Use of the 3D exoscope for the supracerebellar infratentorial approach in the concorde position: an effective and ergonomic alternative. Illustrative cases

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BACKGROUND The supracerebellar infratentorial approach provides wide flexibility as a far-reaching corridor to the pineal region, posterior third ventricle, posterior medial temporal lobe, posterolateral mesencephalon, quadrigeminal cistern, and thalamus. Traditionally, the patient is placed in the sitting position, allowing gravity retraction on the cerebellum to widen the supracerebellar operative corridor beneath the tentorium. What this approach gains in anatomical orientation it lacks in surgeon ergonomics, as the sitting position presents technical challenges, forces the surgeon to adopt an uncomfortable posture while performing the microsurgical dissection/tumor resection under the microscope, and is also associated with an increased risk of venous air embolism.

OBSERVATIONS In this article, the authors present the use of the three-dimensional (3D) exoscope with a standard prone Concorde position as an alternative for the treatment of lesions requiring a supracerebellar infratentorial approach for lesions in the pineal region, posterior third ventricle, and the superior surface of the cerebellar vermis. The authors present four illustrative cases (one pineal cyst, one ependymoma, and two cerebellar metastases) in which this approach provided excellent intraoperative visualization and resulted in good postoperative results. A step-by-step description of our surgical technique is reviewed in detail.

LESSONS The use of the 3D exoscope with the patient in the prone Concorde position is an effective and ergonomically favorable alternative to the traditional sitting position for the treatment of lesions requiring a supracerebellar infratentorial approach. This technique allows improved visualization of deep structures, with a possible decreased risk of potential complications.

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KEYWORDS supracerebellar; infratentorial; posterior fossa; exoscope; surgical approach; ergonomics; pineal region; pineal cyst; ependymoma; cerebellar metastasis; neuronavigation; 3-dimensional; robotic assisted

The supracerebellar approaches provide wide flexibility as a far-reaching corridor to the pineal region, posterior third ventricle, posterior medial temporal lobe, posterolateral mesencephalon, quadrigeminal cistern, and thalamus. The supracerebellar approach takes advantage of the natural subdural space between the cerebellum and tentorium, allowing the surgeon to avoid brain transgression. Although anatomically appealing, the operative corridor is usually deep and presents technical challenges to the depth of the approach and the important deep venous system encountered.

The main supracerebellar routes are divided into supratentorial and infratentorial approaches. The infratentorial routes are divided into a continuum as one moves further away from midline: the classic midline approach, the lateral or paramedian approach, and the far lateral approach. The supratentorial approaches include the occipital transtentorial, interhemispheric transcerebellar variations, and transcortical transventricular approaches.

The supratentorial approaches are reserved for large tumors extending supratentorially or laterally into the trigone, or if the ventrally displaced deep veins prohibit the infratentorial routes. We prefer the infratentorial approaches in almost all cases unless the tumor harbors a large supratentorial component or if the displaced deep veins are obstructive. The infratentorial approaches are typically associated with less risk of neurological morbidity.

The midline supracerebellar infratentorial approach with use of the conventional microscope allows the surgeon to utilize the natural corridor between the cerebellum and tentorium cerebelli to reach

ABBREVIATIONS 3D = three dimensional; CT = computed tomography; MRI = magnetic resonance imaging.

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the pineal region and posterior third ventricle. This approach reaches over the lower slope of the cerebellum into the deep structures surrounding the superior and inferior colliculi. The use of endoscopic assistance for supracerebellar infratentorial approaches to the pineal/quadrigenital area has also been described, and has been associated with minimal brain retraction, avoidance of the Galenic veins, no risk to the fornical bundles, and improved visualization regardless of the ventricular size (when compared with the transventricular endoscopic approach).

As classically described in the supracerebellar infratentorial microsurgical approach, the patient is placed in the sitting position so that gravity retraction on the cerebellum widens the supracerebellar operative corridor and is associated with minimal accumulation of blood and fluids within the operative field. Some of the limitations of the sitting position include the following: (1) Long corridor: the surgical corridor is usually long (>7 cm from the craniotomy site) and narrow and does not readily allow for dissection of the inferior aspect of a pineal/cerebellar tumor that is covered by the apex of the culmen. (2) Venous air embolism: it may occur during any surgical procedure in which an opening in a vascular structure is above the level of the heart. In neurosurgery, venous air embolism occurs most commonly in procedures performed in the sitting position. When the embolus remains in the venous circulation, depending on the volume and rate of air entrapment, it may cause an initial reduction in end-tidal carbon dioxide, followed by reduced blood pressure and/or increase in heart rate, and finally significant hemodynamic compromise which could include cardiac arrest. In patients with a patent foramen ovale (or other form of septal defect), there is an increased risk of paradoxical embolus, stroke, coronary artery embolism, or other end-organ arterial air embolism. Thus, patients undergo bothersome additional preoperative work-up for detection and management of this potential complication, including placement of a right heart catheter, transthoracic Doppler, and transesophageal echocardiography with a ‘bubble test’ to rule out intracardiac shunt. (3) Surgeon ergonomics: when the patient is positioned sitting, surgeons must operate in the uncomfortable operating position of having their arms extended, leading to shoulder and arm fatigue, which may be taxing during the microsurgical dissection and tumor resection with the long corridor to the site of the lesion. (4) Limited magnification, illumination, and short field depth at high magnification with the conventional operative microscope. Since the depth of the approach is so long, use of the operative microscope can reach its limit in terms of magnification. A high light setting is required for illumination of the resection site. Limited magnification and lighting may interfere with proper visualization of the vein of Galen and associated deep draining veins (basal veins of Rosenthal). In addition, frequent adjustment of the operative microscope is required at high magnification due to the short depth of field present.

The introduction of a three-dimensional (3D) exoscope system has provided new possibilities in visualization and ergonomics in neurosurgery. Compared with the standard operating microscope, use of the 3D exoscope has demonstrated higher magnification potential, improved depth perception, comparable stereoscopic impression, and a clear benefit concerning the ergonomic possibilities for the surgeon. The first clinical report applying the 3D exoscope on 19 different microsurgical procedures showed good outcomes in all cases. Recently, our group has reported the use of the exoscope for resection of brain tumors such as brain metastases and glioblastoma tumors, and has demonstrated its use in surgical approaches to the middle cranial fossa and lateral skull base. The large depth of field and the introduction of voice-control functions improves exoscope mobility, decreases the need to refocus after positioning, and provides unobstructed operative corridors. Flexible positioning of the camera allows the surgeon’s posture to be kept in a neutral position with uncompromised viewing angles. Moreover, the immersive 3D surgical experience displayed on the monitors is an asset not only for the primary surgeon, but for all observers as well, fostering a positive teaching environment for residents, fellows, and medical students.

In this article, we present the use of the 3D exoscope with a standard prone Concorde position as an effective and ergonomic alternative for the treatment of lesions requiring a supracerebellar infratentorial approach. First, we present four illustrative cases in which this approach was demonstrated to be an effective alternative to the traditional approach using the standard sitting position and conventional microscope. Then, a step-by-step description of our surgical technique is reviewed fully in the Discussion section.

Illustrative Cases

Case 1: Pineal Cyst

A 27-year-old female with past medical history of asthma presented with worsening dizziness and headaches for 1 year. The headache was described as worse in the morning and after exerting physical exercise. The patient also reported intermittent episodes of vomiting and right ear fullness/pain with tinnitus. Magnetic resonance imaging (MRI) with and without contrast revealed a pineal gland cyst exerting pressure on the superior colliculi (Fig. 1A and B). Despite trying conservative medical management for 3 months, her headaches increased in frequency and duration. She underwent elective pineal cyst resection and drainage by a supracerebellar infratentorial approach with the 3D exoscope. Her intra- and postoperative course was uneventful. Postoperative MRI revealed resection of the cyst, with decreased compression of the posterior aspect of the pineal region and improvement in symptoms.
of the midbrain (Fig. 1C and D). The patient remained neurologically intact through her hospitalization and was discharged on postoperative day 2 with complete resolution of her preoperative headaches.

**Case 2: Anaplastic Ependymoma**

A 29-year-old male with a past medical history of autism presented to the emergency department with intermittent episodes of severe headaches and confusion. A noncontrast computed tomography (CT) of the head revealed ventriculomegaly and obstructive hydrocephalus due to a cystic posterior third ventricle mass causing cerebral aqueduct compression (Fig. 2A and B). An MRI of the brain confirmed presence of a contrast-enhancing mixed cystic and solid pineal region mass, 2.3 × 1.1 × 1.7 cm with a 1.1 × 1.0 × 1.4 cm anterior cystic component compressing the cerebral aqueduct (Fig. 2C and D). The patient and his family were counseled on the need for surgery and treatment of his obstructive hydrocephalus. An endoscopic third ventriculostomy in combination with a diagnosis: axial view (A) and sagittal view (B). Preoperative brain MRI confirming the presence of a contrast-enhancing mixed cystic and solid pineal region mass: sagittal T2 sequence (C) and sagittal T1 postcontrast sequence (D). Asterisk represents the cystic component of the lesion. The tentorium has a steep upward trajectory. Postoperative MRI brain showing good resection of anaplastic ependymoma: sagittal T2 sequence (E) and sagittal T1 postcontrast sequence (F). Notice the significant decrease in the ventricular size compared with (C) and (D).

confirmed the diagnosis of an anaplastic ependymoma. One month later, the patient underwent a second-stage procedure using our supracerebellar infratentorial approach with the 3D exoscope for definitive resection of this lesion without any complications. Postoperative MRI of the brain demonstrated resection of the mass and expected postoperative changes (Fig. 2E and F). He remained neurologically intact through his hospitalization.

**Cases 3 and 4: Cerebellar Metastatic Lesions**

The last two patients illustrate the utility of the supracerebellar infratentorial approach using the 3D exoscope and the Concorde position for resection of superior cerebellar metastases.

The first patient is a 68-year-old male with a past medical history notable for hepatitis C, opioid use disorder, left middle cerebral artery stroke 4 months prior to presentation secondary to left internal carotid artery stenosis treated with endovascular stenting (receiving dual antiplatelet therapy), and recent diagnosis of lung adenocarcinoma. He presented with 6 weeks of unsteadiness and 1 week of nausea/vomiting. An MRI of the brain revealed bilateral cerebellar lesions concerning for metastases with mild mass effect upon the fourth ventricle (Fig. 3A and C). The patient underwent successful resection of these lesions via a suboccipital craniotomy using our proposed approach. Postoperative MRI of the brain showed complete resection of the cerebellar lesions (Fig. 3D and E). The patient recovered well postoperatively with no complications. The patient went on to be treated with adjuvant stereotactic radiosurgery to the resection cavities of the tumors resected and his untreated brain metastases.

The second patient is a 65-year-old male with history of hypertension, hyperlipidemia, chronic obstructive pulmonary disease, and remote history of heavy smoking (2 packs per day for 40 years) who was referred by his primary care provider to the emergency department due to progressively worsening gait instability and frequent falls for approximately 2 weeks. A noncontrast CT of the head revealed two large cystic cerebellar masses with a possible hemorrhagic component and significant obstructive hydrocephalus (Fig. 4A and C). An MRI confirmed the presence of two masses in the vermis and left cerebellum suggestive of metastases (Fig. 4D and F). The patient was brought to the operating room for resection of both masses using a supracerebellar infratentorial approach. Of note, a right frontal external ventricular drain was placed prior to flipping the patient to the Concorde position. Postoperative MRI of the brain revealed complete resection of both cerebellar tumors (Fig. 4G and I). The patient did well postoperatively and was discharged home directly from the intensive care unit on postoperative day 2. The tumor was confirmed to be non-small cell lung carcinoma by histopathology.

**Discussion**

**Observations**

In this section, we present a step-by-step description of our proposed supracerebellar infratentorial approach using the 3D exoscope with the patient in the Concorde position. Key technical nuances and potential pitfalls of the procedure are highlighted.

**Patient Positioning**

After general anesthesia, the patient undergoes placement of a Mayfield head holder and is rolled onto chest rolls placed on the operating room table into the prone position. The Mayfield head holder is secured with the head of the patient in a neutral Concorde position.

**FIG. 2.** Initial CT head showing obstructive hydrocephalus due to a cystic posterior third ventricle mass causing cerebral aqueduct compression: axial view (A) and sagittal view (B). Preoperative brain MRI confirming the presence of a contrast-enhancing mixed cystic and solid pineal region mass: sagittal T2 sequence (C) and sagittal T1 postcontrast sequence (D). Asterisk represents the cystic component of the lesion. The tentorium has a steep upward trajectory. Postoperative MRI brain showing good resection of anaplastic ependymoma: sagittal T2 sequence (E) and sagittal T1 postcontrast sequence (F). Notice the significant decrease in the ventricular size compared with (C) and (D).
position with the body of the patient placed in slight reverse Trendelenburg for relaxation of the shoulders (Fig. 5A). A chin tuck is achieved with the patient’s head to flatten the curvature of the subocciput with the upper cervical spine in order improve surgical exposure to the posterior fossa. It is important to confirm that a space of at least two-finger breadths is left between the chest and the chin to prevent strangulation of the endotracheal tube and interference of venous blood return in the neck. The arms are well padded, the body is secured to the bed with multiple straps (important for lateral bed movements), and the patient’s head is registered using neuronavigation.

Skin Landmarks, Incision, and Tissue Dissection

After hair clipping and sterilization of the skin, a midline incision is traced from the inion to the upper edge of C1. The dermis is dissected down with a monopolar cautery. The splenius capitis and semispinalis capitis muscles are spread by a single bloodless cut through the common midline fascia (linea alba). The muscles are detached from the occipital bone. The incision can be extended slightly superiorly, if needed, to allow for the potential harvest of pericranium for a watertight dural closure later. The structures are separated by placing a cerebellar retractor.

Craniotomy

The size of the craniotomy may vary depending on the size/depth of the lesion of interest. We traditionally drill two burr holes using a 5-mm cutting bit on the superolateral margin of the planned craniotomy. These burr holes are usually 4 to 5 cm apart and high enough to expose the inferior edge of the transverse sinuses on each side. A suboccipital craniotomy is then completed down to the foramen magnum. The drill’s footplate near the dural sinuses is avoided and the drill bit is used to skeletonize the bone over the transverse sinuses and torcula.

Dural Opening

Once the craniotomy is completed, the 3D exoscope which has been draped is brought into the surgical field (Fig. 5B). The exoscope base is stationed adjacent to the surgeon and the robotic arm and camera are positioned over the surgeon’s right shoulder in a low trajectory to visualize the suboccipital region in the midline. The surgeon can utilize the 3D heads-up display of the exoscope and position the camera handpiece optimally while maintaining neutral stance. The dura is conventionally incised in a Y-shaped manner. Care is taken to caution the midline cerebellar sinus of the falx. Each dural flap is reflected away from the cerebellum with dural stitches secured to the overlying skin incision.

Intradural Supracerbellar Infratentorial Approach

The exoscope can be angled inferiorly to permit proper visualization of the superior cerebellar surface to access the infratentorial corridor while the surgeon maintains a neutral position using the heads-up display. Slight retraction of the superior cerebellar surface is performed by using the suction tip. Bridging veins that are encountered from the superior cerebellar surface to the tentorium are cauterized and cut to permit better relaxation of the cerebellum. The precentral cerebellar vein leading to the superior vermian vein can be sacrificed safely. This vein travels from the anterior vermis toward the vein of Galen. However, other more anterior diencephalic veins residing on the posterior surface of the mesencephalon and brainstem should be always preserved. As a reference, there is a thick veil of arachnoid

![Fig. 3. Preoperative brain MRI showing multiple enhancing cerebellar lesions concerning for metastases: sagittal T1 postcontrast sequence showing inferior lesion (A) and sagittal (B) and axial (C) T1 postcontrast sequences showing superior lesion. Notice the steep acute angle formed by the tentorium in (B). Resection by standard sitting position in these cases can be particularly challenging. Postoperative brain MRI showing complete resection of both superior (D) and inferior (E) cerebellar lesions. Both panels depict surgical cavities on T1 postcontrast sequences.](image-url)
encasing the precentral vein. The cerebellum gradually descends with dissection of the supracerebellar arachnoid bands, exposing the pineal region and/or the tumor. The vein of Galen is easily visualized with the 3D exoscope at the tentorial apex in addition to the basal veins of Rosenthal laterally (Fig. 5C).

The operative trajectory is further directed anteriorly and inferiorly to properly visualize the lesion of interest beneath the vein of Galen in the midline. The robotic arm is moved slightly superior and forward achieve a more inferior and anterior view into the pineal region. Dynamic retraction of the handheld suction mobilizes the apex of the cerebellar culmen and exposes the exact location of the lesion in the pineal region or posterior third ventricle (Fig. 5), while minimizing fixed retraction injury on the surrounding tissues. The arachnoid membranes over the posterior margin of the lesion are dissected free and care is taken not to retract down on the lesion since it is resting on the tectal plate of the brainstem.

The tumor resection follows the basic principles of tumor microsurgery, namely, tumor debulking and devascularization followed by extracapsular dissection. The margins of the lesion are carefully coagulated with bipolar cautery, and generous pieces of specimen are sent for pathologic analysis. After satisfactory tumor resection, the posterior third ventricle is carefully inspected for any blood clot and removed. The dura is closed in a water-tight fashion with use of an alloderm duroplasty. The bone flap is replaced and secured with plates and screws and the closure of the wound is performed in a standard fashion.

At our institution, the patient is monitored in the neurosurgical intensive care unit for 24 hours postoperatively. Careful and frequent neurological
examinations were performed that included extraocular muscle movements particularly upgaze difficulty.

**Lessons**

The supracerebellar infratentorial approach provides wide flexibility as a far-reaching corridor to the pineal region, posterior third ventricle, posterior medial temporal lobe, posterolateral mesencephalon, quadrigeminal cistern and thalamus. Compared to supratentorial approaches, infratentorial approaches are less invasive and take advantage of the natural subdural space along the supracerebellar space to avoid brain transgression while placing dural venous structures at less risk.

Although anatomically appealing, the sitting position presents technical challenges for the neurosurgeon. Under the microscope, the surgeon is forced to adopt an uncomfortable posture with their arms extended while performing the microsurgical dissection/debulking part of the procedure. Furthermore, the sitting position is associated with an increased risk of venous air embolism. Use of the prone neutral Concorde position with the conventional microscope for the supracerebellar infratentorial approach also presents a technical challenge to the neurosurgeon in terms of adequate visualization, surgeon neck and body position, and limited magnification due to the long surgical corridor.

The use of the 3D exoscope with the patient positioned in the prone neutral Concorde position is an effective and ergonomic approach to the supracerebellar infratentorial approach.
alternative to the traditional sitting position for the treatment of lesions requiring a supracerebellar infratentorial approach. Proper positioning of the exoscope camera provides optimal illumination at a long working distance during the approach. The light intensity used by the exoscope is at a lower intensity than the operative microscope since a light-emitting diode light is used. The neurosurgeon can position themselves in a neutral position and perform surgery using a high-definition heads-up display that provides overall surgeon comfort and less neck strain that would be associated with use of the binocular operative microscope. The positioning of the exoscope camera and arm over the shoulder of the surgeon permits a direct midline view of the subocciput. The wide field of view and depth perception permits excellent visualization of deep venous structures (vein of Galen and its associated veins) to safely perform surgery along this long trajectory even with a steep upward trajectory of the tentorium. The slight adjustment of the exoscope can permit visualization inferiorly and anteriorly to the vein of Galen for resection of the pineal and/or posterior third ventricle lesion of interest.

The high-definition heads-up display permits direct visualization of the microsurgery by all members of the surgical team including the residents, fellows, medical students, as well as operating room technicians and nurses. This provides an opportunity for engagement and education of the entire surgical team.

As with any new technology utilized in the operating room, the neurosurgeon must be comfortable with use of the 3D exoscope. The surgeon should become familiar with the exoscope and gain experience by applying it with straightforward surgical approaches. Use of the exoscope in less complex approaches can permit the neurosurgeon to understand the proper positioning of the exoscope, use of 3D visualization, high magnification, and visualization with the heads-up display to apply those skills with more advanced approaches such as the supracerebellar infratentorial approach. We found depth perception with the 3D exoscope worked well for supracerebellar approaches. Some authors have reported less optimal visualization utilizing the exoscope with narrow surgical corridors during middle ear surgery or when performing an anterior cervical disectomy and fusion in obese patients.

References

Disclosure
Dr. Hadjipanayis is a consultant for Synaptive Medical, NX Development Corporation (NXDC), Stryker Corporation, and Hemerion. He receives financial compensation as a consultant and lecturer for Synaptive (manufacturer of the Synaptive MODUS V device), NXDC, a privately held company, markets Geolan (5-ALA, aminolevulinic acid hydrochloride). He receives royalty payments for the sale of Geolan. No other disclosures were reported.
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Conception and design: Hadjipanayis, Schupper. Acquisition of data: all authors. Analysis and interpretation of data: all authors. Drafting the article: all authors. Critically revising the article: Hadjipanayis, Schupper, Yaeger. Reviewed submitted version of manuscript: Hadjipanayis, Schupper, Yaeger. Approved the final version of the manuscript on behalf of all authors: Hadjipanayis. Statistical analysis: Hadjipanayis, Schupper. Administrative/technical/material support: Hadjipanayis. Study supervision: Hadjipanayis.

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