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Supraorbital Keyhole Approach—A Minimally Invasive Versatile Approach to Skull Base Lesions

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Abstract

Background Over the last two decades, there have been development of approaches that are minimally invasive but achieve maximum effective results with minimal morbidity. The supraorbital keyhole approach (SOKHA) through the transciliary incision is minimally invasive approach that permits effective management of skull base lesions with minimal injury to the soft tissue and surrounding brain.

Aims The aim of this study was to evaluate the efficacy and safety of SOKHA for skull base lesions.

Settings and Design This is a prospective study in a tertiary neurosurgical teaching institute in a metropolitan city.

Materials and Methods Twenty-one patients of various pathology were operated using the SOKHA through the "eye-brow incision." The pathologies included pituitary adenoma, craniopharyngioma, epidermoid, tuberculum sella, and planum sphenoidale meningioma. The authors describe in detail the surgical approach employed by them for these various pathologies.

Results All neoplastic lesions in this series could be addressed effectively with near total or total excision. No fresh postoperative deficits were noted except a case who developed ipsilateral anterior cerebral artery infarction that resulted in lower limb weakness. One patient developed postoperative abscess requiring surgical excision. At follow-up, all patients revealed a cosmetic scar hidden by the eye brow.

Conclusion The SOKHA is an effective minimally invasive procedure with proven safety for the management of anterior, selected middle skull base lesions and to provide excellent cosmesis with minimal trauma to the adjacent brain. The authors, however, feel that it is technically demanding and surgeons should employ a stepwise progression from simple to more complex lesions.

Keywords
- transciliary incision
- keyhole surgery
- supraorbital approach
- minimally invasive neurosurgery approach
- frontoorbitotomy

Key Messages

The SOKHA for skull base pathologies is a minimally invasive approach and has equivalent results as the traditional approaches. It can be combined with an orbitotomy to provide better access and less brain retraction. This results in less adjacent brain trauma and good cosmetic results.

Introduction

Operative neurosurgery has made constant development over the last few decades. Initial phase, as developed by the pioneers, was that of establishing the safety of the procedures and make them acceptable to the medical fraternity and the patient population. Following this,

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accuracy of operative neurosurgery became the emphasis especially with the development of imaging techniques, microneurosurgery, navigation, etc. The last few years have witnessed the development of a multitude of minimally invasive neurosurgical approaches to achieve the same effective results. These minimally invasive procedures reduce the morbidity and hospital stay of these patients.[1] The supraorbital keyhole approach (SOKHA) by a transciliary incision is a minimally invasive approach to skull base lesions. The concept of supraorbital keyhole surgery was first developed by Perneczky from Germany.[2–6] The authors state their experience with the efficacy of this approach on various anterior cranial fossa pathologies.

Subjects and Methods

The authors have operated on 21 patients ranging from 7 to 65 years with a sex ratio of 11:10 (M: F) (►**Table 1**). The pathologies included pituitary adenoma, craniopharyngioma, meningioma (tuberculum sella and planum sphenoidale), and epidermoid (►**Fig. 1**). Preoperative appropriate and exact diagnostic imaging was performed in all cases. As this was the initial experience of the senior author, strict selection criteria were applied for inclusion into this operative procedure. Only the smaller lesions without vascular encasement were included in this study. For pituitary adenomas, transsphenoidal (microscopic / endoscopic) tumor decompression is our surgical approach of choice for sellar with or without suprasellar extension. However, for predominantly suprasellar tumors (where the suprasellar component is not expected to descend during surgery or which are not radically excisable) and those with parasellar extension, we prefer a transcranial approach and the SOKHA is a minimally invasive option for this.

Surgical Technique

Positioning

After induction and intubation, the patient is kept in supine position with neck slightly extended (to facilitate frontal lobe retraction). The head may be turned to opposite side, the degree of which depends on site and pathology. For pituitary adenoma and craniopharyngioma, the head is rotated by around 15 degrees to opposite side, while it is kept neutral by the senior author for meningiomas (tuberculum sella and planum

Table 1 Clinical details of the study

Serial no	Age/Sex	Pathology	Postoperative complications	Follow-up
1	7 y/male	Craniopharyngioma	Diabetes insipidus managed medically	60 mo, no symptoms, no recurrence
2	65 y/female	Right ICA aneurysm trapping		30 mo, no symptoms
3	40 y/female	Pituitary adenoma		12 mo, no symptoms, no recurrence
4	55 y/female	Tuberculum sella meningioma		33 mo, no symptoms, no recurrence
5	26 y/male	Pituitary adenoma		20 mo, no symptoms, no recurrence
6	46 y/male	Left basifrontal meningioma		56 mo, no symptoms, no recurrence
7	24y/male	Left frontal epidermoid		60 mo, no symptoms, no recurrence
8	6 y/male	Craniopharyngioma	Diabetes insipidus managed medically	28 mo, no symptoms, no recurrence
9	36 y/male	Left frontal glioma—Grade II		No symptoms at 3 mo, lost for follow-up afterward
10	48 y/female	Suprasellar epidermoid		27 mo, no symptoms, no recurrence
11	38 y/female	Tuberculum sella meningioma		16 mo, no symptoms, no recurrence
12	28 y/male	Recurrent pituitary microadenoma		10 mo, no symptoms, no recurrence
13	26 y/male	Left caroticocavernous fistula—trapping		24 mo, no symptoms
14	38 y/male	Planum sphenoidale meningioma		27 mo, no symptoms, no recurrence
15	60 y/male	Planum sphenoidale meningioma	Delayed cerebral abscess—excised uneventfully	13 mo, no symptoms, no recurrence
16	47 y/female	Pituitary macroadenoma		20 mo, no symptoms, no recurrence
17	42 y/female	Tuberculum sella meningioma		10 mo, no symptoms, no recurrence
18	64 y/female	Tuberculum sella meningioma		14 mo, no symptoms, no recurrence
19	27 y/female	Tuberculum sella meningioma		21 mo, no symptoms, no recurrence
20	38 y/female	Pituitary macroadenoma	Ipsilateral distal ACA territory infarct	9 mo, no fresh symptoms, no recurrence
21	60 y/male	Clinoidal meningioma		12 mo, no symptoms, no recurrence

Abbreviations: ACA, Anterior Cerebral Artery; ICA, internal carotid artery.

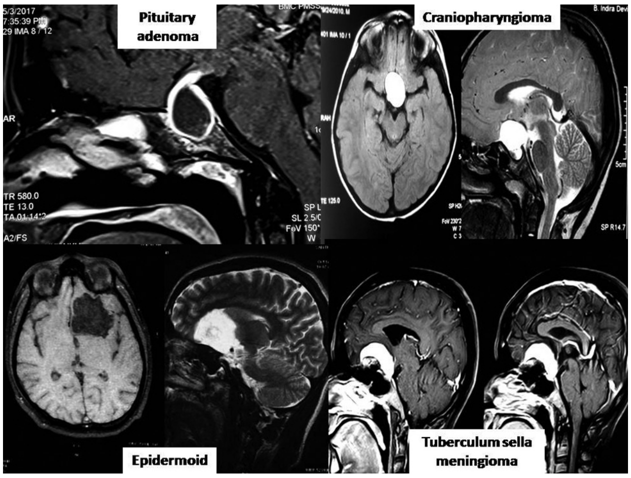

Fig. 1 The imaging of some of the pathologies operated by the supraorbital keyhole approach—pituitary adenoma, craniopharyngioma, epidermoid, and tuberculum sella meningioma.

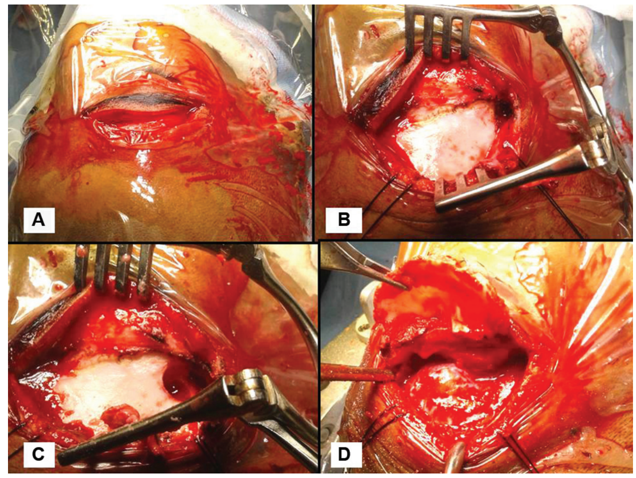

Fig. 2 The exposure in supraorbital keyhole approach: (**A**) Supraciliary skin incision, (**B**) exposure of the frontal bone and orbital rim, (**C**) burr hole made, and (**D**) supraorbital craniotomy bone flap raised.

sphenoidale). The head is slightly elevated to help venous drainage. The author uses spinal drain to drain cerebrospinal fluid (CSF) postdural opening.

Incision and Exposure

After protecting eyes and preparation, a transciliary incision is made starting from the supraorbital incisura extending laterally to the frontozygomatic area following the orbital rim. Initially a supraciliary incision (►**Fig. 2A**) was employed but for most of the cases the senior author now employs a transciliary incision. The supraorbital nerve is preserved to prevent any numbness. The pericranium along with the subcutaneous tissue is dissected away superiorly using monopolar cautery or periosteal elevator (►**Fig. 2B**). Temporalis muscle is separated, retracted to make way for the burr hole at the lateral end of incision. The authors prefer to separate the periorbita from the orbital roof using a Howarth's dissector. This is done to facilitate the orbital roof cuts in frontal craniotomy (frontoorbitotomy).

Craniotomy and Dural Opening

A burr hole is made just behind the temporal line (under the elevated temporalis muscle; ►**Fig. 2C**). The direction of the drill is important and should be superomedial to avoid trauma to orbit/periorbita. A small frontal craniotomy is performed. The size of the bone flap is approximately 3×2.5cm. The orbital roof cuts are made using a small osteotome and mallet. The periorbita is protected with the broad end of the brain spatula during this procedure. The authors now raise a free frontoorbital bone flap including 2 cm of orbital roof (►**Fig. 2D**). Durotomy is done in C fashion with base anteriorly and kept away with stay sutures (►**Fig. 5A**).

Intradural Procedure and Closure

After the durotomy, CSF is drained from the lumbar spinal drain already in situ. This helps in frontal lobe retraction. Using Leyla retractor, the frontal base is retracted until the opticocarotid cistern is reached. This is opened and the CSF drained that helps in relaxing the frontal lobe. The pathology is now visualized and appropriately tackled (►**Fig. 3A–D**). Pituitary adenomas and craniopharyngiomas are subtotally excised using the ultrasonic surgical aspirator leaving behind the capsule that may be adherent to vital structures like the stalk or the hypothalamus. Meningiomas are internally decompressed followed by total excision of the capsule and cauterization of the dural base. Epidermoids are excised totally in a similar fashion (►**Fig. 4A–D**). Specialized long instruments are used for this purpose. After perfect hemostasis and a thorough saline or Ringer lactate wash at body temperature, the dura is closed and bone is replaced and secured by mini plates or silk sutures. Wound is closed with subcutaneous and subcuticular sutures (►**Fig. 5B–D**).

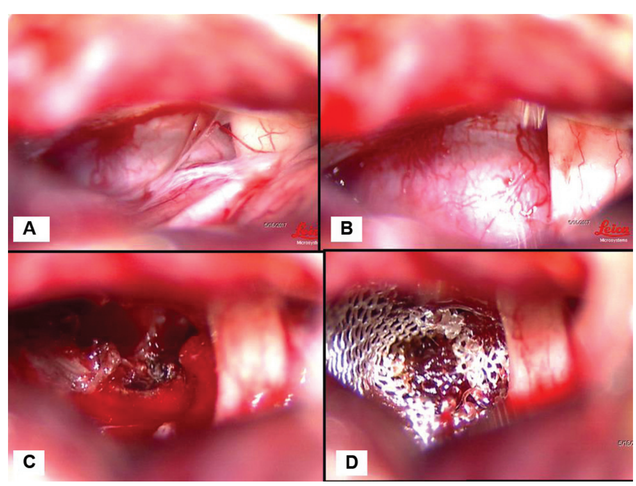

Fig. 3 The excision of a pituitary adenoma: (**A**) Visualization of the tumor with arachnoid covering medial to right optic nerve, (**B**) tumor exposed, (**C**) intratumoral decompression done, and (**D**) hemostasis after excision of the tumor.

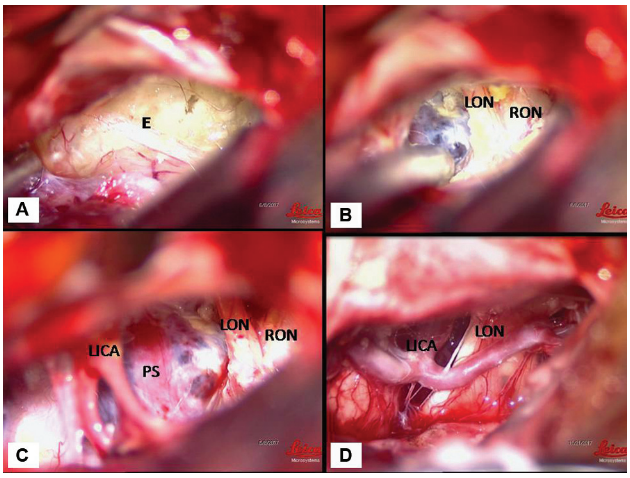

Fig. 4 The intradural steps in excision of an epidermoid. (**A**) Visualization of the epidermoid after frontal lobe retraction, (**B**) intratumoral decompression, (**C**) visualization of the neurovascular after removal of the tumor capsule, and (**D**) another case after removal of the epidermoid capsule. E, epidermoid; LON, left optic nerve; LICA, left internal carotid artery;; PS, pituitary stalk; RON, right optic nerve.

Results

All the pathologies could be tackled effectively through this minimally invasive approach (subtotal and total excision wherever applicable) without any expansion of the craniotomy to a more conventional pterional craniotomy. Gross total excision in all meningiomas and complete decompression/evacuation in the glioma and epidermoid was done. In the pituitary tumors and craniopharyngiomas near total decompression was done. No mortality was encountered in this series. One patient had a distal anterior cerebral artery injury during surgery due to encasement of the vessel by the pituitary adenoma. This could be controlled but the patient developed a distal anterior cerebral artery infarction from which she gradually recovered to normalcy clinically. One patient developed a frontal abscess that was excised subsequently. Two patients of craniopharyngioma developed transient central diabetes insipidus that was managed effectively. All patients had a cosmetic scar (transciliary scars were not visible). No recurrences were noted in our follow-up of 24 months (mean) in any of the tumor patients. Aneurysm patient and Carotico-Cavernous Fistula (CCF) patients did not have any fresh symptoms and were asymptomatic at follow-up.

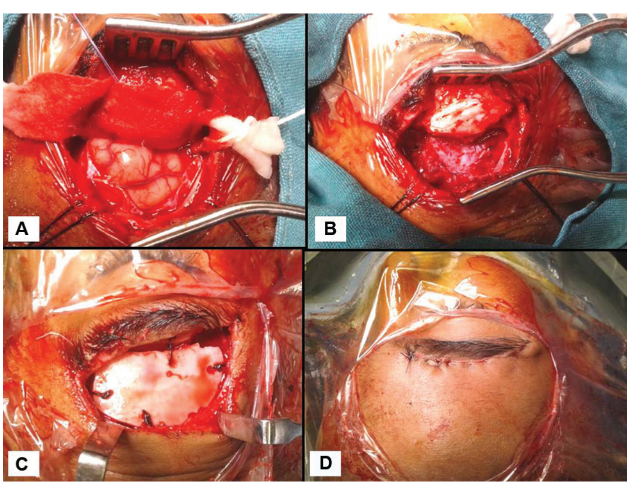

Fig. 5 Supraorbital keyhole approach closure steps. (**A**) After opening of the dura and flap reflected anteriorly, (**B**) dural closure, (**C**) bone flap replacement with silk sutures, and (**D**) skin closure.

Discussion

The aim of present-day operative neurosurgery is to achieve maximum efficacy with minimum of iatrogenic traumatization.[7] The superficial or surface brain lesions require larger craniotomies sometimes as large as the lesion. However, the deeper lesions are more accessible with small exposures. This is the reason for the success of a small supraorbital approach.[7] The eyebrow incision and SOKHA are a modification of the regular subfrontal craniotomy with a minimalization of craniotomy and the incision.[1,2] ►**Table 2** enumerates the structures that may be visualized using this approach.

It is important at the outset of the practice of this approach, that the operating neurosurgeon should select the cases ideally suited for this approach—smaller pathologies occurring within anterior skull base and not encasing neurovascular structures. ►**Table 4** enumerates the selection criteria for different pathologies in the current study. As more experience is gathered, more complex lesions can be successfully excised using this minimally invasive approach. Among the aneurysms, it is advisable to attempt to clip only the smaller unruptured anterior circulation aneurysms initially before progressing to complex aneurysms. The authors along with many other surgeons have recommended against this approach for ruptured and complex aneurysms as their rupture during surgery will be quite distressing and hard to control in available restricted field.[8] Chandra et al as well as Bhatoe in addition to many others have employed the SOKHA for clipping anterior circulation aneurysms for both unruptured and ruptured ones with success.[1,3,9,10] They advocate the early wide opening of the carotid and proximal (medial) sylvian cisterns and proximal arterial control.[3,9,11] "Temporary clipping practice" is advised prior to aneurysmal dissection so that temporary clip placement is smooth in the event of intraoperative aneurysmal rupture.[9] Laterally placed middle cerebral artery (MCA) aneurysms (close to the sphenoid ridge) are considered unsuitable for this approach.[3] Lupret et al advocate this approach for the Anterior Communicating Artery (ACoA) aneurysms followed by internal carotid artery and Posterior Communicating Artery (PoCoA) aneurysms.[2] They advise against the use of this approach for MCA and posterior circulation aneurysms and where there is brain edema.[2] A surgeon should place the patient's safety as the utmost priority to perform this procedure. Benefit of doubt should always be given to the conventional pterional approach in case of any uncertainty of approach as the size of the craniotomy plays no part in the outcome of aneurysm surgery.[2] ►**Table 5** enumerates the relative contraindications for SOKHA.

Table 2 Locations that can be accessed with supraorbital craniotomy

Ipsilateral	Midline
■ Orbital roof, cranial nerves I, II, III, IV ■ Anterior and posterior clinoid process ■ Roof and lateral wall of cavernous sinus ■ Basal frontal lobe, gyrus rectus, sylvian fissure. ■ Anteromedial temporal lobe, uncus hippocampi ■ Internal carotid artery, ophthalmic artery, posterior communicating artery, anterior choroidal artery ■ A1, A2 divisions of anterior cerebral artery, M1, M2 divisions including perforator of middle cerebral artery ■ P1, P2 divisions of posterior cerebral artery, superior cerebellar artery including perforator ■ Superficial temporal vein	■ Crista galli ■ Olfactory groove, planum sphenoidale ■ Tuberculum sellae ■ Lamina terminalis ■ Anterior third ventricle ■ Pituitary stalk ■ Interpeduncular fossa ■ Anterior communicating artery, distal basilar artery

Small transciliary incision with minimal temporalis muscle exposure, minimalized craniotomy, and meticulous closure have contributed to excellent cosmesis of this approach.[8] The authors have given up the supraciliary incision for the more cosmetic transciliary incision. There are different variations in this craniotomy as elaborated in ►**Table 3**. The senior author includes part of the orbital roof in the osteotomy (frontoorbitotomy), that is, the basal variation in Jho et al.[12] This helps in greater dural exposure and lesser and easier brain retraction apart from increased working volume and reduced working depth.[12] However, significant postoperative periorbital edema is noted.[12] Brain retraction is also facilitated by the placement of a lumbar drain after induction and aspiration of CSF after dural opening.

The intradural dissection of the lesion and its excision follows the same microneurosurgical techniques and principles as in the other conventional approaches. Generally, intratumoral decompression is followed by excision of the tumor capsule after carefully dissecting it away from the critical neurovascular structures. After excision of the lesion perfect hemostasis is secured in the usual manner. The dura is closed watertight, bone flap replaced and secured with mini plates in the medial, superior aspects of the craniotomy or by silk sutures. The former is more cosmetically acceptable but may become visible under the skin as a protrusion in thin individuals.[1]

The SOKHA is a cosmetically elegant approach and avoids unnecessary excessive brain and skin exposure and temporal muscle atrophy sometimes associated with the conventional pterional approach.[13] In the selected cases, the lesions could be excised successfully without any major complications. This approach also contributes to shorter postoperative hospital stay in view of lesser incidence of complications such as CSF leak, epilepsy, and infection.[7,13] This approach, however, is not without its disadvantages. The major disadvantages are reduced operative field with a narrow operative corridor (reduced working angle) that can compromise visualization and manipulation of the surgical instruments and problems with large frontal sinuses.[2,3,14–21] To overcome this, special keyhole-adapted microinstruments have been advocated and also used by the authors in this series. It is not feasible

Table 3 Variations in the supraorbital keyhole craniotomy

Sl. no.	Variation type	Areas accessed	Limitations
1.	Lateral	• The essence of this variation is to partially remove the lesser sphenoid wing exposing the frontal and temporal dura mater • Also, on removing clinoid process, paraclinoid segment of internal carotid artery can be visualized	The opposite neurovascular structures may not be adequately visualized
2.	Medial	• This variation is to facilitate the surgical view of suprasellar and interhemispheric structures • Enhances the possibility of interhemispheric and sub frontal dissection	The lateral most structures not well visualized
3.	Basal	• The essence of this variation is to gain more oblique view of the deep seated prepontine and interpeduncular region via sub frontal exposure afterremoving orbital rim and partial removal of orbital roof	Chances of CSF leak increases and closure needs to be meticulous

Abbreviation: CSF, cerebrospinal fluid.

Table 4 Indications for SOKHA

Sl. no.	Pathology	Indications for SOKHA
1	Craniopharyngioma	Predominantly suprasellar
2	Pituitary adenoma	Predominantly suprasellar
3	Tuberculum sella	Small to medium size
4	Frontal glioma	Easily accessible
5	Epidermoid	Moderate size, accessible
6	CCF trapping	Easily accessible, and is minimally invasive
7	Planum sphenoidale meningioma	Easily accessible, and is minimally invasive
8	Clinoidal meningioma	Easily accessible, no encasement of major vessels and is minimally invasive

Abbreviation: SOKHA, supraorbital keyhole approach.

Table 5 Relative contraindications for SOKHA

Sl. no.	Relative contraindications
1	Very large tumors
2	High vascularity
3	Encasement of major vessels
4	Ruptured aneurysms
5	Giant/complex aneurysms

Abbreviation: SOKHA, supraorbital keyhole approach.
The above are some of the relative contraindications for SOKHA. However, with experience surgeons may venture into the above pathologies in a graded manner.

to have a third hand to assist the operating surgeon in this restricted field. Hence, inability of introduction of a second suction in the event of aneurysmal rupture will be troublesome and hard to control. Endoscopes have helped for better visualization of these lesions especially the "blind corners" of the lesion (structures hidden behind the lesion) and can be used to assist the surgeon in this approach.[8,9] Although this approach minimizes injury to the scalp and bone, it may not cause less brain injury that is dependent on the surgeon's microneurosurgical techniques. The learning curve is quite steep and technically demanding. Hence, a gradual stepwise progression from the pterional to the minipterional to SOKHA is recommended.[13] Easier pathologies like epidermoid should be attempted first and a gradual progression to more complex lesions is advised. SOKHA is considered as the surgical approach of choice in anterior cranial base meningiomas (tuberculum sella and planum sphenoidale), epidermoids, chiasmal gliomas, and for simple anterior circulation aneurysms.[13] Its complimentary approach, the extended endoscopic approach, is considered the procedure of choice for pituitary adenomas, craniopharyngiomas, and clival chordomas.[13]

Conclusion

The SOKHA through a transciliary incision is an effective and cosmetically superior approach for several lesions situated in the anterior skull base. It is an elegant option instead of the more traditional subfrontal or pterional approaches. As in other minimally invasive procedures, a learning curve is prevalent and the authors advocate the excision of smaller and simpler lesions first before advancing to larger and more complex lesions.

Conflict of Interest
None declared.

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