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Original Article

Minimal invasive trans-eyelid approach to anterior and middle skull base meningioma: a preliminary study of Shanghai Huashan hospital

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Abstract: Transpalpebral or trans-eyelid approach is a modified trans-orbital access to lesions of anterior cranial fossa and sellar region. But whether this approach is also suitable for tumors extending laterally to the temporal lobe or middle cranial fossa is not clarified. We would like to share our experiences from the cadaveric anatomy study to clinical operations. We used 5 cadavers to study trans-eyelid approaches in a step-by-step fashion. And then assisted by an experienced ophthalmologist for incisions, we treated 3 female patients via this approach: One with spheno-orbital meningioma, one with sellar tuberculum meningioma, and the other with medial sphenoidal wing meningioma. After studying the cadavers, we made several revisions to the previously reported approach: 1) move the incision close to the edge of the eyelid, which resembled the double-eyelid incision. 2) A vascularized periosteum flap was dissected for repairing the opened frontal sinus and reconstruction of the skull base. 3) The dura was sutured up with a slice of temporalis muscle. Then we treated 3 patients by this approach. All tumors were totally resected as Simpson Grade I. Complications included orbital apex syndrome and transient oculomotor paralysis because of tumor invasion into orbit and cavernous sinus. No cerebrospinal fluid leakage. We find that trans-eyelid approach is suitable for lesions not only at anterior cranial base or sellar region, but also extending to middle cranial base, especially around sphenoidal wings within 2 cm range or spheno-orbital region. Thus, we propose whether it appropriate to nominate this approach as 'trans-eyelid pterional approach', since it may treat some anterior and middle cranial fossa lesions with a mini-craniotomy around pterion.

Keywords: Transeyelid, skull base, meningioma, minimal invasive neurosurgery

Introduction

Transpalpebral or trans-eyelid approach is a recently developed, modified tans-orbital access to lesions of anterior cranial fossa and sellar region with mini-craniotomy of the orbit roof [1-3]. This incision was commonly used to treat lesions in the orbit by the ocular plastic surgeons [4-7]. However, two major series of clinical cases have been reported to treat intracranial lesions: one is 8 cases by Dr. Andaluz [8], among which are 5 aneurysms, 2 pituitary adenoma and 1 craniopharyngioma, and the other is 40 cases by Dr. Abdel Aziz [9], among which are 31 aneurysms, 7 meningiomas, 1 glioma and 1 cavenoma. In those cases, lesions were mainly situated at anterior cranial base or sellar region, which leads us to wondering about whether this approach is also suitable for tumors extending laterally to the temporal lobe or middle cranial fossa. In addition, there was no sufficient data on whether this approach was suitable for Asian people [10, 11]. After carefully studying several cadavers and the anatomy of orbit [12], we practiced the trans-eyelid approach for the first time in January 2013. Since then, we have operated on three meningioma cases, two of whom recovered well, but one had some complication due to the tumor invasion. Meningioma is a common tumor of skull base and if completely resected, the prognosis is usually very good [13-15]. We would like to share our experiences from the cadaveric anatomy study to clinical operations.

Table 1. Clinical data of three meningioma patients

Case#	Age	Sex	Side	Diagnosis	Volume (cm^3)	Resection extent	Complications
1	53	F	L	Spheno-orbital meningioma	3.5*3.0*4.5	Simpson 1	Orbital apex syndrome
2	52	F	/	Tuberculum sellae meningioma	2.5*1.5*2.5	Simpson 1	None
3	49	F	L	Medial sphenoidal ridge meningioma	2.5*2.5*2.5	Simpson 1	Transient oculomotor paralysis

Abbreviations: F, Female; L, Left.

Materials and methods

Cadavers

Five cadavers were used to practice the transpalpebral approach by 2 neurosurgeons and 1 ophthalmologist, who later operated on the patients. We followed the surgical procedures described previously step by step [8, 9].

Patients

Three female patients (**Table 1**) of skull base meningioma were operated on via the trans-eyelid approach, one with spheno-orbital meningioma, one with medial sphenoidal ridge meningioma, and the other with sellar tuberculum meningioma. All procedures were approved by the ethics committee and Department of Neurosurgery at Huashan Hospital, and written informed consent forms were signed by all patients. The patients had CT, MRI, MRA and Virtual Reality to demonstrate the possibility of enough tumor exposure with the mini-craniotomy.

Surgical procedures

After general anaesthesia, we placed a continuous lumbar drain and then the patient was placed supine, secured by a Mayfield headset, with the head slightly extended and rotated 30° towards the contralateral side of the approach, bringing the malar eminence to the highest point. Betadine diluted with normal saline at 1:1 ratio solution was used to prepare the surgical area. 1:100,000 epinephrine diluted in saline was injected alone the incision for hemostatic effect and proper surgical plane.

The incision was marked before anaesthesia so that we could identify the upper eyelid crease and the crow's foot. The lateral end of the incision was within the 'safety zone', 2.5 cm lateral to the lateral canthus, and the medial end was 5-8 mm medial to the medial canthus. The exact incision was marked again after draping and made sharply by No.15 blade, with 2 ophthalmologists and 1 neurosurgeon working cooperatively. The plane between the orbicularis oculi and the orbital septum was bluntly developed superiorly and laterally, which extended continuously to the plane between periosteum and galea aponeurotica. An accessory incision could be made alone the hairline to free the vascularized periosteum flap about 2.5 cm×4.5 cm for repairing the anterior skull base in case of the frontal sinus opened, where the subperiosteal drain might be led out. The medial landmark of this periosteum flap was the supraorbital notch, in order not to injure the supraorbital neurovascular bundle, while the lateral landmark was the superior temporal line. The temporalis muscle was elevated from the superior temporal line and the frontozygomatic process to expose the temporal bone about 1.5 cm lateral to the spheno-orbital keyhole. Subperiosteal dissection was achieved superiorly and laterally of the orbit roof.

A MacCarty burr hole, or the pterion keyhole, was made by a high-speed nitrogen drill, which exposed the periorbita, the frontal lobe and the temporal lobe dura. Then the 1-piece front-orbital mini-bone flap was elevated by a 5-cut style described by Dr. Aziz and many other authors. The sphenoid wing, part of lateral wall of orbit and the orbit roof were drilled to increase exposure according to different tumors. If the bony frontal sinus opened, we inserted some gel foam soaked with gentamicin saline solution and sealed with bone wax. 3 fishhooks were used to retract skin flap and temporalis, and one 3/4 malleable was used to protect periorbita and the vascularized periosteum flap.

The dura was opened and reflected towards orbit by 2-3 sutures. The lumbar drain was opened to drain CSF and the sylvian fissure was dissected to relax the brain and increase the exposure of the tumor.

After the tumor was removed, the dura was sutured up with a slice of temporalis muscle. A

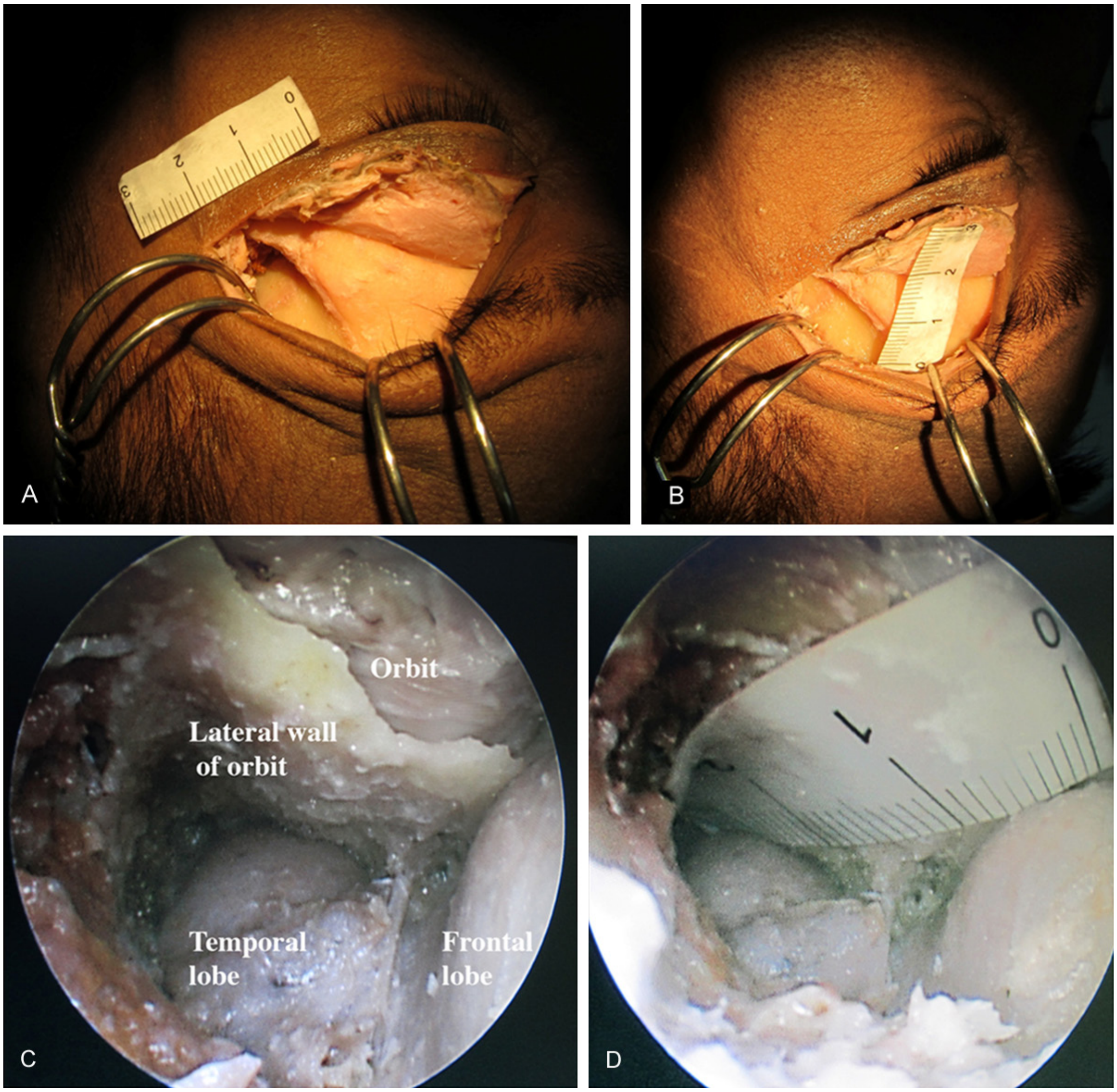

Figure 1. Cadaveric study of trans-eyelid approach. A. The lateral end of incision to the lateral canthus was less than 2.5 cm. B. The maximum of bone exposure is about 2.5 cm above the edge of orbit rim. C. The endoscopic view after bone drilling, showing the anatomy relationship of orbit, lateral wall of orbit, temporal lobe and frontal lobe. D. The maximum exposure of the temporal lobe is about 2 cm lateral to the superior orbital fissure.

piece of absorbable synthetic dural graft could be used to optimize dura water-tightly. The vascularized periosteum flap was reflected over the frontal sinus. The mini-bone flap was restored and secured with 3 titanium plates and several screws on three parts, usually one on frontal bone, one on fronto-zygomatic process and the other above superior temporal line, where the temporalis muscle was sutured back to. The periorbita alone the orbit rim was accurately aligned and sutured with galea aponeurotica. The skin was finally closed with a 6-0 absorbable suture.

Virtual reality for simulation was from Dextroscope system, Volume Interactions, Singapore, and Neuro-endoscope was from MINOP system, Aesculap, German.

Results

Cadavers

All cadavers were dissected without any difficulty and we found both trans-eyelid and trans-orbital approaches had similar operative angle. The main difference was that trans-eyelid

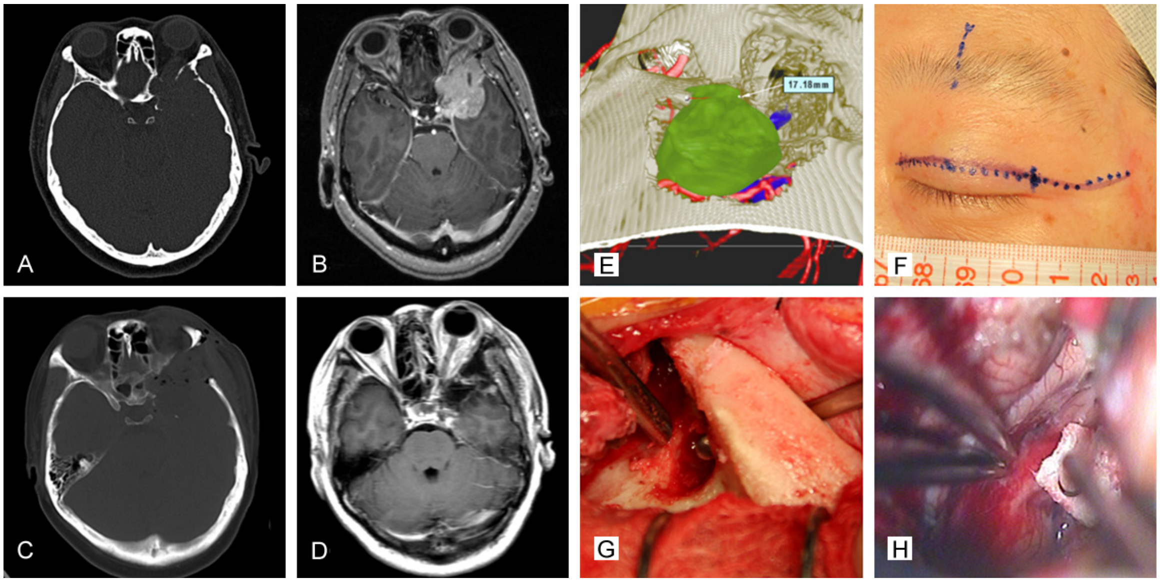

Figure 2. Case 1, a left spheno-orbital meningioma. A. Preoperative CT showed tumor corroded the lateral wall of the orbit. B. MRI before operation showed that the tumor was homogeneously enhanced and invaded into the orbit. C. Post-operative CT showed the tumor was removed and the range of bone window for exposure. D. MRI after the surgery, showed that the tumor was totally removed. E. Virtual reality simulated the bone window, the boundary of the tumor, the exposure of the tumor through the mini-craniotomy, and the relationship of tumor, vessel, and optic nerve. F. Design of incision, marking the supra-orbital notch and nerve-vessel bundle. G. Spheno-orbital burr hole exposing the periorbita, frontal lobe and temporal lobe. H. Resecting the tumor.

approach had a better exposure of the middle cranial fossa since the incision was about 1.5 cm more laterally (**Figure 1**). This was confirmed in the virtual reality simulations and actual operations.

Patients

After carefully studying the anatomy of cadavers, we suggested several revisions to the previously reported procedures by N. Andaluz and K. Abdel Aziz:

1) The incision might be moved a little lower close to the edge of the eyelid, which resembled the double-eyelid incision and a plastic surgery many young Chinese people would love to have.

2) A vascularized periosteum flap was dissected for repairing the opened frontal sinus and reconstruction of the skull base.

3) The dura was sutured up with a slice of temporalis muscle, which we thought was very important to keep the dura water-tightly.

The changes were made in all three cases and detailed information of them were as followed.

Case 1

Left spheno-orbital meningioma, was a female patient, 53 years old, who had intermittent headache with left facial numbness for 2 years and blurring vision of left eye in half a year. PE found her left eye protrusion, and VOD was 1.0 and VOS was finger count at 1 meter. Both direct and indirect light reflection of left eye was decreased. Visual field of left eye remained only nasal superior visual island. Corneal reflection of left eye was decreased, and abduction of left eye was also impaired. During the operation, we found the tumor invaded the superior orbital fissure and cavernous while nerve III, IV, V1 and VI were not identified, but the subdural part of optic nerve could be identified easily. We felt the Simpson Grade I resection was achieved since the tumor, dura and bone were all removed. Finally we used the artificial absorbable dura, DuraGen and fascia lata of her left thigh to repair the defect of dura. The patient could see finger movement within 30 cm at the first two days after operation, but totally lost light perception later even with high-dose methylprednisolone therapy. She suffered orbital apex syndrome permanently. There were no signs of recurrence after one-year follow-up.

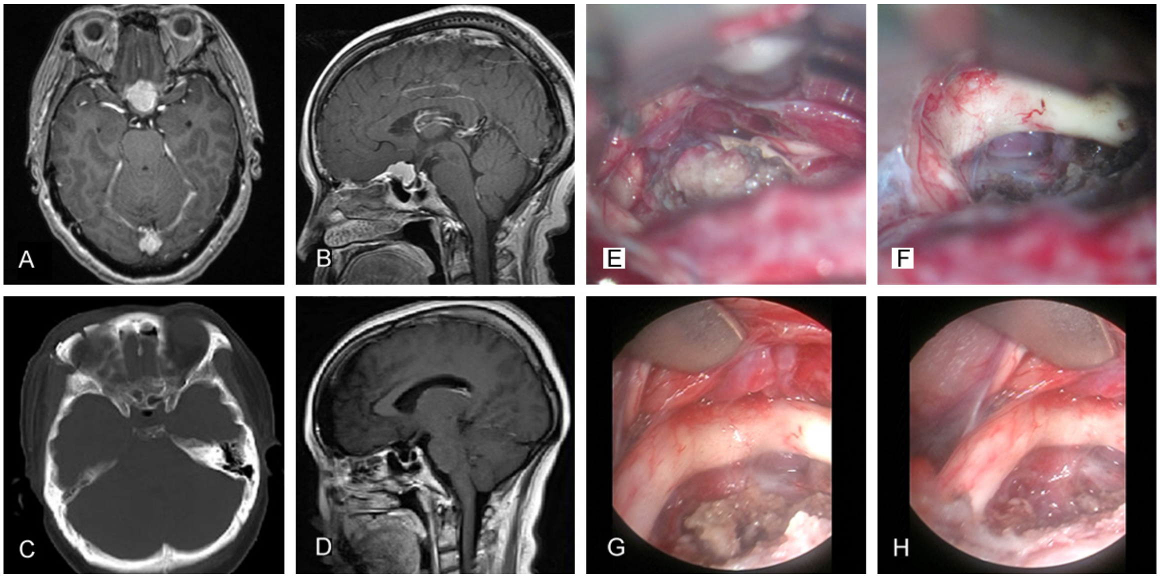

Figure 3. Case 2, a tuberculum sellae meningioma. A, B. MRI axial and sagittal view of tumor before operation. C, D. CT Axial and MRI sagittal view of tumor after operation. E. Resecting the tumor under microscope and the relationship between tumor and vessels. F. After tumor removal under microscope. G. Tumor residual under endoscope. H. After radical tumor removal under endoscope.

No cerebrospinal fluid leakage happened and the wound healed well. Postoperative pictures were as shown in **Figures 2**, **5A** and **5B**.

Case 2

Sellar tuberculum meningioma, was a female patient, 52 yrs, who had bilateral blurred vision and intermittent headache for 2 years. Her VOU was 0.9 and visual field was normal. Serum endocrinological tests were also normal. The surgical route was similar to those described previously by Dr. Andaluz and Dr. Aziz. Tumor was totally resected as Simpson Grade I. There were no signs of recurrence after one-year follow-up. No cerebrospinal fluid leakage happened and the wound healed well. Cosmetic outcome of the eyes was well. Postoperative pictures were as shown in **Figures 3**, **5C** and **5D**.

Case 3

Left medial sphenoidal ridge meningioma, was a female patient, 49 yrs, who complained intermittent headache for 10 months. She had rheumatic heart disease with moderate mitral stenosis and regurgitation. Her VOU was 1.0 and visual field was normal. The surgical route of this patient was similar to case 1. The tumor corroded the sphenoid wing and the anterior clinoid process, and was totally resected as Simpson Grade I. The oculomotor nerve was preserved well, but the patient suffered transiently oculomotor nerve paralysis within 2 months after the operation and then fully recovered by the end of 3 months. There were no signs of recurrence after one-year follow-up. No cerebrospinal fluid leakage happened and the wound healed well. Cosmetic outcome of the eyes was well. Postoperative pictures were as shown in **Figures 4**, **5E** and **5F**.

We used virtual reality to simulate the surgical approach, from designing the mini-bone flap and the surgical route (**Figures 2E** and **4B**), to identifying the relationship between the tumor and major vessels. We also applied neuroendoscopic assisted technique (**Figure 3G** and **3H**), which was helpful to identify the residue of the tumor and the extent of resection more accurately.

Discussion

Previously reported lesions via the transpalpebral or trans-eyelid approach were mainly situated at the midline of anterior cranial base or sellar region [8, 9, 16-19]. We found that this approach was also suitable for lesions extending to middle cranial base or temporal lobe, which situated around sphenoidal wing about 2

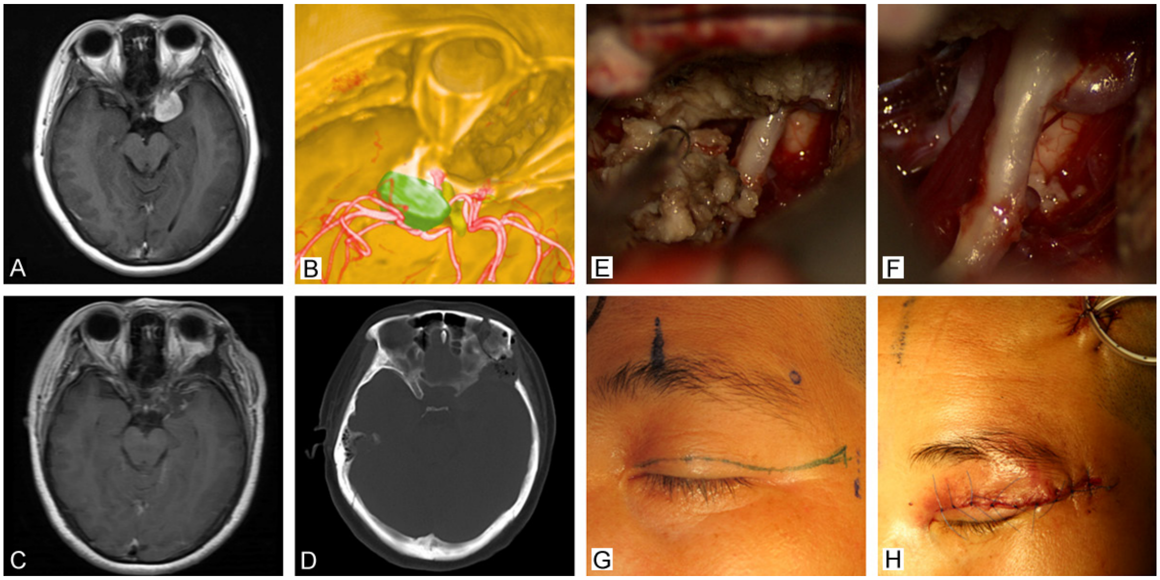

Figure 4. Case 3, a left medial sphenoid ridge meningioma. A. MRI axial view of tumor before operation showed the tumor homogeneously enhanced. B. Virtual reality view of simulating the tumor removal and relationship between the tumor and vessels. E. Resecting the tumor under microscope, and the tumor partly wrapped around the ICA. F. After tumor removal under microscope, all vessels were preserved well. G. Design of incision. H. Closure of skin.

cm, especially for meningioma originating extra-durally and corroding the sphenoid wing or even invading the orbit. After drilling off the hyperplasia or damaged bone and cauterizing the dura, the main blood supply of the meningioma was lessened. More operating space and angle was acquired, which would facilitate removing the tumor. Mariniello used lateral orbitotomy for removal of sphenoid wing meningiomas invading the orbit in 18 cases showed a good result [20].

Pterional or modified pterional approach have been developed over 100 years. Dr. Perneczky developed the supraorbital keyhole approach with eyebrow incision [2, 3] and Dr. Jho [1] described an orbital roof craniotomy to anterior cranial fossa. Dr. Andaluz and Dr. Abdel Aziz first reported trans-eyelid approach to treat intracranial lesions [8, 9]. The transpalpebral or trans-eyelid approach of ocular plastic surgery was well developed based on substantial experience. It's also called the upper eyelid, upper blepharoplasty, upper eyelid crease, and supratarsal fold approach.

As roughly compared with the trans-orbital keyhole approach, advocated by Dr. Perneczky and Dr. Jho, with eyebrow incision on cadavers (data not published), the trans-eyelid approach had a bit more restricted working angle for lesions at anterior cranial fossa and sellar region, due to the incision was close to the eyelid. But more working space of temporal lobe or middle cranial fossa was acquired. Future cadaveric study will use CT or MRI navigation to measure the exposure quantitatively [21, 22] As stated by Andaluz and Aziz, 'selection for this approach should not be based upon the anatomical structures to be exposed, but rather on the vector or working angle anticipated to be required' [8, 9].

Resecting an anterior and middle skull base tumor usually needs more working angle than aneurysm clipping. Relaxation of the brain is also sometimes not easy at the early stage of resecting the tumor. Case 1, a left spheno-orbital meningioma, appeared unresectable through trans-eyelid approach at the first sight of reviewing the MRI slides. But after CT, MRI and MRA data reconstruction by virtual reality, we found that the superficial part of the tumor was just below the temporalis muscle and didn't exceed 2 cm, including the entire lateral wall of the orbit. If the sphenoidal wing and the lateral wall of the orbit were drilled off, and the periorbita was retracted, the tumor could be removed totally. This was proved during the operation. The tumor corroded the sphenoid

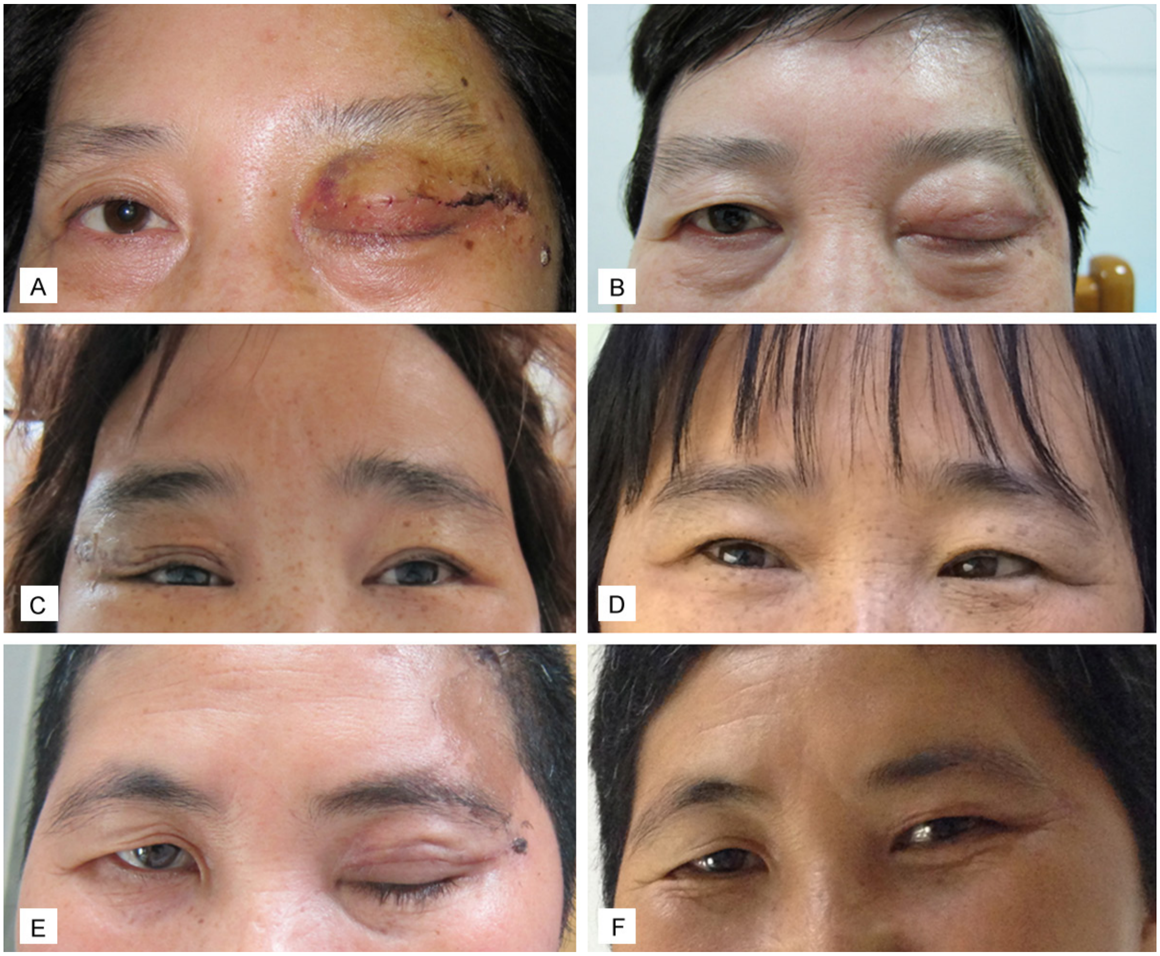

Figure 5. Follow-up pictures showing that the camouflage of the incision by the overlying lid. A, B. Case 1 suffered orbital apex syndrome 2 weeks and 3 months after operation. C, D. Case 2 had an excellent cosmetic recovery after 2 weeks and 3 months. E, F. Case 3 suffered transiently oculomotor nerve paralysis at 1 month, but fully recovered by the end of 3 months.

wing and the lateral wall of the orbit, and the main blood supply was from the bone and dura. After the extra-dural part of the meningioma was removed and the dural base was cauterized, the bleeding of intra-dural part was not too difficult to control. The internal carotid artery and optic nerve were shifted due to the tumor, which was another difficult part of this approach. Virtual reality provided us information of their routing in advance, while neuronavigation and Doppler were used to identify them in real time.

The reconstruction of skull base includes the dura, the orbit roof and the muscle. The dura base of meningioma was removed to achieve Simpson Grade I and a DuraGen was used to cover the dural defect. We acquired a piece of femoral lata fascia to repair the dural defect in Case 1, since there was not much fascia to get from this keyhole approach. If the dura could be sutured up, a slice of temporalis muscle was used to keep the dura water-tightly. Also a vascularized periosteum flap was dissected for repairing the opened frontal sinus and reconstruction of the skull base. The mini-bone flap was restored and fixed by titanium plates and screws. No CSF leakage was found in these three cases.

Complications included orbital apex syndrome and transient oculomotor paralysis because of tumor invasion into orbit and cavernous sinus. Both cosmetic outcome and the radical extent of resecting the skull base tumors always needs balanced. As for this approach, cosmetic outcome seems more important. One limitation of this study is that we didn't have intra-operative EMG monitoring of extra-ocular cranial nerves at Huashan Hospital. In the future, we are going to set up these monitoring routinely.

The eyelid anatomy of Asian people is a little different from other races, such as the content of extra-ocular fat and the attaching point of elevator aponeurosis [23], and that is why the crease of eyelid in Asian people is not so obvious as in Western people. When getting older, the crease of the upper eyelid will be more remarkable. Since many young people are interested to have a plastic surgery of double eyelid, it is feasible to move the incision more close to the edge of the eyelid, which resembles the incision of double eyelid surgery and may also be suitable for young people.

In conclusion, we find that transpalpebral or trans-eyelid approach is suitable for lesions not only at anterior cranial base or sellar region, but also extending to middle cranial base, especially around sphenoidal wings within 2 cm range or spheno-orbital region. Thus, we propose whether it appropriate to nominate this approach as 'trans-eyelid pterional approach', since it may treat some anterior and middle cranial fossa lesions with a mini-craniotomy around pterion. People with older age and remarkable crease of the upper eyelid are more suitable for this approach. Intra-operative EMG monitoring may be a solution to preserve function of extra-ocular cranial nerves. This is a safe and minimally invasive approach, with an acceptable cosmetic results.

Acknowledgements

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Disclosure of conflict of interest

None.

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