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Extended Unifrontal craniotomy for midline anterior cranial fossa meningiomas: A better shot at preservation of neurovascular structures

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ABSTRACT

Numerous surgical approaches have been described for the resection of anterior cranial fossa meningioma. The common problems associated with these approaches are excessive brain retraction, injury to neurovascular structures, transection of superior sagittal sinus (SSS), and a higher risk of new-onset anosmia. The authors describe a unilateral extended frontal approach with the aim to minimize brain handling without the need for SSS transection and possibly better olfaction preservation. Methods: Thirteen patients with anterior cranial fossa meningioma were operated on using the novel technique of unilateral extended frontal skull base approach. The clinical presentation, radiological studies, intraoperative findings, and outcome at follow-up were recorded. Results: Gross total tumor resection could be achieved in 12 out of 13 patients. At least one of the olfactory tracts could be anatomically preserved in all patients, and superior sagittal sinus was preserved in all patients. Functional olfaction preservation was achieved in 8 patients. No patient developed new-onset anosmia. Conclusions: The extended unilateral frontal approach is a viable and reliable alternative for extended bifrontal technique for the resection of large midline anterior cranial fossa meningiomas with avoidance of SSS ligation, decreased brain handling with better olfaction preservation while achieving comparable tumor resection and acceptable cosmetic outcomes.

1. Introduction

Anterior cranial fossa (ACF) meningiomas form 12–20% of all intracranial meningiomas.[1] They are a heterogenous group of lesions which can be further classified according to the site of attachment into midline (olfactory groove meningioma, planum sphenoid, and tuberculum sellae meningioma) and lateral lesions.[2] The surgical resection of these tumors, especially the larger lesions is often challenging due to significant brain edema and proximity to important neurovascular structures. Numerous surgical approaches have been described for their resection which can be broadly categorized as Anterior sub-frontal approach, lateral sub-frontal approach, and superior interhemispheric approach.[3] The choice of the surgical approach has to be individualized to the tumor characteristics and surgeon's comfort and skill.[3] However, conventional approaches often involve frontal lobe retraction, excessive manipulation of the edematous brain tissue, and inherent risk to the critical neurovascular structures. The bilateral fronto-orbital approach aims to minimize brain retraction, but it has higher chances of causing anosmia and involves transection of the anterior superior sagittal sinus (SSS), which is not as safe as once thought.[4,5] We present a unilateral extended frontal skull base approach for the resection of large ACF meningiomas, which preserves SSS and provides better olfaction preservation.[6]

2. Material and methods

Thirteen patients with large (size >4 cm) anterior cranial fossa meningioma were operated on using the described technique (vide infra) from January 2019 to December 2021. The average age of the patients was 45.4 years, with the majority females (84.6%). Headache was the most common complaint (11/13 cases) followed by visual impairment (7/13 cases), behavioral disturbances (5/13 cases), and seizures (5/13 cases). Olfaction was intact in 70% of the patients (8/13) on preoperative assessment. All the tumors measured at least 4 cm in one of the dimensions with a mean volume of 57.5 cc. There was mass effect due to tumor with edema of the adjacent brain parenchyma in all the cases. Informed and written consent was obtained from all the patients before surgery. Right-sided craniotomy (11/13) was performed in most of the cases. Left side was chosen in two patients as the tumor was asymmetrically extending into the left optic canal.

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Abbreviation list

ACF –	Anterior cranial fossa
SSS –	Superior saggital sinus
CSF –	Cerebrospinal fluid
ACOM –	Anterior communicating artery
GTR –	Gross total resection

2.1. *Surgical technique* (Video 1)

General anesthesia was given, and the patient was positioned supine on the operating table with their head secured in a Sugita head clamp. The neck is extended with the head kept above the heart level with rotation of 15–20° to the contralateral side. A curvilinear skin incision was marked posterior to the hairline starting 1 cm anterior to tragus to the contra-lateral mid-pupillary line, and the scalp flap was raised with a separate pedicled pericranial flap. The supraorbital nerves were dissected and preserved in all cases. Burr holes were made at the keyhole and midline and connected using Gigli saw wires to complete a frontal craniotomy with a 1-cm extension beyond the midline (Video 1). The basi-frontal dura and periorbita were dissected, and the orbital cuts were made using a chisel at the ipsilateral fronto-zygomatic suture and connected across the orbital roof through the frontonasal suture, running just anterior to the frontal-ethmoid suture and cribriform plate to the medial border of the opposite orbital rim. The skull base was flattened, and the sphenoid ridge was drilled to facilitate Sylvian exposure if needed. Going from the lateral trajectory towards the midline lesion (Fig. 1), the frontal dura was stripped from the frontal base and tumor attachment, and its extent was identified and confirmed with neuronavigation. The hypertrophied bone in the skull base was drilled to further widen the surgical corridor. The ethmoidal arteries were identified early and coagulated (Fig. 2). Dural attachment of the tumor was coagulated, and radial cuts were made on the coagulated dura and progressive tumor debulking with extension of dural cuts was done till the periphery of the tumor was reached. The corridor created after the tumor debulking was used to access the midline and contralateral part of the tumor rather than going around through the tumor–brain interface. Falx was defined and cut to access the hidden contralateral portion of the tumor. Following adequate tumoral debulking, the tumor capsule was dissected from the tumor arachnoid while preserving the arachnoid and the normal vasculature outside the arachnoid layer. The olfactory tracts were dissected and preserved. A uniform arachnoid bulge into the tumor cavity suggested complete tumor resection. Neuronavigation was used to access all the margins of the tumor cavity, including the area of attachment, to ensure completeness of resection. Duraplasty was performed in all the cases using a pericranial patch and fibrin glue. A pedicled pericranial patch was used to exteriorize the frontal sinus after packing it with gel foam and bone wax to prevent CSF leaks. The bone flap was fixed using plates and screws, and the gaps were filled using the preserved bone dust for adequate cosmesis.

3. Results

The mean operative time was 5.1 h (range 3.5–6.4 h). The average estimated blood loss was 950 ml. Tumor extension into the optic canal was seen intraoperatively in 9 patients for which optic canal decompression and tumor removal were done. The mean length of stay was 8.2

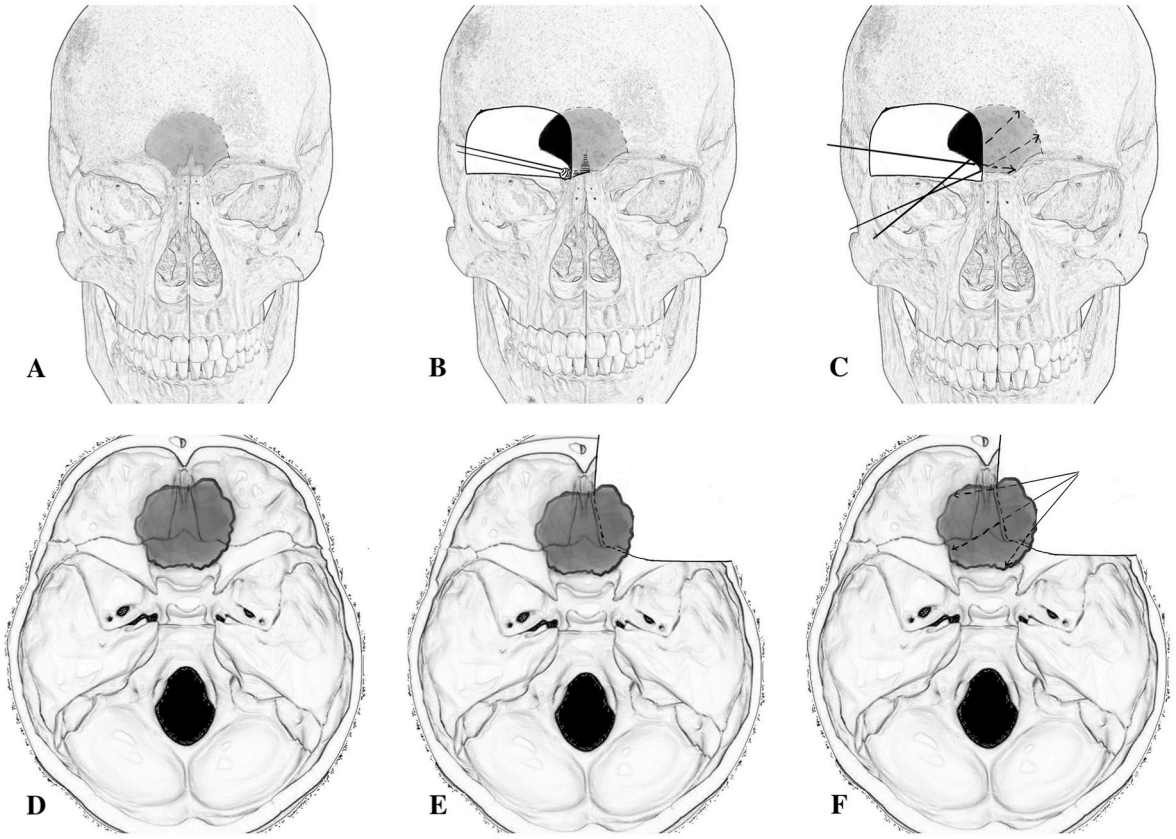

Fig. 1. The principles of unilateral extended frontal approach. (a) schematic coronal image showing tumor outline (b) unilateral frontal craniotomy with orbital osteotomy exposes the tumor attachment and the hypertrophied bone which can be drilled (shaded portion). (c) This allows access to the tumor on the contralateral side without brain retraction and the need to transect the SSS (d,e,f) schematic axial representation showing the extent of craniotomy skirting along the cribriform plate to access the tumor base with a better chance of preservation of olfactory tracts.

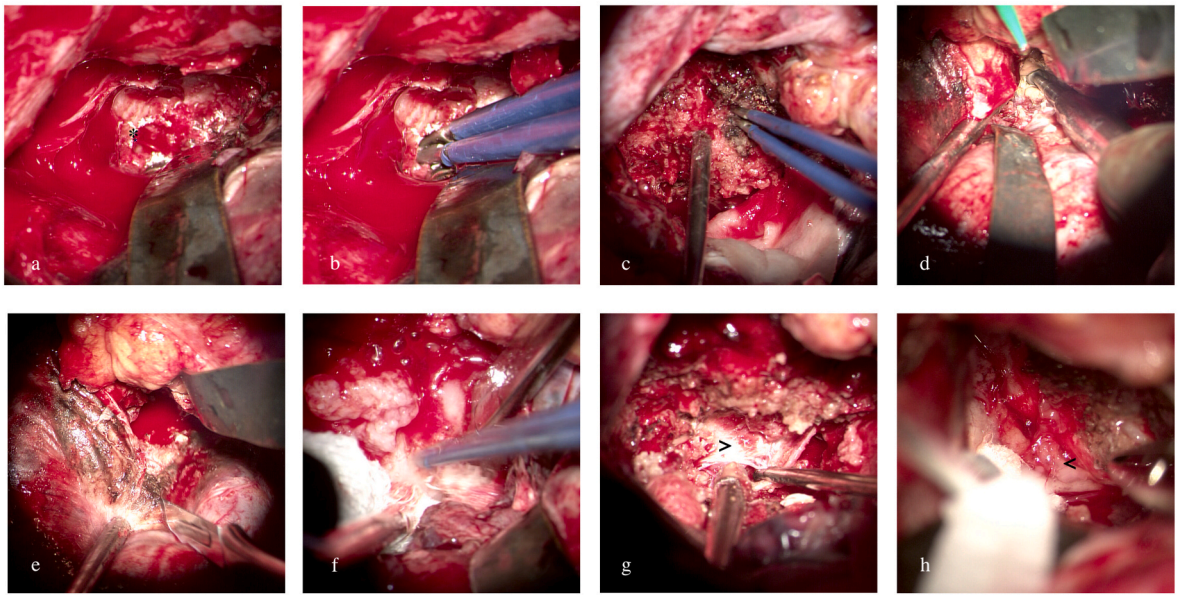

Fig. 2. Surgical steps (a) basifrontal dura dissected from skull base and bleeding from anterior ethmoidal artery seen (marked by *) (b)anterior ethmoidal artery coagulated (c) & (d) skull base and dura over tumor coagulated and hyperostotic bone in skull base drilled to gain corridor to midline tumor (e) radial cuts given in the coagulated dura over the tumor (f) internal tumoral debulking and dissection of tumor capsule with arachanoid (g) identifying and cutting the falx (denoted by >) to gain access to tumor on contralateral side (h) tumor cavity showing complete tumor resection and preserved olfactory tract (marked by <).

days. At least one of the olfactory tracts could be anatomically preserved in 76% of patients with bilateral olfactory preservation in 40% of cases. Cutting of SSS or intradural Sylvian exploration was not needed in any case. Gross total resection of the tumor could be successfully achieved (11/12) in all but one patient (Figs. 2 and 3). In this patient, the lesion was densely adherent to ACOM complex and ensuing perforators, so a thin sleeve of the tumor was left on the vessel.

There was an inadvertent dura tear on frontal convexity during craniotomy causing frontal contusions which was managed with medical measures; this patient eventually had poor neurological outcome. One patient developed an unexplained midbrain stroke in the left posterior cerebral artery territory on the fifth postoperative day and did not have any intraoperative vascular injury; this patient had neurological deterioration and expired during the same hospital stay. There was

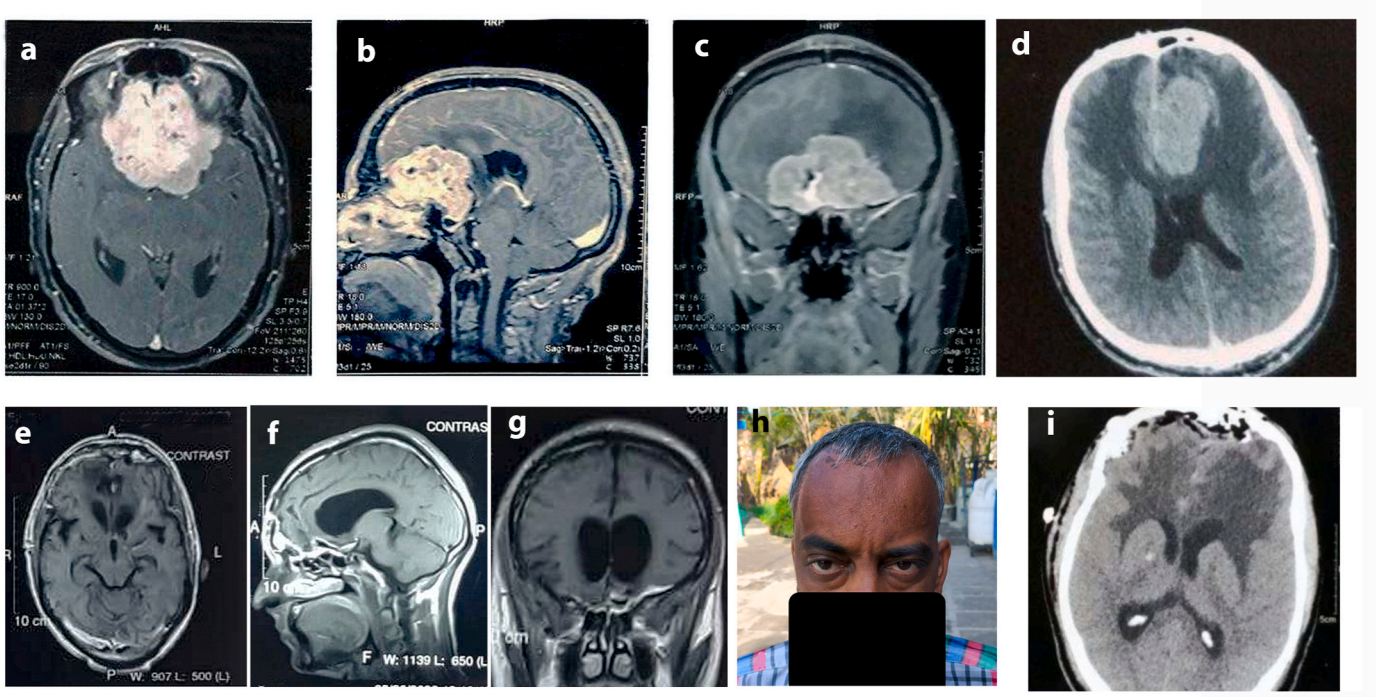

Fig. 3. (a,b,c) preoperative axial, sagittal and coronal contrast images showing a large anterior cranial fossa meningioma (e,f,g) postoperative radiology at follow up showing complete resection of tumor. (h) post-operative cosmetic outcome in right sided unilateral extended frontal approach. Olfaction was preserved in the post-operative period and the personality changes improved (d, i) pre-operative CT head showing the lesion with significant perilesional edema, and post-operative scan showing the lack of frontal contusions post-procedure with no increase in brain edema.

transient CSF rhinorrhea in one patient, which resolved spontaneously within 24 h with conservative measures without any complications. There were no long-term complications related to the approach except in one patient who had dural injury and brain injury during craniotomy. None of the patients had problems related to brain retraction or venous infarction.

No tumor recurrence was seen in any of the cases on follow-up (mean follow-up duration 16.5 months) (Figs. 3–5). In the case of residual tumor left adherent to the vessel wall, there was no evidence of tumor progression over one year. 10 out of 12 patients at the last follow-up scored five on the Glasgow outcome scale but one patient had a disability due to frontal contusion. At follow up, 11 patients could be assessed for post-operative olfaction (two patients couldn't be assessed one with poor outcome due to frontal contusion during craniotomy and another death due to brainstem infarct). Post-operative olfaction was preserved in 8 patients (olfaction was preserved in 8 out of 13 patients at pre-op). There was no instance of new-onset anosmia post-surgery. All the patients with pre-operative personality changes reported gradual improvement over the follow-up. Acceptable cosmesis could be achieved in all the cases (Figs. 3 and 4).

4. Discussion

The ideal surgical approach to the midline anterior skull base meningiomas should provide adequate tumor exposure, decrease working distances, minimize the need for brain retraction while providing access to identify and preserve the critical neurovascular structures. It should also ensure adequate dura closure and prevent CSF leak. Even though several approaches have been described in the literature, none tick all the boxes. However, the bilateral orbito-frontal approach provides distinct advantages by reducing brain retraction, decreasing the working corridor, and providing early assess to vascular supply.[4] We describe a versatile approach to the midline anterior skull base lesions that combines aggressive resection with minimal brain handling. Although numerous variations of unilateral approaches have been described previously,[7–9] this technique is a highly tailored approach with each element included with a particular aim. Unlike previously described techniques that prefer to open dura over the normal brain and dissect the brain-tumor interface, our technique opens dura over the tumor and avoids dissecting the surrounding normal brain parenchyma, which is often edematous and vulnerable to injury in large tumors. We followed the principles of cutting the tumor base after devascularization and proceeding in centrifugal fashion. We use the natural corridor created by internal tumor debulking to access the midline and contralateral side instead of using the conventional route of dissection between the brain-tumor interface. Moreover, we respect the tumor arachnoid and dissect the tumor-arachnoid interface to preserve the layer of arachnoid all around, which helps to preserve the vessels and nerves in a separate (sub-arachnoid) plane. This technique of extra-arachnoidal dissection is similar to the concept described by the authors for the extra-arachnoid excision of convexity meningiomas.[6] This leads to minimal interaction and manipulation of the "innocent bystander" neurovascular structures leading to better preservation.

Extended bifrontal technique, useful for large ACF tumors with brain edema helps to decrease brain handling and retraction and enables early tumor devascularization but it is associated with higher chances of loss of olfaction (36.8% olfaction preservation).[10] Furthermore, anterior tip of SSS is ligated and reflected after cutting the falx which may lead to stasis and thrombosis of anterior SSS causing venous infarcts in a subset of patients. Post-operative bilateral frontal lobe edema and venous infarct has been reported in 16–26% of patients.[4,11] The unilateral approach provides an opportunity for better olfaction preservation (73% in this study) which is an indispensable sense especially in the visually impaired besides being an important quality of life determinant.[5,10] This

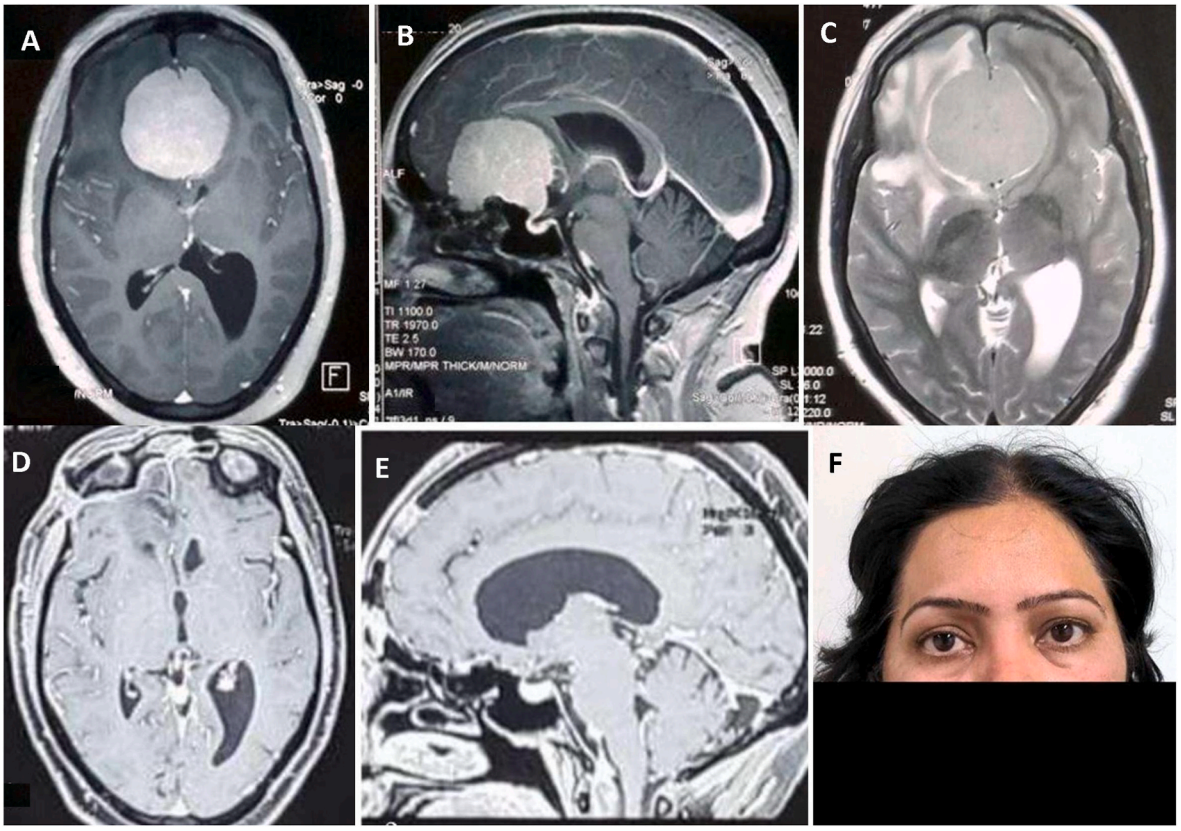

Fig. 4. (a,b,c) preoperative radiology showing meningioma involving olfactory groove and planum with mass effect and edema of surrounding brain parenchyma (d, e) postoperative radiology showing no evidence of tumor with minimal postoperative changes in the brain parenchyma. (f) postoperative cosmetic outcome.

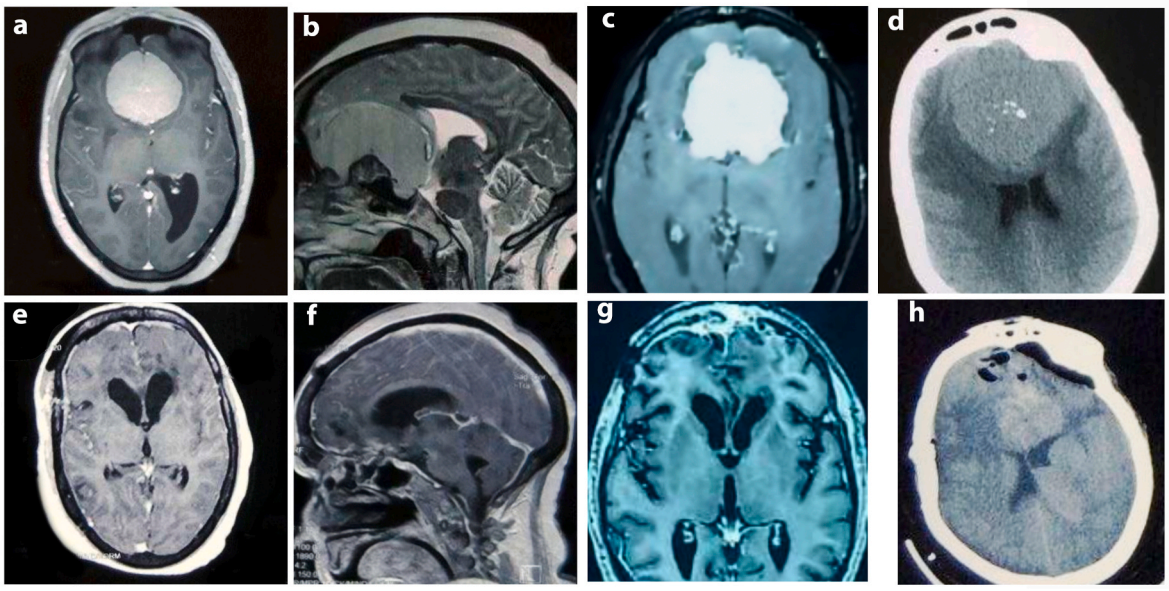

Fig. 5. (a,b and c) preoperative and post operative (e, f and g) MRI images of two patients showing large ACF meningioma with edema of bilateral frontal lobes (e, f and g) post-operative MRI with complete tumor resection. Vision improved post-operatively, and olfaction was preserved. (h) post-operative CT Head showing absence of brain contusions and no increase in brain edema c/f pre-operative CT (d).

approach preserves olfaction and reduces the chances of damage to the contralateral frontal lobe and prevents damage to SSS.[12] The unilateral approaches described so far involve intradural exploration through sub-frontal or trans-sylvian corridors, therefore have the risks of brain handling and retraction and damage to critical structures.[5] Our described technique for large ACF meningiomas replaces the need of extended bifrontal craniotomy while combining the advantages of both and avoiding their shortcomings. Olfaction could be preserved in all 8 patients with intact preoperative olfaction with this technique compared to 24.4–55% olfaction preservation rates in the current literature.[10,13–15]

The overall gross total excision rate in our study (GTR 92.3%) is comparable to those reported in the literature for both unilateral frontal (94.6%) and bifrontal (90.9%) approaches.[16,17] The dura closure is difficult with extradural techniques but we encountered CSF rhinorrhea in 1 out of 13 cases (7.7%) which is consistent with the literature.[17]

We preferred a two-piece fronto-orbital craniotomy to make the orbital cuts with minimal periorbita manipulation under direct vision, which was essential as the anterior skull base was often hyperostotic. The orbital osteotomy helped to minimize the frontal lobe retraction and early control of the anterior ethmoidal artery, besides reducing the length of the surgical corridor and enabling us to reach the tumor extension on the contralateral side. The extension of the craniotomy beyond the midline was just a rescue step in early cases to enable access to the contralateral side, should we need it. But with growing experience with the technique, we could further tailor the horizontal extent of craniotomy to that of a fronto-orbital craniotomy.

In principle, this technique resembles the extended endoscopic transnasal approach which also aims to achieve early access to the vascular supply and ACF dura while minimizing neurovascular manipulations. However, we access the lesion via the lateral extradural skull base corridor instead of the trans-nasal route. This helps avoid the major drawbacks associated with the endoscopic approach, like limited access to tumors extending laterally to the optic nerve, higher risk of vascular compromise, and CSF leak. Moreover, olfaction preservation is rarely possible with the extended endonasal approach used for ACF meningioma though recently, few authors have reported some degree of olfaction preservation with the endoscopic approach.[18,19]

The study has some limitations. The sample size is not large enough and there is no control group to assess the superiority of this approach over others. The bone work seems extensive at first however, it adds little to the overall surgical time, and allows excellent reconstruction and cosmesis. The frontal sinus is usually breached in the procedure, but it can be easily exteriorized, and CSF leak can be avoided. Dissecting and preserving the tumor-arachnoid also has a learning curve to it. The surgeon must be oriented to the tumor extension and relation to neurovascular structures as the microsurgical anatomy using this corridor is seemingly different from that in the more familiar intradural route.

5. Conclusion

The extended unilateral frontal approach emerges as a viable and dependable alternative to the bifrontal approach in the resection of large midline anterior cranial fossa meningiomas with edematous brain. This technique successfully circumvents anterior SSS ligation and minimizes brain manipulation. Importantly, this approach has a high rate of olfaction preservation while achieving comparable tumor resection and maintaining acceptable cosmetic outcomes.

Video legends

0.00–0.1 – pre-operative radiology.
0.1–0.9 – steps of craniotomy and orbital osteotomy.
0.10–0.21 – anterior ethmoidal artery coagulation.
0.22–0.58 – cutting dura over the tumor and internal decompression of the tumor.
0.59–1.12 – defining and cutting falx.
1.13–1.28 – tumor removal on the contralateral side.
1.29–1.34 – tumor dissection and olfactory tract preservation.
1.35–1.38 – post-operative radiology and cosmetic outcome.

CRediT authorship contribution statement

Pravin Salunke: Conceptualization, Investigation, Methodology, Project administration, Resources, Supervision, Validation, Writing – original draft, Writing – review & editing. **Keshav Mishra:** Data curation, Formal analysis, Investigation, Methodology, Resources, Software, Validation, Visualization, Writing – original draft, Writing – review & editing. **Madhivanan Karthigeyan:** Conceptualization, Data curation,

Investigation, Methodology, Project administration, Resources, Supervision, Validation, Visualization, Writing – review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Nil.

Appendix A. Supplementary data

Supplementary data related to this article can be found at https://doi.org/10.1016/j.wnsx.2024.100352.

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