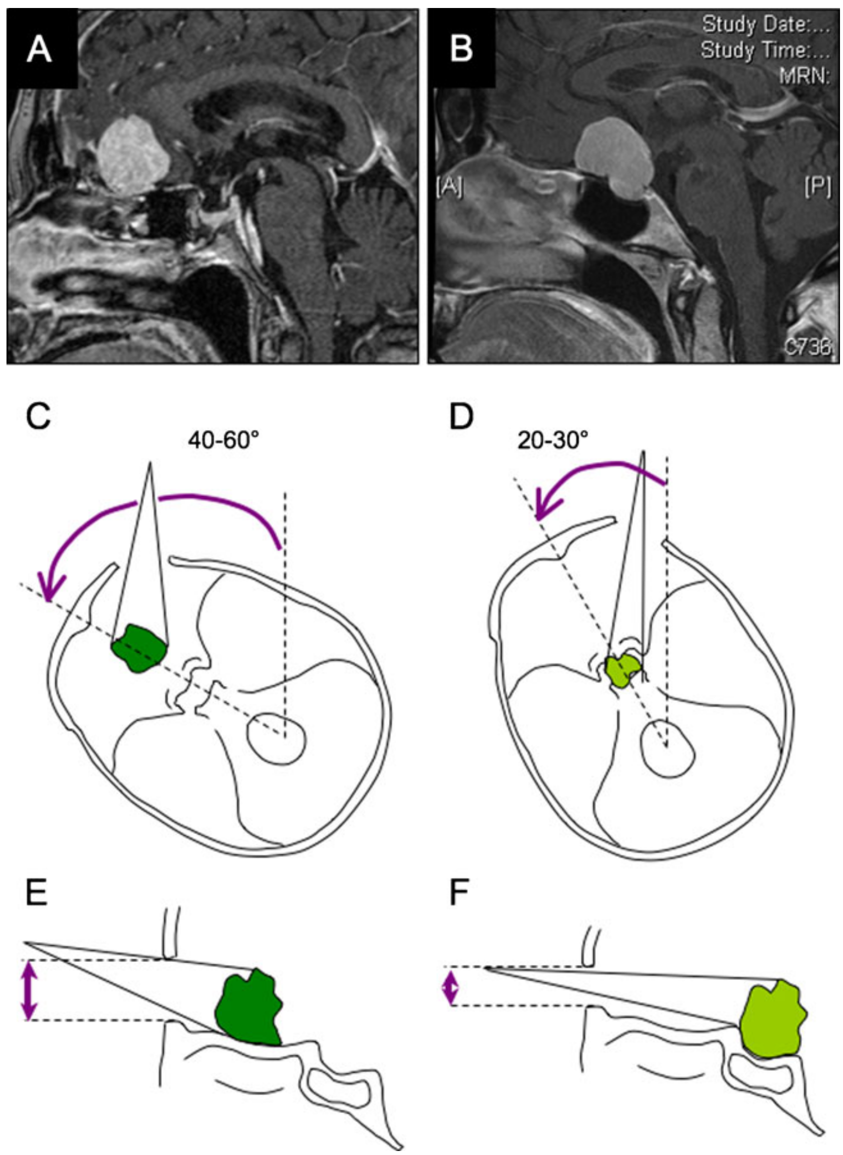

Fig. 2 Operative technique: preoperative planning for an eyebrow craniotomy for an olfactory groove (**a**) and a tuberculum sella meningioma (**b**)

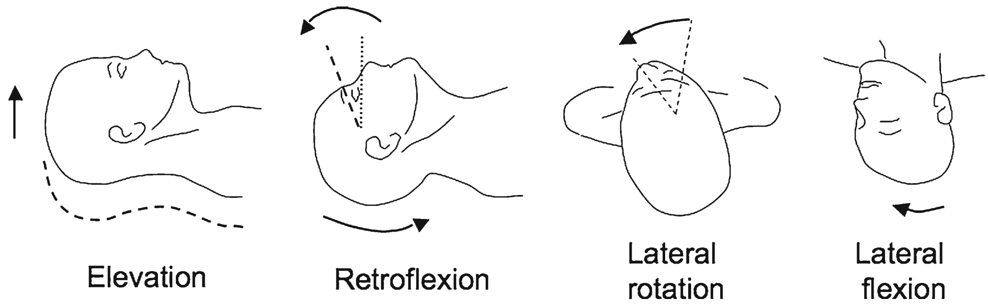

Fig. 3 Head positioning for the eyebrow craniotomy. The extent of lateral rotation is dependant on the nature of the pathology

approximately 40–60° for anterior cranial fossa, and 20–30° for sellar region as discussed above. Lateral flexion (approx 10°) creates an ergonomic working position for the surgeon (Fig. 3).

Skin incision and craniotomy for the eyebrow approach

The skin is infiltrated using 1 % Xylocaine with 1:200,000 adrenaline and the skin incision is placed parallel to the orbital bar, either through or just above the eyebrow. Incision made just above the eyebrow may minimize the risk of violating the hair follicles that can lead to alopecia (Fig. 4a). Medial border of the incision is the supraorbital notch, which marks the supraorbital branch of the frontal nerve, as described above. In the lateral direction, the incision can extend up to approximately 1 cm postero-lateral to the bony edge of the eyebrow, to safely avoid the main stem of the frontal branch (Fig. 4a). If required, the incision can be extended as inferior as the zygoma. Depth of the skin incision extends through the fascia of the frontalis muscle, exposing the periosteum. The single musculocutaneous layer is retracted using fishhooks with elastic bands (Fig. 4b). The incision spares the pericranium in order for a small flap to be harvested for later use.

A single burr hole is placed over the keyhole, which lies just posterior to the frontal process of the zygomatic bone (Figs. 1b and 4a, b). The first cut of the craniotomy is placed in a curved fashion starting from the burr hole, turned backwards and superiorly, and brought down just lateral to the supraorbital notch to spare the supraorbital branch (Figs. 1b and 4b). The second cut is placed in a straight line, parallel to the orbital bar and brought in medially to meet the termination of the first cut to complete the craniotomy (Figs. 1b and 4c). The orbital bar occupies the basal part of the access corridor, blocking part of the surgical view along the retraction plane (Fig. 4c). The inner edge of the orbital bar is drilled away expanding the view along the skull base (Fig. 4d). The dura is hitched over the orbital roof using absorbing sutures to elevate it away from the frontal lobe and opened in a curved fashion with its base towards the orbital bar.

There is also an option to remove the orbital bar (highlighted in Fig. 1a) prior to the durotomy, which expands the

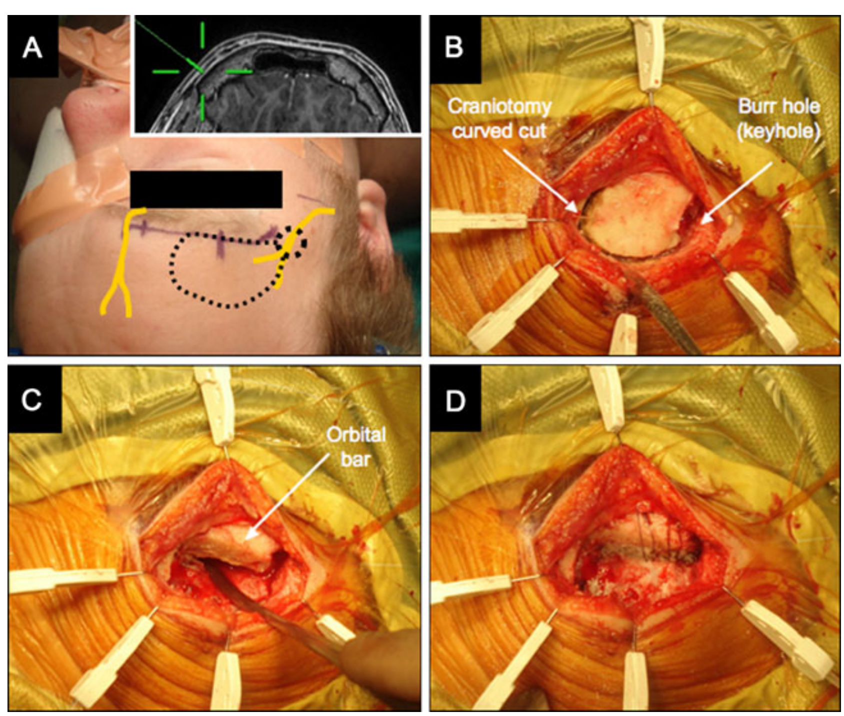

Fig. 4 Skin incision and craniotomy for the eyebrow approach. Intraoperative views of a right sided eyebrow craniotomy (**b**–**d**). Neuronavigation helps in localizing and avoiding the frontal sinus (**a**, inset)

angle of access and reduces the distance to surgical targets. This manoeuvre has been described as a safe alternative for expanding the classic eyebrow craniotomy [8]. Although this is an appealing option, our experience shows that flattening the orbital bar was sufficient to establish adequate access in most cases.

Case example of a tuberculum sellae meningioma (OPERATIVE VIDEO)

Preoperative MRI scans (Fig. 5a, b) are studied meticulously to construct a mental picture of the neurovascular relationships (see Fig. 5c, d). Following durotomy, the right optic nerve is visualized, as it is pushed forward by the tumour mass. Proximal dissection planes are established followed by progressive diathermy of the tumour blood supply from the skull base. Tumour is then debulked through the interoptic and optico-carotid windows, both of which are expanded by the herniating tumour bulk (Fig. 5c, d). Following sufficient debulking, peritumoural dissection planes are further developed; the distorted parasellar anatomy is gradually revealed and the posterior surfaces of the tumour are exposed (Fig 5e, f). The contralateral optic nerve is noted to be pressed against the adjacent carotid artery by the tumour. On removal of the tumour the contralateral ophthalmic, superior hypophyseal, posterior communicating and anterior choroidal arteries are revealed (Fig. 5e, f).

Closure and reconstruction of bone flap

Dura is approximated, with the use of hitch stiches and if necessary a dural substitute. Inadvertent opening of the frontal sinus must be closed with bone wax, pericranial fascia and/or tissue glue. Bone flap is replaced and secured using titanium mini-plates and/or mesh (Fig. 6a). Care is taken to level the bone flap with the surrounding cranium. Skin incision is closed with continuous interlocking nylon sutures (Fig. 6b), which are removed at 5–7 days (Fig. 6c). We do not employ wound drains.

Indications

The eyebrow craniotomy can be applied for selected pathologies involving the anterior skull base (Table 1). More advanced applications can include pathologies of the middle and posterior skull base [6, 7]. The eyebrow approach can be used in combination with the transsphenoidal approach as a two stage procedure especially for pathology of the sellar region.

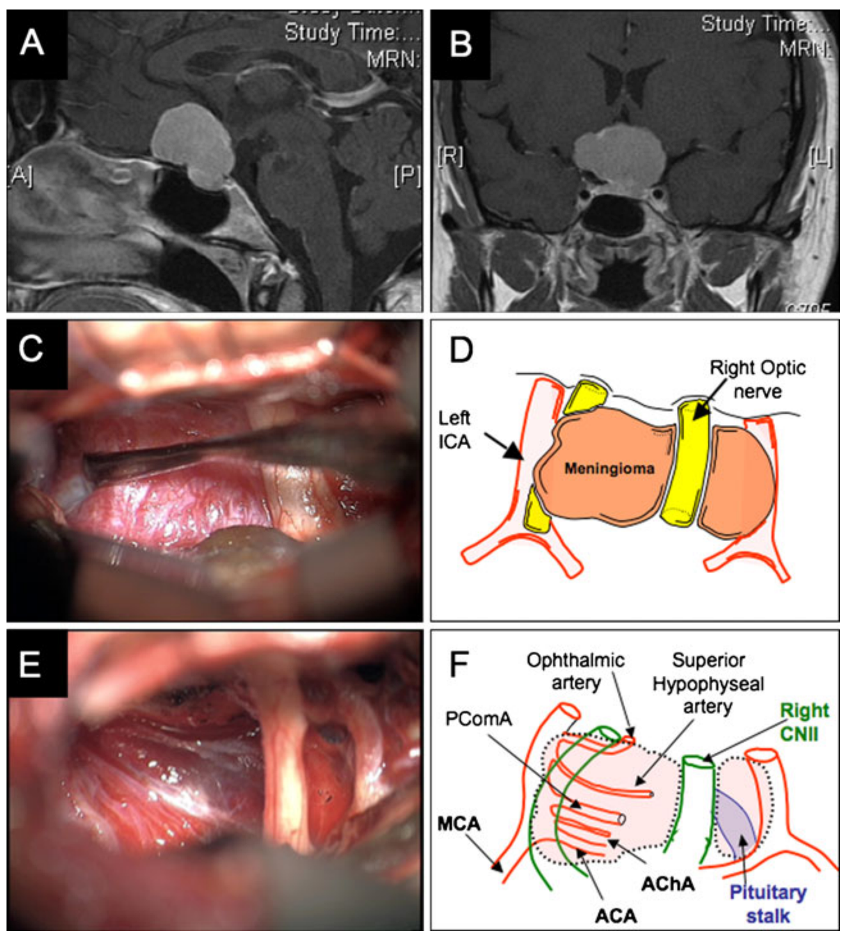

Fig. 5 Case example of a tuberculum sellae meningioma approached via a right sided eyebrow craniotomy. Preoperative T1 weighted MRI imaging with contrast in sagittal (**a**) and coronal (**b**) planes. The distorted neurovascular anatomy is revealed after the tumour has been removed (**c**–**f**)

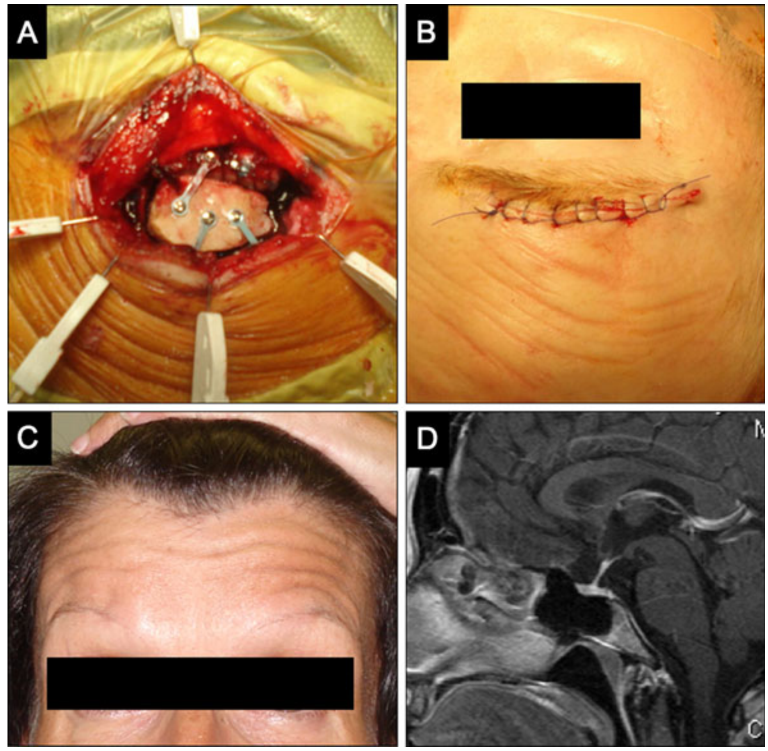

Fig. 6 Reconstruction of bone flap (**a**) and closure of incision (**b**). Photograph of the patient 3 months post-operatively reveal good frontalis muscle function (**c**). Post-op MRI scan shows resection of the tumour (**d**)

Limitations

The use of the eyebrow craniotomy is limited to selected cases, mainly involving the anterior cranial fossa. The choice of cases is largely determined by the experience of the operating surgeon as there is an operative learning curve to using this approach. Some lesions (e.g., residual suprasellar pituitary adenoma) are more easily tackled by the eyebrow approach than other pathologies (e.g., acute vascular aneurysms).

One of the disadvantages of this approach is the narrow and potentially deep surgical corridor (i.e., greater working distance), with limited visualisation and manoeuvrability compared to more traditional transcranial approaches. These have been gradually overcome with various strategies including the use of the operating microscope and the design of novel low profile ("tube shaft") instruments to improve access and view [7]. An operative endoscope (0–70°) can be also used for improved visualization [1].

Table 1 Possible indications for the eyebrow craniotomy

Pituitary adenomas
• Large suprasellar pituitary adenoma (still usually approached transsphenoidally)
• Residual suprasellar pituitary adenoma[a] (to resect the suprasellar component post-transsphenoidal surgery, especially if the adenoma was firm and unlikely to descend)
Suprasellar craniopharyngioma[a]
Meningiomas
• Tuberculum sella & Planum sphenoidale meningiomas[a]
• Olfactory groove meningiomas[a]
Vascular
• Aneurysms (Advanced indications and easier if undertaken as an elective procedure. Most anterior circulation aneurysms, can be accessed)
• Frontal cavernomas & AVMs (especially if located at the frontal pole)
Miscellaneous
• Gliomas & Metastasis (only for carefully selected cases involving the frontal pole and with minimal mass effect)
• Dermoids (selected cases around the frontal lobe)
• Cribriform sphenoid encephalocoele (combined repair with transsphenoidal approach)
• Optic nerve decompressions

[a] An alternative to the extended transsphenoidal approach

Table 2 Post-operative management issues

Neurological observations	Significant neurological or visual deficits warrant an urgent CT or MR scan of the brain
Wound care	- Suture removal at 5–7 days post-surgery. Swab suspected infections
	- Contrasted CT brain to exclude intracranial abscess
	- Consider post-op antibiotic cover if frontal sinus is breached
CSF leak	- Incremental intervention, including wound stitches, CSF diversion (i.e., lumbar puncture or drain) and re-closure of frontal sinus
	- CSF rhinorrhea implies breach of the frontal sinus and likely need for lumbar drain
DVT prophylaxis	- Early mobilisation, TED stockings, pneumatic calf compressors
	- Consider low molecular weight heparin 24 h post-surgery
Steroid use	- High dose steroids use in tumour cases
	- Sellar/suprasellar pathologies may need hydrocortisone cover
Fluid balance	Adequate fluid hydration and beware of the risk of post-op diabetes insipidus and delayed SIADH in parasellar pathology

How to avoid complications

The eyebrow craniotomy is associated with a similar range of complications as more traditional transcranial approaches (Table 2). Major surgical complications such as neurovascular injuries can be minimised by the knowledge and understanding of the distorted surgical anatomy as discussed above.

Specific complications related to the skin incision and soft tissue retraction are 1) the injury to the frontal branch of the facial nerve and 2) the supraorbital branch of the ophthalmic division (trigeminal nerve). The most practical way to avoid these structures is to highlight the likely anatomical course on the surgical field prior to the skin incision. Long-term sensory loss from neuropraxia of the supra-orbital nerve is usually fairly limited due to overlap of the cutaneous innervation of that region of the scalp. Frontalis muscle function usually fully recovers from the trauma of surgery by 4–6 weeks post-operatively.

Violation of the frontal sinus can be a complication of an eyebrow craniotomy. Preoperative imaging and intra-operative neuronavigation can be used to localise and avoid its lateral edge. If the opening the sinus cannot be avoided than careful repair (as described above) is important.

Specific perioperative considerations

Post-operative issues are summarized in Table 2.

Specific perioperative measures for eyebrow craniotomy cases are also dictated by the involvement of the optic and the endocrine apparatus. Visual acuity and visual fields assessment are recommended for establishing a baseline prior to surgery. Patients being treated for lesions close to the pituitary gland are best managed jointly with endocrine team for monitoring and if necessary replacing any hormonal deficiencies pre- and post-operatively.

Depending on the nature and site of the pathology, patients are usually discharged on day 3–7 post-operatively and are followed up in dedicated skull base clinics at 6–12 weeks. Follow-up MRI scan is performed at 3–6 months postoperatively (Fig. 6d).

Specific information to give to the patient about the surgery and potential risk

Potential complications (see Table 3), tailored to the nature of the pathology should be discussed with the patient along with the measures taken to minimise these risks. They should also be informed about the possibility of prolonged hospital stay necessary to deal with these complications and the potential need for adjuvant treatment (e.g., radiotherapy) for any residual/recurrent lesion.

Conclusions

Performing an eyebrow craniotomy for anterior skull base lesions requires meticulous preoperative planning to create the optimal surgical corridor to the lesion and to formulate the

Table 3 Operative complications

Major complications (<0.1 % risk; case dependant)
- Major vascular injury
- Blindness from optic nerve/chiasmal injury
- Death
Other complications (~5–40 %; case dependent)
- Bleeding
- Infection (wound infection, frontal sinusitis, meningitis etc.)
- Neurological deficits
- Frontalis palsy
- Breach of the frontal sinus & CSF rhinorrhoea
- Fits (likely driving restrictions)
- Pituitary dysfunction & need for hormone replacement
- Diabetes insipidus & SIADH
- Residual tumour, need for further surgery & adjuvant radiotherapy
- Other medical complications (e.g., respiratory, cardiovascular)

debulking strategy. Use of the eyebrow craniotomy is safe with good cosmetic results and potentially lower morbidity.

Conflicts of interest None.

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