The Pterional Port in Dual-Port Endoscopy: A 2D and 3D Cadaveric Study

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Abstract

Objective We propose a novel dual-port endonasal and pterional endoscopic approach targeting midline lesions of the anterior cranial fossa with lateral extension beyond the optic nerve.

Methods Ten dual-port approaches were performed on five cadaveric heads. All specimens underwent an endoscopic transtuberculum/transplanum approach followed by placement of a pterional port. The endonasal port was combined with an endoscopic extradural pterional keyhole craniectomy. The pterional port was placed at the intersection of the sphenoparietal and coronal sutures. The extradural space was explored using two-dimensional and three-dimensional endoscopes.

Results The superolateral access provided by the pterional port may improve the ability to achieve a gross total resection of tumors with lateral extensions. The complete opening of the optic canal achieved through the dual-port approach may enable resection of the intracanalicular portion of a tumor, a crucial step in improvement of visual function and reduction of tumor recurrence.

Conclusion The pterional port may enhance control of midline anterior skull base lesions with lateral extension beyond the optic nerve and optic canal. Dual-port endoscopy maintains minimally invasiveness and dramatically increases the working limits and control of anatomical structures well beyond what is attainable through single-port neuroendoscopy.

Keywords

- 3D
- dual port
- cadaver
- endoscopy
- endonasal
- pterional

Introduction

The development of the expanded endoscopic endonasal approach and the associated surgical tools has pushed the limits of endoscopic transnasal access to the ventral skull base. Many authors have described the advantages of endoscopic approaches for midline skull base tumors.^{1–4} However, tumors with firm consistency, retrosellar extension, large suprasellar components, encasement of the optic apparatus,

or invasion of the optic foramina laterally cannot be treated exclusively using this approach.⁵

Cranionasal malignancies, sellar-based lesions, and spheno-orbital lesions with large sagittal and coronal plane extensions may require a combined or staged procedure to achieve optimal resection.^{6–11}

The concept of approaching skull base lesions exclusively with “dual-port” or “multiport” endoscopy has not been widely studied.^{12–14} A simultaneous approach may ease

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mobilization and removal of mass lesions, assist anatomical orientation, and provide circumferential visualization of neurovascular structures, especially when displaced by the tumor all without the aggressiveness of a frontolateral craniotomy.

We propose a novel simultaneous dual-port endonasal and pterional endoscopic approach to access midline lesions of the anterior cranial fossa with lateral extension beyond the optic nerve and investigate the feasibility and potential clinical benefits of combining these two approaches into a single procedure. In addition, we provide different endoscopic perspectives of the same anatomical region to enhance understanding of the surgical anatomy.

Methods

Ten endonasal and pterional dual-port approaches were performed on five preserved cadaveric heads injected with colored latex (red for arteries, blue for veins). All specimens underwent an endoscopic transtuberculum/transplanum approach followed by placement of a pterional port.

The pterional port provided a corridor for an endoscopic extradural approach to the anterior clinoid process and optic nerve through a pterional keyhole craniectomy. After initial exposure, the dissection proceeded with two surgeons and two endoscopes (one in each port), in a simultaneous or alternating fashion to complete anteromedial exposure.

Dissections were performed using 0- and 30-degree two-dimensional optics (4-mm diameter, 18-cm length; Karl Storz, Tuttlingen, Germany) and 0-degree three-dimensional (3D) optics (4.9-mm diameter, 30-cm length; Visionsense, New York, New York, United States). Images were recorded and stored using the Karl Storz AIDA system and the Visionsense software, respectively. An Anspach eMax 2 Plus (DePuy Synthes, West Chester, Pennsylvania, United States) electric neurosurgical drill was used. An endoscope holder and a Greenberg retractor system were used to perform bimanual dissection and drilling.

Surgical Positioning

Three-point fixation was achieved using a Mayfield head holder. The head was positioned with a 5-degree extension, with the vertex tilted slightly down and oriented 30 degrees to the ipsilateral side of the pterional port. Positioning was designed to give priority to the endonasal port; the pterional port took on an auxiliary role.

Endonasal Endoscopic Port

The endonasal transtuberculum transplanum approaches were all performed with a binostril approach, as previously described.^{2,15,16} The natural ostia of the sphenoid sinus were enlarged in a medial and inferior direction with curettes, sphenoid punches, and Kerrison rongeurs. Approximately 2 cm of the posterior nasal septum was removed to create a large cavity and to facilitate binostril access to the sphenoid sinus. The anterior sphenoidotomy provided exposure of the planum sphenoidale, tuberculum sellae, sella, and the intra-sphenoidal clivus in the midline (►Fig. 1A).^{2,15-17}

Fig. 1 Endonasal port. (A) Exposure and identification of the anatomical landmarks in the sphenoid sinus. (B) After bone removal, the underlying structures and their anatomical relationships with the optic nerve are appreciated. CR, clival recess; ICA, internal carotid artery; LOCR, lateral optic-carotid recess; MOCR, medial optic-carotid recess; ON, optic nerve; OS, optic strut; PG, pituitary gland; PS, planum sphenoidale; TS, tuberculum sellae.

After initial exposure of the sella and planum sphenoidale, the bone overlying the medial optic-carotid recess (OCR) was removed maintaining an extradural dissection (►Fig. 1B). Dissection of the coronal plane was extended with a posterior ethmoidectomy and partial removal of the medial pterygoid plate to allow for full access to the lateral recess and the lateral wall of the sphenoid sinus (►Fig. 2).¹² The extradural dissection continued on the posteromedial side of the paraclival internal carotid artery (ICA) where the remaining clivus and

Fig. 2 Internal surface of the skull base and bony anatomical landmarks. ACP, anterior clinoid process; LSW, lesser sphenoid wing; OC, optic canal; OS, optic strut; PS, planum sphenoidale; SOF, superior orbital fissure; TS, tuberculum sellae.

the petrous apex bone were drilled. Complete bone removal around the cavernous and paraclival segments of the ICA was completed to allow for lateral and medial mobilization of the vessel (►Fig. 1B).¹²

Pterional Port

An anteriorly curved vertical skin incision of ~5 cm was made starting 1 cm above the zygomatic arch at the anterior border of the hairline and proceeding toward the midpupillary line.¹² An interfascial dissection was completed,¹⁸ and the temporalis muscle was dissected subperiosteally and retracted in an anteroposterior direction until the pterion was exposed.

Drilling of the pterional keyhole craniectomy began at the intersection of the sphenoparietal and coronal sutures (►Fig. 3A). Small parts of the greater wing of the sphenoid, frontal, and parietal bones were removed until the lesser wing of the sphenoid was identified between the frontal and temporal dura. The dura was bluntly dissected from the bone, and drilling continued anteriorly until a 2.5 × 2.5-cm oval or trapezoid-shaped craniectomy with an anterior base was achieved. The larger bone opening at the anterior part of the craniectomy facilitated surgical maneuverability of instruments and dissection of deep-sited structures.

Removal of the lesser wing of the sphenoid along the sphenoid ridge progressively increased the extradural working space (►Fig. 3B). After sufficient space was obtained, a rigid endoscope was introduced to improve illumination and visibility.

An endoscope holder was used to perform bimanual dissection and drilling, and the procedure continued with removal of the lateral wall of the orbit until identification of the meningo-orbital dural fold (MODF), a duplication of the dura that stretches between the periorbita and temporal lobe dura at the superior orbital fissure (SOF) (►Fig. 3C, 3D).

The bone around the SOF and orbital roof was drilled, thinned, and removed. The MODF was divided and the anterior cranial fossa dura was detached using blunt dissection to expand the extradural space while reducing brain retraction (►Fig. 3E, 3).¹⁹ This maneuver increased exposure of the lateral and superior aspects of the anterior clinoid process (ACP) and facilitated identification of the roof of the optic canal (►Fig. 3G, 3). The frontotemporal dura was elevated using a 1-cm retractor blade attached to a Greenberg retractor system until exposure of the ACP was sufficient for drilling, the base of the ACP and the optic canal roof were safely identified, and the roof and lateral wall of the optic canal were removed using a diamond-tipped drill. The ACP was hollowed out by drilling the central cancellous bone and leaving a thin shell of cortical bone to protect the surrounding neurovascular structures (►Fig. 3I). The remaining shell of bone was then safely removed with a dissector to expose the oculomotor nerve laterally and the optic nerve medially. The residual clinoid tip was dissected and removed from the petroclinoid and interclinoid ligaments with pituitary forceps. The complete removal of the ACP provided full exposure of the paraclinoid structures (►Fig. 3J).

Results

The initial dual-port dissection provided full control of the anterior perisellar area. The dual dissection provided maximal medial exposure from the endonasal perspective and full control of the anatomical region lateral to the paraclinoid ICA from the pterional surgical corridor (►Fig. 4A, 4B). After initial exposures through the endonasal and pterional ports were completed, the dissection continued with two surgeons and two endoscopes (one in each port) in a simultaneous or alternating fashion.

Through the endonasal port, the bone overlying the medial OCR was removed bilaterally. It appeared as an indentation in the bone that was formed at the medial junction of the parasellar carotid canal and the optic canal. This was a critical landmark in locating the optic nerve canal as it joined the middle clinoid process and represented the pneumatization of the middle clinoid process and the lateral aspects of the tuberculum sellae.²⁰ The decompression of the medial wall of the optic canal was continued laterally. Inferiorly, the parasellar cavernous ICA and the lateral OCR were observed. The lateral OCR represented the pneumatization of the optic strut that corresponds to the inferolateral border of the optic canal.

Bone removal continued over the cavernous sinus, ICA, and SOF. To better understand the anatomical relationships, the cavernous sinus was opened with dissection of the endosteal dural layer and exposure of the clinoid and cavernous ICA. The parasellar segment of the ICA was C-shaped in all our specimens, and from an endonasal perspective the convexity of the "C" was directed anterolaterally. It rested inferiorly to the optic nerve and superiorly to and covering the abducens nerve, ophthalmic branch of the trigeminal nerve, trochlear nerve, and oculomotor nerve as they are coursed to the orbit.

The inferomedial and superomedial aspects of the optic canal were readily accessed and decompressed using angled endoscopes and angled instrumentation. However, the superior, superolateral, and inferolateral portions of the optic canal were inaccessible from the endonasal port.

Through the pterional port, superolateral access to the optic nerve and clinoid region was achieved. This corridor allowed for full control of the orbital roof up to the bone opening made through the endonasal port at the planum sphenoidale. The endoscopic extradural anterior clinoidectomy and optic nerve decompression achieved through the pterional port complemented the endonasal exposure and provided for full circumferential control of the paraclinoid ICA and optic nerve as well as a complete exposure of the anterior perisellar area (►Fig. 4C–4E).

Removal of the roof and lateral wall of the optic canal enhanced exposure of the key anatomical structures of the paraclinoid area. While drilling, a small amount of bone dust sometimes occluded the visual field, requiring cleaning of the endoscopic lens. Submerged drilling could not be accomplished because water would drain through the endonasal port.²¹ However, this issue can be mitigated with use of an endoscope sheath for irrigation.

While unroofing the optic canal in a medial to lateral direction, care was taken not to injure the underlying optic sheath.

Fig. 3 Right pterional port. (A) The craniectomy is initiated with a burr hole at the intersection of the sphenoparietal and coronal sutures. (B) Increased extradural space is gained with drilling of the lesser wing of the sphenoid. (C) The periorbital is kept intact and serves as a landmark for removal of the lateral roof of the orbit until the meningo-orbital dural fold is exposed. (D) Three-dimensional (3D) image of exposure of the periorbital. (E, F) Two-dimensional (2D) and 3D images of the division of the meningo-orbital dural fold performed to improve exposure of the extradural space. (G, H) 2D and 3D images of the detachment of the frontal dura and exposure of the anterior clinoid process. (I) The cancellous portion of the anterior clinoid process is removed and its cortical bone is thinned. (J) 3D view following the anterior clinoidectomy. ACP, anterior clinoid process; FD, frontal dura mater; LSW, lesser sphenoid wing; MODF, meningo-orbital dural fold; OS, optic strut; PO, periorbital; SOF, superior orbital fissure; TD, temporal dura mater.

Fig. 4 Dual-port endoscopy: endonasal and right pterional ports. (A, B) Two-dimensional and three-dimensional (3D) images of the endonasal perspective of the right parasellar area. (C) Pterional port perspective of the right parasellar area. (D) Division of the falciform ligament and opening of the optic sheath. (E) 3D anatomy of the right parasellar area. (F) 3D view following division of the falciform ligament and opening of the optic sheath. ACP, anterior clinoid process; *clin.ICA*, clinoid segment of the internal carotid artery; CN3, oculomotor nerve; ICA, internal carotid artery; FD, frontal dura mater; FL, falciform ligament; ON, optic nerve; OS, optic sheath; PG, pituitary gland; PO, periorbital; SOF, superior orbital fissure; TD, temporal dura mater.

The optic sheath was situated medially and the superior orbital fissure was situated laterally in relation to the clinoid space (—Fig. 4D). This maneuver was facilitated in a dual-port approach; the endonasal port provided control of the optic nerve.

Final removal of the ACP was facilitated by the unroofing of the optic canal and partially removing the optic strut through the endonasal port. The remainder of the optic strut (intracranial projection of the lateral OCR) was resected anteromedially under the optic nerve sheath, and provided 360-degree bone decompression of the optic canal.

The residual clinoid tip was, in some specimens, dissected and removed from the petroclinoid and interclinoid ligaments. This maneuver exposed the clinoid space and the clinoid segment of the ICA, that is, the segment between the proximal and distal dural ring of the ICA. The clinoid segment of the ICA ran along the posterior margin of the optic strut and was covered by a thin periosteal membrane. The inferior surface of the clinoid space was formed by a thin layer of periosteum mixed with epineurium that covered the oculomotor nerve and separated this space from the cavernous sinus. The anterior compartment of the cavernous sinus

was situated inferolateral to the clinoid space, and they were separated by a thick dural membrane. The falciform ligament and optic sheath were finally incised parallel to the long axis of optic nerve to achieve a complete decompression while avoiding the ophthalmic artery that ran inferomedially to the optic nerve (►Fig. 4F).

Discussion

The use of combined simultaneous approaches has been mainly suggested for use in the treatment of giant adenomas with multilobular extensions. Since the report of a transsphenoidal and transcranial frontotemporal craniotomy by Loyo et al in 1984, various combinations of transsphenoidal (TS) and transcranial (TC) approaches using microscopy and endoscopy have been reported. These include the microscopic TS and TC approach,^{22–25} the endoscopic TS and microscopic TC approach,²⁶ and the TS and transventricular endoscopic approach.^{27–29}

Approaching lesions using a dual-port endoscopic approach has yet to be studied in depth. Only a few cadaveric studies have demonstrated the feasibility of performing simultaneous endoscopic multiport approaches to the subarachnoid basal cisterns, clivus, petrous apex, cavernous sinus, sellar, and suprasellar regions.^{12–14}

The development of the endonasal approaches provided direct access to the pathology, avoiding brain retraction, with minimal manipulation of neurovascular structures and decreased morbidity.^{1–4} However, midline skull base lesions with lateral extensions beyond the optic nerve impose some difficulties and limitations to the endonasal approaches, likely favoring a transcranial approach. The endonasal route provides optimal access to the anatomical region medial to the paraclinoid ICA including the medial portion of the cavernous sinus, the carotid cave, and the medial aspect of the optic canal. The complex anatomy of the region lateral to the clinoid ICA, including the SOF and anterior cavernous sinus, is hidden by the carotid artery and optic nerve when approached from medial to lateral as in the endonasal route. The simultaneous pterional port complements the endonasal exposure by providing unobstructed access to the anatomical region lateral to the paraclinoid ICA and optic canal.

We performed a dual-port endoscopic approach through endonasal and pterional ports. The pterional port served an auxiliary role and assisted work done through the endonasal port, compensating for the limitations of the endonasal port without the aggressiveness of a frontolateral craniotomy. An extradural route to the ACP and optic nerve region was used and provided a minimally invasive superolateral approach that avoided infracture of the subdural space and its associated complications. Through the simultaneous endonasal and pterional endoscopic dissections, our goal was not only to describe the anatomy of the areas of interest, but to provide a different perspective of the anatomical relationships, the versatility and limitations of the approaches, and the feasibility of combining them into a single procedure.

This dual-port endoscopic technique is similar to the combined cranionasal approach that has been suggested for

malignant neoplasms of the anterior skull base, but it extends the paradigm to a new location and possibly different types of lesions.^{7,10,11}

Cranionasal malignancies, meningiomas, pituitary adenomas, or craniopharyngiomas with extension beyond the optic nerve or invasion of the optic canal are pathologies that could potentially be treated using a dual-port endoscopic approach. The superolateral access provided by the pterional port may improve the ability to achieve a gross total resection of tumors with lateral extensions. The complete opening of the optic canal achieved through the dual-port approach may enable resection of the intracanalicular portion of a tumor, which is a crucial step in improving visual function and reducing tumor recurrence.^{30–32} The challenging endonasal vascular dissection and potential for arterial injury may be improved with the aid of the pterional port, which could be used as a microsurgical working corridor. Further, reconstruction techniques for skull base defects may be optimized with the use of pericranial flaps and with lateral control of the anterior cranial base, decreasing the risk of a cerebrospinal fluid fistula.

Recent advances in 3D endoscopy provided high-resolution images that detailed the depth of the surgical field and critical spatial relationships of vital neurovascular structures. The 3D view helped facilitate dissection and aided in depth-oriented tasks while improving understanding of the advantages and limitations provided by each port. This combined approach highlights the utility of 3D endoscopy in appreciating anatomical relationships, which is useful not only for educational purposes but also in assisting in-depth perception and manual dexterity during surgery.^{33–36}

In the future, dual-port or multiport approaches will likely become increasingly popular with the refinement of robotic neurosurgery.

Conclusion

A dual-port endoscopic approach is feasible and has the potential to improve the management of midline anterior skull base lesions with lateral extension beyond the optic nerve and optic canal. The pterional port maintains minimally invasiveness and dramatically increases the working limits and control of anatomical structures well beyond what is attainable through single-port neuroendoscopy.

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