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ORIGINAL ARTICLE - NEUROSURGICAL ANATOMY

Endoscopic transorbital transtentorial approach to middle incisural space: preclinical cadaveric study

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Abstract

Background Endoscopic transorbital approach is a novel development of minimally invasive skull base surgery. Recently, anatomical studies have started to discuss the expanded utilization of endoscopic transorbital route for intracranial intradural lesions. The goal of this cadaveric study is to assess the feasibility of endoscopic transorbital transtentorial approach for exposure of middle incisural space.

Methods Anatomical dissections were performed in four human cadaveric heads (8 sides) using 0- and 30-degree endoscopes. A stepwise description of endoscopic transorbital transtentorial approach to middle incisural space and related anatomy was provided.

Results Orbital manipulation following superior eyelid crease incision with lateral canthotomy and cantholysis established space for bone drilling. Extradural stage consisted of extensive drilling of orbital roof of frontal bone, lessor, and greater wings of sphenoid bone. Intradural stage was composed of dissection of sphenoidal compartment of Sylvian fissure, lateral mobilization of mesial temporal lobe, and penetration of tentorium. A cross-shaped incision of tentorium provided direct visualization of crural cistern with anterolateral aspect of cerebral peduncle and upper pons. Interpeduncular cistern, prepontine cistern, and anterior portions of ambient and cerebellopontine cisterns were exposed by 30-degree endoscope.

Conclusion The endoscopic transorbital transtentorial approach can be used as a minimally invasive surgery for exposure of middle incisural space. Extensive drilling of sphenoid wing and lateral mobilization of mesial temporal lobe are the main determinants of successful dissection. Further studies are needed to confirm the clinical feasibility of this novel approach.

Keywords Endoscopic transorbital · Transtentorial · Middle incisural space · Minimally invasive

Introduction

Expanded endoscopic endonasal approaches have provided minimally invasive access for ventral skull base lesions with satisfactory results over the past decade [14]. Refinement of surgical instrumentation, advancement in image acquisition and navigation systems, and thorough knowledge of related endoscopic anatomy are all the paramount components of successful operation. Endoscopic endonasal transmaxillary transpterygoid approach is one variant of expanded endonasal approach to reach pterygopalatine fossa, infratemporal fossa, Meckel cave, and petrous apex [10, 15, 24]. Despite development of transpterygoid approaches as lateral extension of endonasal approach, configuration of nasal cavities, internal carotid arteries, cranial nerves, and bilateral orbits form the anatomical limitations to access lateral portion of skull base.

Recently, the concept of endoscopic transorbital approach has been announced as an alternative minimally invasive surgery for skull base lesion located in the anterior and middle cranial fossae [5, 6, 16, 18, 23]. Interestingly, more and more anatomical studies have expanded the application of endoscopic transorbital approach to intracranial intradural region [1, 3, 4, 8, 9].

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The middle incisural space is a narrow area composed of supratentorial compartment, located between temporal lobe and midbrain, and infratentorial compartment, located between upper pons and cerebellum. Lateral surface of midbrain and upper pons form the medial wall of middle incisural space, and lateral boundaries are hippocampal formation on the mesial temporal lobe and petrous bone. The roof of middle incisural space is composed of optic tract anteriorly and of inferior surface of thalamus posteriorly [20]. Due to its deep location and surrounding vital structure, surgical approach to middle incisural space is a clinical challenge. Several skull base approaches have been used to manage lesions within middle incisural space [7, 11, 13, 17, 21, 25]. Nevertheless, retraction of temporal lobe, damage of bridging veins, and limited surgical field are the major drawbacks of transcranial approaches.

Exposure of mesial temporal lobe using endoscopic transorbital approach has been reported by previous studies [1–4]. The middle incisural space is slightly posterior to the mesial temporal lobe, and tentorium cerebelli obscures entrance into middle incisural space from middle cranial fossa. The aim of this cadaveric study is to assess the feasibility of endoscopic transorbital transtentorial approach to middle incisural space.

Methods

Anatomical dissections were performed in four cadaveric heads (eight sides) at the Skull Base Laboratory of National Defense Medical Center. The internal carotid arteries and jugular veins were injected with red and blue latex. Endoscopic dissections were performed by using rigid 4-mm-diameter, 18-cm-length, and 0-degree and 30-degree endoscopes (Karl Storz, Tuttlingen, Germany). A high-definition camera and a digital video recorder system (Karl Storz) were used for image acquisition. A stepwise anatomical dissection of the endoscopic transorbital transtentorial approach to middle incisural space was provided. The whole procedure was performed using a three-hand technique with two operators participating in. The assistant operator held the endoscope to cooperate with the major operator and kept the endoscope on the top of the working corridor. The major operator performed the dissection procedure with bimanual coordination.

Results

The endoscopic transorbital transtentorial approach to middle incisural space was composed of the following three major components: (1) superior eyelid incision and periorbita dissection; (2) extradural bone drilling; and (3) intradural dissection. The intradural dissection was further divided into the following three steps: (1) opening of Sylvian fissure; (2) lateral mobilization of mesial temporal lobe; and (3) penetration of tentorium.

Superior eyelid incision and periorbita dissection

The skin was incised along the curvature of superior eyelid with lateral canthotomy, 2 cm straight incision starting at the lateral corner of eye and extending laterally (Fig. 1a). Lateral cantholysis, dissecting and cutting the superior and inferior cruxes of the lateral canthus tendon, was done to relieve orbital pressure and increase tolerance of orbital manipulation (Fig. 1b). Deep to the orbicularis oculi muscle, continued dissection posteriorly toward the orbital rim was performed within the preseptal plane. Keeping the integrity of the preseptal plane intact is helpful to avoid damage of surrounding levator aponeurosis.

While reaching the orbital rim, a clear plane was identified between the periorbita and the roof of the orbit. The periorbita was elevated circumferentially along the inner aspect of the orbital wall toward the orbital apex (Fig. 1c). The first landmark on the superolateral quadrant of the orbit was meningolacrimal artery, passing through the Hyrtl's foramen. Further dissection posteriorly and medially exposed the meningo-orbital band over lateral aspect of superior orbital fissure (SOF) and optic nerve within optic canal. Zygomatico-facial and zygomatico-temporal bundles, passing through zygomatico-orbital foramens, were encountered first on the inferolateral quadrant of the orbit. With dissection posteriorly and medially, zygomatic bundle over the anterolateral segment of the inferior orbital fissure (IOF) and infraorbital nerve over the middle segment of the IOF were identified (Fig. 1d). Therefore, orbital roof of the frontal bone, lessor, and greater wings of the sphenoid bone were exposed after periorbita dissection.

Extradural bone drilling

Wide range of craniectomy was recommended to establish surgical space for subsequent intradural dissection. Anterolateral and posterolateral boundaries were temporalis muscle and pterion of the sphenoid bone, respectively. Superior limit was orbital plate of the frontal bone, and inferior limit of craniectomy was horizontal portion of the greater sphenoid wing, above the infratemporal fossa. While closing the orbital apex, SOF and IOF were important surgical landmarks in the posterior wall of the orbit. Medial boundary of craniectomy was the imaginary line connecting the lateral aspect of SOF and middle portion of IOF (Fig. 2a).

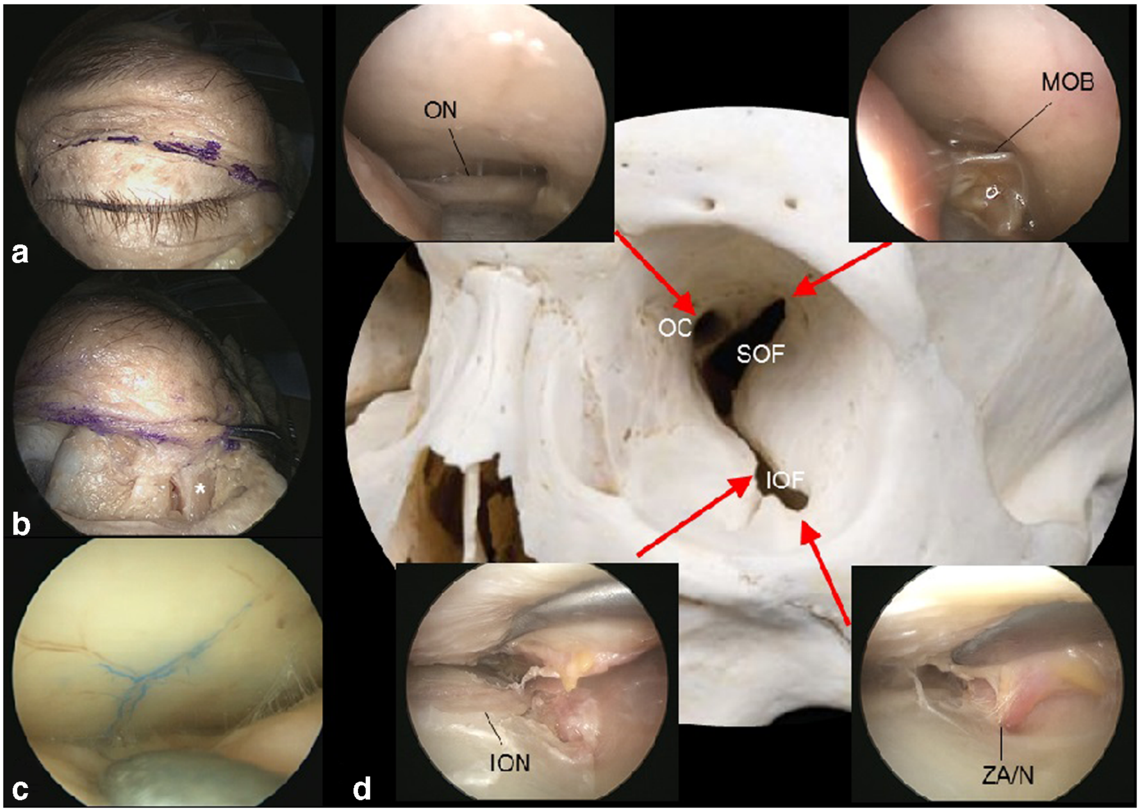

Fig. 1 Endoscopic transorbital approach via the superior eyelid (left side). A skin incision (dotted line) is made along the curvature of superior eyelid with lateral canthotomy (**a**). After performing lateral cantholysis, the orbicularis oculi muscle is dissected laterally to expose the frontal process of the zygomatic bone (asterisk) (**b**). Orbit is retracted inferiorly and medially to expose the dissection plane between the periorbita and orbital wall (**c**). OC, SOF, and IOF are important bony landmarks for transorbital access (**d**). ON passes within OC. MOB is situated at the lateral aspect of SOF. ZA/N and ION mean the position of anterolateral segment and middle segment of IOF, respectively. ON, optic nerve; MOB, meningo-orbital band; ION, infraorbtial nerve; ZA/N, zygomatic artery/nerve; OC, optic canal; SOF, superior orbital fissure; IOF, inferior orbital fissure

Anterior cranial fossa dura and middle cranial fossa dura were exposed laterally after drilling of the orbital roof and the greater sphenoid wing (Fig. 2b). On the superomedial quadrant, the lessor sphenoid wing, including the anterior clinoid process, was totally removed (Fig. 2c,d). Removal of the lessor sphenoid wing and anterior clinoidectomy were performed with careful drilling using a diamond drill. The lateral and medial landmarks of drilling were the meningo-orbital band over the lateral aspect of the superior orbital fissure and the intracanalicular segment of the optic nerve over the optic canal. Drilling of the lessor sphenoid wing and anterior clinoidectomy had three steps as follows: (1) starting from lateral aspect of superior orbital fissure with further progression from lateral to medial; (2) performing optic canal unroofing and freeing the intracanalicular segment of optic nerve with extension from medial to lateral; and (3) removing the remnant of anterior clinoid process, having only bony connection with optic strut, by disc rongeur. The lessor sphenoid wing corresponded to sphenoidal compartment of the Sylvian fissure intradurally, and anterior clinoidectomy allowed intradural exposure of the opticocarotid region. While performing dural opening, two horizontal incisions were made over the dura of the basal frontal lobe and temporal lobe separately. Then, two perpendicular incisions connecting the medial and lateral ends of the horizontal incisions were performed with resultant square-shaped durotomy.

Intradural dissection—opening of Sylvian fissure

The sphenoidal compartment of the Sylvian fissure was exposed after opening the dura (Fig. 3a). The outer arachnoid membrane over the anterior aspect of the Sylvian fissure was incised to get entrance into the sphenoidal compartment of the Sylvian cistern, where M1 segment of the middle cerebral artery (MCA) existed (Fig. 3b). Once the pre-bifurcation portion of M1 segment had been identified, dissection proceeded

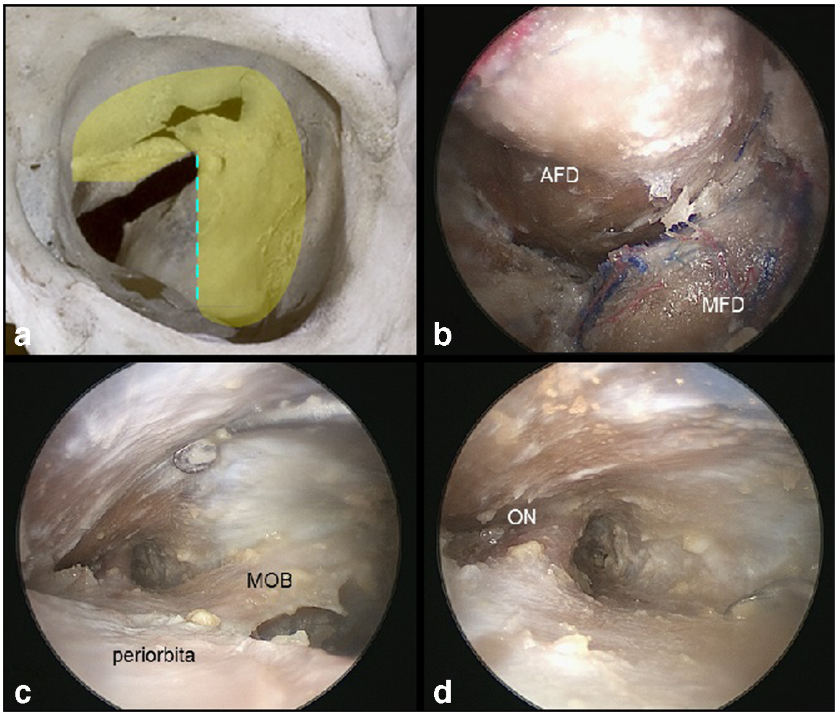

Fig. 2 Extradural stage of endoscopic transorbital transtentorial approach. Planned range of craniectomy is in yellow (**a**). Imaginary connection between lateral aspect of SOF and middle segment of IOF (dotted line) is the medial boundary of greater wing drilling. Drilling of greater wing of sphenoid wing and orbital plate of frontal bone exposes the AFD and MFD (**b**). Extradural drilling of lessor sphenoid wing is important for intradural Sylvian fissure dissection and exposure of opticocarotid region (**c**). Performing anterior clinoidectomy frees the optic nerve and allows more mobilization of orbital contents inferomedially (**d**). The optic strut, located behind and below the intracanalicular segment of optic nerve, is not seen directly. AFD, anterior cranial fossa dura; MFD, middle cranial fossa dura; ON, optic nerve; MOB, meningo-orbital band

laterally toward the limen insulae with identification of post-bifurcation portion of M1 segment and M2 segment (Fig. 3c,d). Following the course of MCA medially, further dissection led to carotid cistern and opticocarotid region with exposure of the optic nerve and carotid bifurcation (Fig. 3e,f).

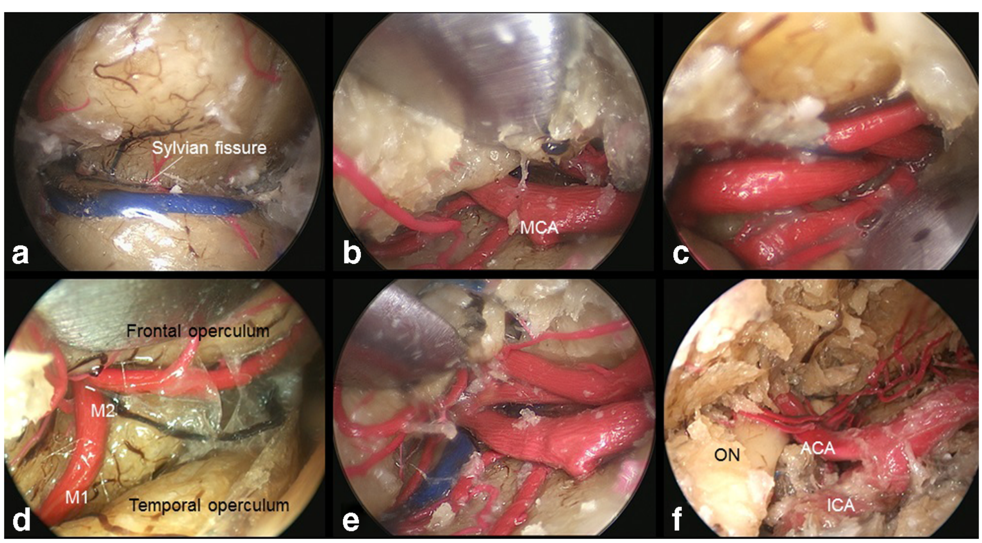

Fig. 3 Stepwise dissection of Sylvian fissure. After opening the dura, posterior orbital gyri, anterior temporal pole, and sphenoidal compartment of Sylvian fissure are under the direct visualization of the endoscope (**a**). Opening the outer arachnoid membrane exposes pre-bifurcation portion of M1 (**b**). Lateral dissection of Sylvian fissure leads to exposure of post-bifurcation portion of M1 (**c**) and site of M1–M2 bifurcation (**d**). Medial dissection of Sylvian fissure along the M1 procures entrance of carotid cistern (**e**). ON, ICA, and carotid bifurcation are identified in the opticocarotid region (**f**). ON, optic nerve; ACA, anterior cerebral artery; ICA, internal carotid artery; MCA, middle cerebral artery; M1, M1 segment of MCA; M2, M2 segment of MCA

Intradural dissection—lateral mobilization of mesial temporal lobe

After wide opening of the sphenoidal compartment of the Sylvian fissure, the next step was to perform lateral mobilization of the mesial temporal lobe away from the tentorium (Fig. 4a). The dissector was used to push uncus laterally and gently along the lateral wall of the cavernous sinus (Fig. 4b). The uncus received blood supply from uncal arteries, small branches of M1 segment, and perforating vessels from posterior cerebral artery (PCA). The perforators were sacrificed to allow lateral mobilization of the uncus until reaching the tentorial edge (Fig. 4c). While performing lateral mobilization of the mesial temporal lobe, the principle of coagulating the feeding vessels close to the mesial temporal lobe and far from the parent vessels must be conformed to avoid damaging adjacent perforators sharing common origin. The sequence of mobilization was recommended as follows: (1) dissecting temporal pole from MCA perforators, allowing slightly inferior mobilization of temporal lobe with wider exposure of upper part of the uncus; (2) dissecting anterosuperior surface from anterior uncal arteries, until the apex of the uncus; (3) dissecting the inferior surface from the perforating arteries; and (4) dissecting the medial surface from the posterior uncal arteries. With lateral mobilization of the mesial temporal lobe, the cerebral peduncle was seen behind the tentorial incisura (Fig. 4d).

Intradural dissection—penetration of tentorium

The tentorium cerebelli was penetrated with cross-shaped incision to get entrance into the middle incisural space. In the midsagittal plane of the cerebral peduncle, the vertical incision started from the tentorial edge superiorly to the superior petrosal sinus inferiorly. The horizontal incision, being parallel to the tentorium incisura, extended to the medial and lateral border of the cerebral peduncle bilaterally (Fig. 5a). While incising the tentorium cerebelli, careful attention should be paid to the surrounding vital structures. The medial boundary of incision was lateral margin of oculomotor trigone, where oculomotor nerve entered the roof of the cavernous sinus. Otherwise, further lateral extension of incision had risk of damage to trochlear nerve and superior cerebellar artery (SCA).

After completing penetration of tentorium, the anterolateral aspect of cerebral peduncle and upper pons was well seen (Fig. 5b). Thalamus perforating arteries and the anterior choroidal artery situated above the oculomotor nerve coursed from anteriorly to posteriorly. The PCA and SCA encircling the cerebral peduncle traveled from medially to laterally. The oculomotor nerve existing from the interpeduncular fossa and the trochlear coursing between the lateral pontomesencephalic segment of SCA and inferior surface of tentorium cerebelli were identified (Fig. 5c,d). An inferiorly pointed 30-degree endoscope demonstrated the superior portion of the cerebellopontine cistern and trigeminal nerve arising on the

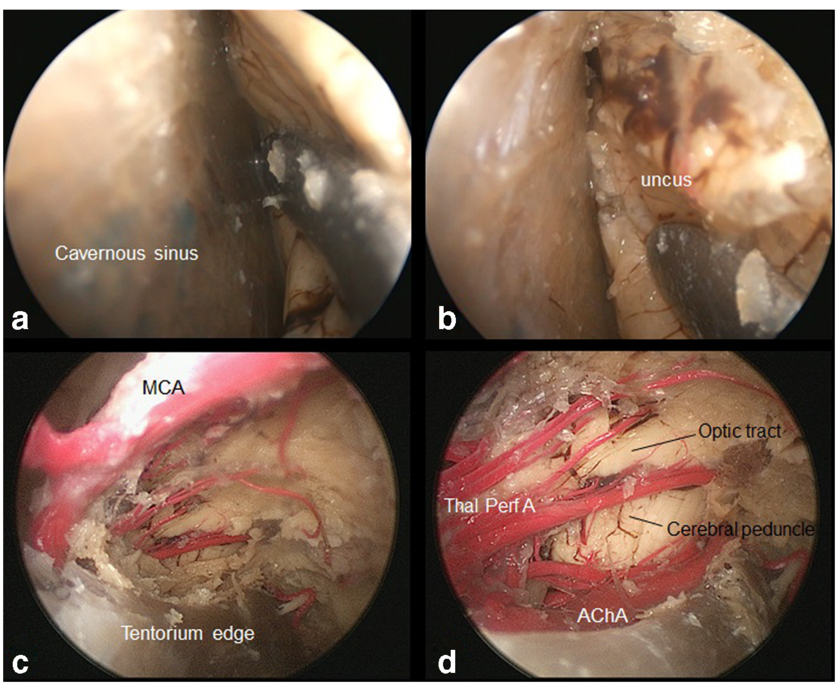

Fig. 4 Lateral mobilization of mesial temporal lobe. The mesial temporal lobe is inferior to the M1 segment of MCA and lateral to the lateral wall of cavernous sinus (**a**). Starting anteriorly to posteriorly, the inferior portion of the mesial temporal lobe is freed from the dura until reaching the tentorial edge (**b**). The superior portion of mesial temporal lobe is freed from perforating arteries of PCA with slight traction laterally (**c**). Lateral mobilization of mesial temporal lobe exposes upper part of cerebral peduncle, and the lower part of cerebral peduncle is behind the tentorium. AChA, anterior choroidal artery; Thal Perf A, thalamus perforating arteries

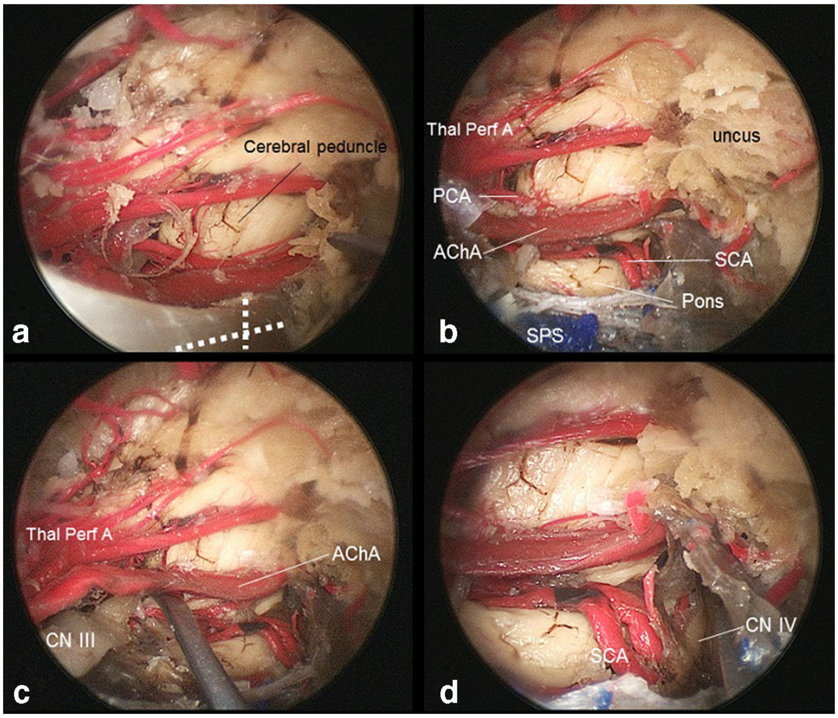

Fig. 5 Penetration of tentorium for exposure of middle incisural space. Prior to tentorium incision, only the superior part of the cerebral peduncle is identified. The tentorium edge is cut with cross-shaped incision (dotted line) to expose the middle incisural space behind the tentorium (**a**). The inferior limit of vertical incision is SPS, and the boundaries of horizontal incision should not exceed the medial and lateral borders of cerebral peduncle. The tentorium is incised to expose inferior part of cerebral peduncle and upper pons (**b**). PCA and SCA course along the pontomesencephalic sulcus, lying at the horizontal level of tentorium edge. CN III starts from the interpeduncular fossa and travels anteriorly to enter the oculomotor trigone. Thal Perf A and AChA, from the anterior to the posterior, course above the CN III (**c**). Trochlear nerve, within infratentorial compartment of middle incisural space, passes forward above the SCA (**d**). AChA, anterior choroidal artery; Thal Perf A, thalamus perforating arteries; PCA, posterior cerebral artery; SCA, superior cerebellar artery; SPS, superior petrosal sinus; CN III, oculomotor nerve; CN IV, trochlear nerve

anterolateral aspect of the mid pons and entering the Meckel cave (Fig. 6a). Medially pointed 30-degree endoscope allowed exposure of the interpeduncular cistern and prepontine cistern (Fig. 6b). Moving the angled endoscope along the lateral surface of the cerebral peduncle led to anterior portion of the ambient cistern (Fig. 6c). Thus, endoscopic transorbital transtentorial approach could gain access to the perimesencephalic cisterns, including the crural cistern, interpeduncular cistern, prepontine cistern, superior portion of the cerebellopontine cistern, and anterior portion of the ambient cistern (Fig. 6a–d).

Discussion

Middle incisural space is a narrow area located between the lateral surface of the upper brain stem and the incisural edge. It consists of the supratentorial component, between the midbrain and the mesial temporal lobe, and the infratentorial component, between the upper pons and the cerebellum. Tentorial incisura is the only communication between these two compartments. Because of its confined area and complex anatomy, the middle incisural space is challenging to surgically access by clinical neurosurgeons. Over the past years, several transcranial skull base approaches have been used to manage different lesions within this narrow space [7, 11–13, 17, 21]. Ulm et al. analyzed and compared six different microsurgical approaches to perimesencephalic cisterns, encompassing pretemporal transsylvian, subtemporal, occipital transtentorial, infratentorial supracerebellar, transtemporal transchoroidal, and transinsular transchoroidal approaches [25]. According to the result of Ulm's analysis, pretemporal transsylvian and subtemporal approaches are better for exposure of interpeduncular and crural cisterns. Occipital interhemispheric and supracerebellar transtentorial approaches are suitable for access to ambient and quadrigeminal cisterns. However, retraction of the temporal lobe, injury of bridging veins, especially the vein of Labbé, and restricted surgical view are the major limitations of transcranial approaches to perimesencephalic cisterns.

In recent two decades, endoscopic endonasal approaches have changed the evolution of skull base surgery accompanying with refinement of surgical instrumentation and thorough knowledge of endoscopic anatomy [15, 24]. Endoscopic endonasal approaches are feasible for midline skull base surgeries, but they are more complicated and technically demanding for paramedian lesions [10, 15]. Because endoscopic

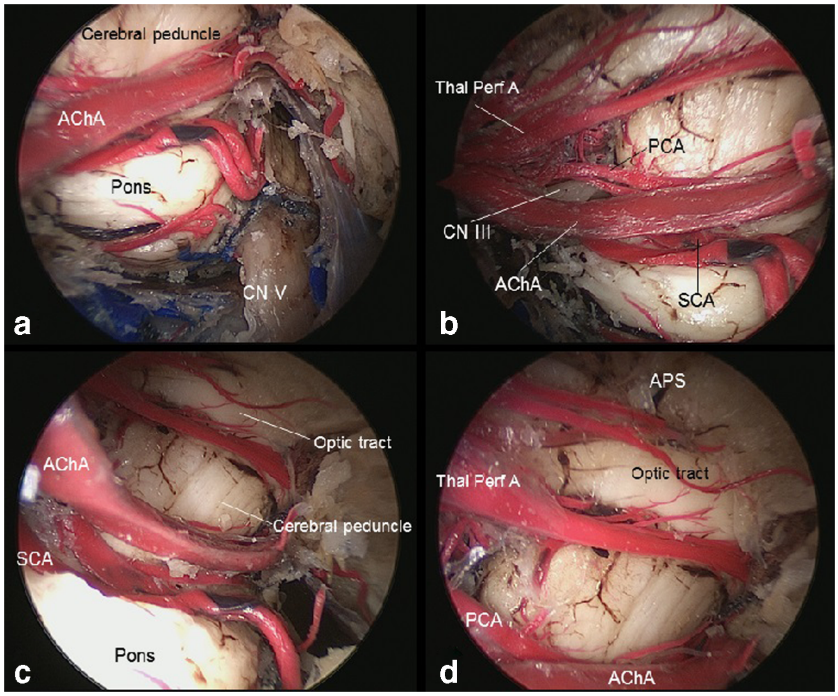

Fig. 6 Detection of perimesencephalic cisterns using 30-degree endoscope. The trigeminal nerve, residing on the cerebellopontine cistern, courses from anterolateral aspect of pons to Meckel cave (endoscope is turned inferiorly) (**a**). Interpeduncular cistern and prepontine cistern are revealed with endoscope pointing medially (**b**). Anterior portion of ambient cistern, posterior to crural cistern, is identified by moving the endoscope along the lateral surface of cerebral peduncle (endoscope is turned laterally) (**c**). APS and optic tract, forming the roof of middle incisural space, are identified with endoscope pointing superiorly (**d**). APS, anterior perforated substance; AChA, anterior choroidal artery; Thal Perf A, thalamus perforating arteries; PCA, posterior cerebral artery; SCA, superior cerebellar artery; CN III, oculomotor nerve; CN V, trigeminal nerve

endonasal approaches provide corridors with medial-to-lateral direction, the nasal osteology, internal carotid arteries, and cranial nerves form the natural obstacles for exposure of the lateral region of the skull base. The endoscopic transorbital approach is introduced recently as a minimally invasive skull base surgery able to overcome the limitations of exposure provided by the endoscopic endonasal approach.

In 2010, Moe et al. first proposed the concept of transorbital neuroendoscopic surgery (TONES) for skull base lesion [18]. Since that time, several studies had been reported to support the clinical feasibility of TONES [19, 22, 23]. In addition, Dallan et al. announced the utilization of combined endoscopic endonasal and transorbital approach for skull base lesion with involvement of multiple compartments [5]. In recent years, the applications of endoscopic transorbital approach have got obvious spread from the extracranial lesion to the intracranial intradural pathogen. In 2014, Chen et al. reported that endoscopic transorbital approach for amygdalohippocampectomy was feasible in cadaveric specimen [3]. In the following year, they published the first clinical case study regarding two patients accepting endoscopic transorbital approach for mesial temporal lesions with satisfactory outcome [2]. Following this surprising result, more cadaveric studies evaluating feasibility of endoscopic transorbital approaches for intradural region have been reported recently [1, 4, 6, 8, 9].

In this study, we describe a novel surgical access to the middle incisural space through the endoscopic transorbital transtentorial approach. Contrary to the endoscopic endonasal approach with medial-to-lateral trajectory, the endoscopic transorbital transtentorial approach for exposure of the middle incisural space needs one anterolateral-to-posteromedial corridor. The configuration of the sphenoid wing corresponds to the ideal surgical pathway of the endoscopic transorbital transtentorial approach. Therefore, the greater and lesser sphenoid wings need to be removed as much as possible. To avoid unnecessary traction of the temporal lobe, it is important to free the temporal lobe from the surrounding structure. At first, the sphenoidal compartment of the Sylvian fissure is opened widely to separate the temporal lobe from the frontal base. After that, the next step is to follow the arachnoid plane medially to dissect the mesial temporal lobe from the tentorium and perforating vessels. Identification of uncal perforators is very important to avoid damaging adjacent perforators sharing common origin. The range of lateral mobilization of this endoscopic transorbital approach is the anterior segment of the mesial temporal lobe. From the neurosurgical viewpoint, the anterior segment of the mesial temporal lobe has the following three surfaces: anterosuperior (anterior segment of uncus), medial (posterior segment of uncus), and inferior (entorhinal area). Each surface has its own blood supply. The middle cerebral artery and anterior choroidal artery form the major vascularization of the anterosuperior surface (anterior uncal artery). The chief parent vessels of the medial surface (posterior uncal artery) and the inferior surface are the anterior choroidal artery and the posterior cerebral artery, respectively. During the identification of the anterior and posterior uncal arteries, it is important to maintain the direction of dissection from the inferior to the superior and to keep the working area below the tentorial edge. This is because the anterior and posterior uncal arteries course from superiorly to inferiorly. Thus, dissecting along the direction of the inferior to the superior can avoid damaging other perforator vessels not related to the mesial temporal lobe. Extensive drilling of the sphenoid wing and lateral mobilization of the mesial temporal lobe are the main determinants of successful approach by providing sufficient working space for instrumental manipulation and further deeper dissection. While performing the transtentorial penetration, the cerebral peduncle is the anatomical reference for tentorium incision. Care should be taken to avoid damage to the oculomotor trigone medially, superior petrosal sinus inferiorly, and the trochlear nerve and superior cerebellar artery posteriorly. Endoscopic transorbital transtentorial approach provides direct view of the crural cistern with a 0-degree endoscope. Otherwise, interpeduncular cistern medially, prepontine cistern in the medial lower corner, superior portion of cerebellopontine cistern in the lateral lower corner, and anterior portion of ambient cistern can be seen with 30-degree endoscope.

Comparing with transcranial approaches, large skin incision and craniotomy, cosmetic deformity, frontalis nerve palsy, temporalis muscle wasting, and damage of the bridging veins can be avoided by the endoscopic transorbital route. The endoscopic transorbital transtentorial approach for the middle incisural space provides an anterior-to-posterior and slight inferior-to-superior trajectory. Thus, the optic apparatus, limen insula, uncus, and parahippocampal gyrus obscuring the surgical field of the transcranial approach do not limit exposure of the perimesencephalic cisterns. With advanced development of the endoscopic transorbital approaches for skull base lesions, neurosurgeons will face new ophthalmic complications not encountered in transcranial approaches. Accidental injury of the orbital content and extensive manipulation of the orbit may cause diplopia, loss of vision, globe malposition, epiphora, and ptosis. The role of the oculoplastic surgeon is of importance to avoid possible ophthalmic complication, repair damage, and reconstruct the bony defect. The superior and lateral orbital walls are removed in this approach, but active reconstruction of the orbital wall is not necessary. However, orbital reconstruction by placing bone graft or titanium mesh between the orbit and the intracranial compartment is required while developing pulsatile exophthalmos postoperatively. Otherwise, routine putting autologous fat tissue into the empty space produced by the sphenoid wing drilling is advised to reduce incidence of enophthalmos. Endoscopic transorbital approaches provide new opportunities and challenges for oculoplastic surgeons. Their active participation and professional expertise can provide paramount assistance. Another concern of transorbital approach is postoperative leakage of the cerebrospinal fluid (CSF). In this study, square-shaped durotomy is used with wide exposure of the intradural space. Almeida et al. used the "H"-shaped dural incision with a final square-shaped opening and Chen et al. adopted the "U"-shaped dural incision based medially [1, 2]. Interestingly, there has been no postoperative CSF leakage reported after the endoscopic transorbital skull base surgery. The possible reason is that the orbital content itself forms the anterior layer of the dural reconstruction and its mechanical support helps the dural healing.

From the result of our study, the endoscopic transorbital transtentorial approach provides a minimally invasive access to the middle incisural space. This approach is originally designed for intracranial lesions, which are not feasible for endoscopic transnasal approach, with occupation of the parasellar region and incisural space. So, pituitary macroadenoma with parasellar extension into the subarachnoid space and clinoid meningioma with suitable size are the ideal pathogens for this novel approach.

This anatomical study is a laboratory investigation with normal cadaveric structure. Therefore, our results do not exactly represent the pathological changes in real surgery. Further applications in appropriately selected patients are needed to prove the clinical feasibility of this minimally invasive skull base surgery.

Conclusion

Endoscopic transorbital approach is an alternative minimally invasive skull base surgery to overcome restricted exposure laterally of the endoscopic transnasal route. In this cadaveric study, endoscopic transorbital transtentorial approach provides successful exposure of the middle incisural space and adjacent perimesencephalic cisterns. This novel pathway may provide another choice other than the transcranial approaches for lesions within middle incisural space. Further clinical studies are needed to confirm the practical feasibility of our result.

Compliance with ethical standards

Conflicts of interest All authors certify that they have no affiliations with or involvement in any organization or entity with any financial interest (such as honoraria; educational grants; participation in speakers' bureaus; membership, employment, consultancies, stock ownership, or other equity interest; and expert testimony or patent-licensing arrangements), or non-financial interest (such as personal or professional relationships, affiliations, knowledge or beliefs) in the subject matter or materials discussed in this manuscript.

Ethical approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Informed consent Informed consent was obtained from all individual participants included in the study.

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Comments The authors describe a beautiful concept for transorbital endoscopic exposure of proximal Sylvian fissure, crural cistern and middle anterior tentorial incisura. The approach is very smart and could potentially be suitable for selected medially located lesions.

The importance of an oculoplastic surgeon for this type of procedures should be in mind.

Identification of uncal perforators compared to the other important anterior choroidal artery perforators or PCA perforators is crucial. This could potentially be very problematic if a choroidal artery cisternal perforator is sacrificed to release the medial temporal lobe.

More laboratory work is needed to make neurosurgeons more familiar with this innovative approach for which I believe there will be a specific indication in some selected cases in skull base surgery.

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