OBJECTIVE: The purpose of this study was to review the endoscopic anatomic features of the anterior brainstem and surrounding cisternal spaces via a transoral-transclival approach.

METHODS: Fifteen adult human cadaveric heads, obtained from 10 fresh cadavers and 5 formalin-fixed cadavers, were used to demonstrate both the feasibility of an endoscopic transoral-transclival intradural approach and its exposure potential. To analyze the exact extension of a safe entry zone through the clivus, 20 skull bases were used to obtain anatomic measurements.

RESULTS: The transoral approach was performed without maxillotomy or mandibulotomy and with a clival opening of 20 by 15 mm. Such a limited clival and dural opening allowed the insertion of the endoscope and instruments, full visualization of the anterolateral brainstem and cisternal spaces around it, and reconstruction of all anatomic layers by means of a paraendoscopic technique.

CONCLUSION: The endoscopic transoral-transclival approach enables full access to the anterolateral brainstem and to the cisternal space around it. The use of the endoscope has the potential to reduce the need for a wider cranial base opening and the danger of postoperative complications.

KEY WORDS: Anatomy, Brainstem, Neuroendoscopy, Transoral-transclival approach

The anterior brainstem and the vertebro-basilar junction are involved in a number of neurosurgical disorders, such as extra-axial and intrinsic tumors, aneurysms, and vascular malformations. Nevertheless, they have long been considered a “no-man’s land” (15). The development of the modern concept of cranial base surgery has provided the neurosurgeon with the technical and anatomic awareness to deal with these challenging anatomic structures. A number of different approaches to these regions have been developed through anterior, anterolateral, and posterolateral routes (11, 16, 17, 30, 31, 33–39). Nevertheless, these cranial base surgical approaches are, in some instances, highly destructive; others require a high degree of cerebral and vascular manipulation, in contrast with the modern concept of keyhole surgery.

Anatomically, the most physiological and shortest route to the anterior surface of the brainstem is represented by an approach performed through the pharynx and the underlying clival bone. This approach offers a direct view of the anterior brainstem and vertebro-basilar junction without requiring dislocation or manipulation of any cerebral or vascular structure. The transoral approach is considered effective for giving access to ventrally located abnormalities of the clivus and craniovertebral junction, and it has been used extensively for treatment of extradural lesions (2, 7, 12, 19, 21, 25).

A transoral-transclival approach to the intradural compartment was described for the first time by Mullan et al. (26) in 1966 for the treatment of an extra-axial tumor. Since then, the approach has been used to treat mainly midbasilar or vertebrobasilar junction aneurysms (13, 27, 32, 41). In 1991, Crockard and Sen (6) reported seven intradural lesions operated on via this approach; the lesions comprised meningiomas and neurofibromas. More recently, Perneczky’s group reported
two cavernous angiomas of the brainstem treated by this approach (28). Aside from these studies, few series and a limited number of cases (29) have been reported, probably because of the technical difficulties (such as the need for working in a narrow and deep cavity and the lack of proper instrumentation) or because of the likelihood of postoperative complications, such as cerebrospinal fluid leakage or velopharyngeal incompetence (6, 13, 18, 20, 27, 32, 38, 40).

Endoscopy has technical characteristics that offer the potential to overcome such difficulties (3, 4, 8, 15). The aims of this study were to demonstrate the feasibility of this approach and its exposure potential through a limited clival and dural opening and to describe the anatomic features of an intradural transoral-transclival approach from the endoscopic perspective.

MATERIALS AND METHODS

This anatomic study was performed at the Institute of Anatomy of the University of Vienna, Austria. Fifteen cadaver heads were used for the study, 10 from fresh cadavers and 5 from formalin-fixed cadavers. The arteries of 10 fresh specimens and both the arteries and veins of 5 formalin-fixed cadavers were injected under pressure with colored silicone rubber (Dow Corning, Midland, MI) via internal carotid arteries and internal jugular veins. The endoscopes used were rigid 0-, 30-, 45-, and 70-degree rod lens endoscopes 2.7 or 4 mm in diameter and 11 or 18 cm in length (Karl Storz, GmbH & Co., Tuttlingen, Germany).

The specimens were placed in a slightly extended position in a four-point pin headrest. A self-retaining retractor system was positioned to keep the mouth open. The soft palate was split in the midline and fixed with sutures. The hard palate was left in place. The pharyngeal mucosa was incised from the anterior arch of the atlas upward through the vault of the nasopharynx to the posterior border of the vomer. The mucoperiosteal layer was retracted laterally, exposing the clivus and the craniovertebral junction. On the clival surface, the pharyngeal tubercle was identified, and a clival craniectomy with an average diameter of 20 mm in length and 15 mm in width was initiated just above it with a high-speed drill. The dura mater was visualized and opened with a vertical incision. A video recorder (S-VHS SVO 9500 MDP; Sony, Tokyo, Japan) and a video-capture system (Digital Still Recorder; Sony) were used for digital acquisition of the endoscopic pictures.

To analyze the exact extension of a safe entry zone through the clivus, we obtained anatomic measurements in 20 skull bases. We measured the length of the retropharyngeal surface of the clivus, and we measured its width at three points: at the base between the occipital condyles, at the level of the pharyngeal tubercle, and at the upper portion of the border with the vomer. The distances between the inferior petrous sinuses (D4), the jugular foramina (D5), and the hypoglossal channels (D6) were also measured. Finally, the distance of the clivus from the superior alveolar arch was measured to evaluate the depth of the surgical field.

RESULTS

Bone Measurements

Figure 1, A and B, shows the distances that were measured between the anatomic structures that may be jeopardized during the transclival approach. Table 1 summarizes these measurements and those obtained by measuring the depth of the surgical field and the extension of the exposed clival surface.

Endoscopic Procedure

After opening the dura mater, the premedullary, the pre-pontine, and the lateral cerebellomedullary cisterns came into direct view (Fig. 2, A and B). The vertebral arteries could be
followed along their cisternal course up to the vertebrobasilar junction at the pontomedullary junction. The origin of the two posteroinferior cerebellar arteries and the anterior spinal artery, as they originated from the vertebral arteries, were visible in the anteriormost lateral cerebellomedullary cistern and in the premedullary cistern, respectively. The fibers originating in Cranial Nerve XII in the preolivary sulcus were also observed at this level. In the prepontine cistern, the basilar artery could be visualized in the lower two-thirds of the field, permitting observation of the typical variability of dimension and course (31). The abducens nerve was identified and followed along its course in this cistern toward Dorello’s canal.

By means of a 30- to 45-degree optic lens and a lateral inclination of the endoscope, it was possible to reach the cerebellopontine cistern from a premeatal route. Along the course of the anteroinferior cerebellar artery, the acoustic facial bundle was identified and followed along its free cisternal course to the internal acoustic channel (Fig. 3, A and B). Anatomic features of the internal acoustic channel could be observed as a result of the optic properties of the endoscope (Fig. 3B). At this level, it was also possible to visualize the labyrinthine arteries in their course toward the internal acoustic channel (Fig. 3, B and C).

Turning the endoscope rostrally and using the same angled optic lens at 30 degrees and 45 degrees, the upper part of the cerebellopontine angle was explored. The main structure under this view was represented by the trigeminal nerve along its course from the pons toward Meckel’s cave (Fig. 3D). By using the same angled optic lens and turning the endoscope laterally and downward, it was possible to reach the posterior part of the lateral cerebellomedullary cistern (Fig. 3, A and C). The interpeduncular fossa was also reached with this approach. Angled optic lenses at 45 or 70 degrees were needed to achieve good visualization. The endoscope was directed upward with an inclination of approximately 45 degrees, following the basilar artery to its superior third, which was hidden by the border of the clival craniectomy. It was thus possible to reach and thoroughly explore the interpeduncular cistern (Fig. 4A).

The perforating branches of the basilar tip and of P1 were visible in detail and could be followed to their entrance in the posterior perforated substance (Fig. 4B). The posterior communicating arteries appeared in the anterolateral part of the surgical field, where they crossed Liliequist’s membrane to reach the posterior cerebral arteries with a lateral deflection (Fig. 4C). The mammillary bodies and the tuber cinereum were also visualized (Fig. 4D). The identification of the oculomotor nerves completed the exploration of the cistern (Fig. 4, A–C).

### DISCUSSION

Minimizing surgical trauma means fewer complications, shorter hospital stays, and reduced overall psychological consequences. Endoscopy is a leading technique of minimally invasive neurosurgical procedures. Recently, an important im-
pulse in the development of endoscopic surgery was provided by the introduction of the transnasal-transsphenoidal approach for surgery of the sellar and parasellar regions (3, 9, 10, 23). This experience has spurred the search for new surgical approaches that would enable access to the entire cranial base (1, 22). Because of the optic properties of the endoscope, it was possible to follow the nerves to their entrance into the IAC and to observe their anatomic features. The VII–VIII bundle was encircled by the loop formed by the AICA. At this level, it was possible to visualize the labyrinthine arteries (LbA) in their course toward the IAC (B and C). By using the same angled optic lens, and by turning the endoscope laterally and downward, it was possible to reach the posterior part of the lateral cerebellomedullary cistern. It was possible to identify the IX and X nerves (IX–X) running laterally and posteriorly from the retro-olivar sulcus to the jugular foramen, covered in their anterior portion by a tuft of the choroidal plexus (CP) exiting from the foramen of Luschka and by the variable looping of the posterior inferior cerebellar artery (AICA). At this level, it was possible to explore the upper part of the cerebellopontine angle. The main structure under this view was represented by the trigeminal nerve (V). It was observed along its course from the pons directed anteriorly and superiorly toward Mekel’s cave (D).

The use of the endoscope offers several theoretical advantages when dealing with the transoral-transclival approach. In our anatomic study, we demonstrated that this approach enables full access to the anterolateral brainstem and to the cisternal space around it, from the spinomedullary junction to the interpeduncular cistern, including a thorough vision of the vertebrobasilar arterial system and of Cranial Nerves III to XII. This endoscopic approach thus provides excellent visualization of some of the most challenging and inaccessible territories of the brain, without requiring extended cranial base destruction.

Furthermore, most of the limitations of the transoral-transclival approach may potentially be reduced by the use of an endoscopic approach. Crockard and Sen (6) suggested a clival opening of 2 by 3 cm for dealing with intradural lesions; in this study, the opening was limited to 20 mm in length and 15 mm in width. Such an opening was demonstrated to be sufficient for the endoscopic view, and it was located in a “safe entry zone” through the clivus, which we tried to delineate by obtaining the bone measurements. These data, although already in the literature, were revised in this light to define the limits of the clivectomy.

It is also worth noting that both labiomandibuloglossotomy and maxillotomy, which are often required with microscopic procedures to increase the view caudally and rostrally, were not needed, and the reduced opening through the clivus did not limit the complete exploration of the cisternal spaces. A limited clival opening can reduce the risk of injuring the condyles with subsequent postoperative instability. Another
The dural opening was minimized; it was sized to allow the introduction of the endoscope and the instruments. With this approach, it was possible to suture the dura, even though it was much deeper than the atlantic arch. This suturing was accomplished by using a paraendoscopic technique, which allowed firm packing and safe sealing (Fig. 5). Both the limited clival and dural opening, with the possibility of reconstructing each anatomic layer, may represent the basis for a reduced occurrence of postoperative cerebrospinal leakage and infection, which represent the main complications of the standard approach.

A minimally invasive approach should be well grounded on anatomic investigations. This study provides a description of anatomic structures that, although widely known by neurosurgeons, are presented from a new perspective, as a result of either the different pathway used or the different optical instruments. The view of the anterior aspect of the brainstem offered in this study may appear, as often happens in anatomic dissection studies, to be simply an idealistic construction. However, it is worth noting that the surgical procedure was similar to that used in the standard microscopic approach and that the exposure widening was attributable to the possibility of reaching blind angles.

The application of this approach is, at present, still far from clinical practice. However, clinical findings on the use of an endoscopic transoral-transpharyngeal approach to treat craniovertebral junction abnormalities have been reported, and the endoscope was also used to assist in the removal of two brainstem cavernous angiomas and a clival ecchordosis physaliphora (5, 14, 28). New technologies and instrumentation, such as instruments able to work through deep keyholes and with angled tips to reach blind angles, new clip applicators, or catheter ultrasound, will make surgical practice easier. The strategy for the endoscopic transoral-transclival approach will presumably be selective and aimed mainly at lesions of the lower ventral brainstem, such as aneurysms, cavernous angiomas, and small intra- and extra-axial tumors.

**CONCLUSION**

This study shows that the transoral-transclival route enables exploration of the cisterns surrounding the anterolateral brainstem from the medulla to the lower diencephalon by means of the endoscope. We obtained a new and original visual perspective of these anatomic structures. The use of minimally invasive endoscopic techniques has the potential to reduce the need for a wider cranial base opening and to decrease the danger of postoperative complications.

**REFERENCES**

The authors have completed a basic theoretical study of the adjunctive use of the endoscope in a transoral-transclival approach to the intradural structures. The study demonstrates that access can be expanded through this approach with the use of the endoscope. Although various clinical factors may result in this approach not gaining wide acceptance or common clinical use, this is a useful article in guiding such attempts. I would also comment that using such anatomic studies as one’s own platform for clinical application of the endoscope is insufficient. Rehearsal in the laboratory on one’s own, developing the necessary facility with the endoscope, and working with the altered view provided are also components of a necessary first step. The authors make a case for the increasing usefulness of the endoscope as an adjunctive imaging tool in neurosurgery.

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In this article, de Divitiis et al. have performed a study of an endoscopic transoral-transclival approach to the clivus and the brainstem. It is clear that the endoscope allows more structures to be visualized than the microscope (1, 2). However, an important question is whether the surgeon can “not only look, but actually do” (i.e., operate) with the endoscope; for instance, if there were to be bleeding from a branch of the basilar artery, can the surgeon stop the bleeding and repair the artery? If a cranial nerve is damaged, can it be repaired? An additional problem with an intradural transoral-transclival approach is repair of the dura at the end of the procedure to prevent meningitis. This is a significant problem with both the endoscope and the microscope. We need to make more progress with regard to techniques than an anatomic study like this allows before we can start using this technique with confidence.

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