J Neurosurg 109:530–535, 2008

Endoscopic anatomy of the fourth ventricle

Laboratory investigation

PIERLUIGI LONGATTI, M.D.,[1] ALESSANDRO FIORINDI, M.D.,[1] ALBERTO FELETTI, M.D.,[1] DOMENICO D'AVELLA, M.D.,[2] AND ANDREA MARTINUZZI, M.D., PH.D.[3]

Departments of [1]Neurosurgery and [2]Neurosciences, Treviso Hospital, University of Padova; and [3]"E. Medea" Scientific Institute, Conegliano Research Centre, Conegliano, Italy

Object. Microsurgical anatomy of the fourth ventricle has been comprehensively addressed by masterly reports providing classic descriptions of this complex region. Neuroendoscopy could offer a new, somewhat different perspective of the "inside" view of the fourth ventricle. The purpose of this study was to examine from the anatomical point of view the access to the fourth ventricle achieved by the endoscopic transaqueductal approach, to enumerate and describe the anatomically identifiable landmarks, and to compare them with those described during microsurgery.

Methods. The video recordings of 52 of 75 endoscopic explorations of the fourth ventricle performed at the authors' institution for different pathological conditions were reviewed and evaluated to identify and describe every anatomical landmark. According to the microsurgical anatomy, at least 23 superficial structures are clearly identifiable in the fourth ventricle, and they represent the comparative basis of parallel endoscopic anatomy of the structures found during the fourth ventricle navigation.

Results. The following anatomical structures were identified in all cases: median sulcus, superior and inferior vela medullare, choroid plexus, inferior fovea, hypoglossal and vagal triangles, area postrema, obex, canalis medullaris, lateral recess, and the foramina of Luschka and Magendie. The median eminence, facial colliculus, striae medullaris, auditory tubercle, and inferior fovea were seen in the majority of cases. The locus caevruleus could never be seen.

Conclusions. On the whole, 20 anatomical structures could consistently be identified by exploring the fourth ventricle with a fiberscope. Neuroendoscopy offers a quite different outlook on the anatomy of the fourth ventricle, and compared with the microsurgical descriptions it seems to provide a superior and detailed visualization, particularly of the structures located in the inferior triangle. *(DOI: 10.3171/JNS/2008/109/9/0530)*

KEY WORDS • anatomy • aqueduct • fourth ventricle • neuroendoscopy • neuronavigation

NEUROENDOSCOPIC anatomy of the fourth ventricle has been reported infrequently in the literature, mainly based on laboratory experiences or, more rarely, in accounts of caudocranial suboccipital surgical approaches.[3,4,6,12,16,19] Even neurosurgeons familiar with flexible endoscopes have scarcely taken advantage of the extraordinary versatility of their instruments to achieve complete visual control of all the ventricular cavities.[7] Nonetheless, the transaqueductal approach to the fourth ventricle performed with flexible scopes has been demonstrated to be safe and technically feasible.[1,9,11,14,17]

Our endoscopic practice has provided a consistent series of different pathological conditions in which transaqueductal navigation has been successfully performed. This gave us the opportunity to attempt to revisit the anatomical structures approached during the endoscopic navigation of the fourth ventricle to compare them with those classically described in microsurgical studies.

Abbreviation used in this paper: PICA = posterior inferior cerebellar artery.

Methods

Between August 1994 and August 2006, 385 endoscopic procedures were performed at our institution; in 75 of these cases, complete transaqueductal endoscopic navigation of the fourth ventricle was accomplished. A description of this patient series was the subject of 2 other papers, which were mostly focused on technical data.[9,10] Because this report is strictly anatomical, we have only briefly summarized the pathological entities leading to endoscopy in Table 1.

We reviewed our cases by retrieving data from both our clinical and video database. Of 75 cases of transaqueductal endoscopic exploration of the fourth ventricle, 23 video recordings were discarded due to the poor quality of the images. In fact, a consistent number of cases in-

TABLE 1
Clinical pathological entities found in reviewed cases

Entity	No. of Cases
intraventricular hemorrhages	27
colloid cysts & cystic craniopharyngioma	4
hydrocephalus	36
ventricular tumors	3
trapped 4th ventricle	5

volve intraventricular hemorrhages, for which we use the endoscope to evacuate acutely.[11] In these cases the view is rarely clear due to the presence of blood, and they are thus scarcely suitable for providing sufficiently defined anatomical landmarks. Therefore, the great majority of the considered cases is represented by patients affected by different conditions of hydrocephalus. According to the most cited texts and papers on human anatomy and central nervous system microsurgery,[16,18,20] at least 23 landmarks may be recognized in the fourth ventricle. All of these structures were searched while reviewing the videotapes of the selected cases, to identify them and to compare the quality of the endoscopic perspective with that provided by microsurgery.

Technical Endoscopic Aspects and Precautions During the Fourth Ventricle Navigation

The surgical approach to the fourth ventricle is through the usual frontal bur hole, 2 cm anterior to the coronal suture and 1.5–2 cm from the midline.[9,10] The direction of the trajectory is toward the foramen of Monro. The frontal horn is first cannulated with a 14 Fr peel-away catheter, and then the flexible endoscope is introduced in the third ventricle and deflexed posteriorly toward the aditus of the aqueduct (Fig. 1). The endoscopic visualization offered to the neurosurgeon exploring the fourth ventricle must take into account the fact that the posterior stirring of the endoscopic tip turns the videoendoscopic images upside down. Therefore the dorsal and ventral anatomical structures are projected in the monitor downward and upward, respectively. In that way, for instance, when the floor of the rhomboid fossa appears above, the fastigium is seen below (Figs. 2–4). Also, the tela choroidea with the affixed plexus is visible in the downward position of the videoendoscopic monitor. These nuisances could seem quite obvious, but if not taken in account they may be the cause of dangerous disorientation. Furthermore, once inside the aqueduct, irrigation is stopped because the instrument itself occupies and shuts the aqueduct with its own volume. Therefore, further increments of liquid could overload the fourth ventricle, which in this particular phase could become completely trapped, leading to threatening bradycardia.[9]

In all of our cases neuroendoscopic navigation of the fourth ventricle was successfully performed; we recorded only 4 episodes of bradycardia and 2 cases of small and clinically irrelevant ependymal contusions of the aditus ad aqueductum cerebri.

Results

Cerebral Aqueduct

When the tip of the endoscope moves toward the aqueductal entrance (aditus ad aqueductum cerebri), the observer is impressed by the morphological variability, with the only constant appearance being that of a circular shape that commonly occurs in pathological conditions of the aqueduct. After the aditus has been crossed, 2 strictures with a lumen enlargement between them, the so-called ampulla aqueducti, are noted. The first stricture is caused by the intraluminal protrusion of the superior colliculi[2,5,20,21] whereas the second one (narrower accord-

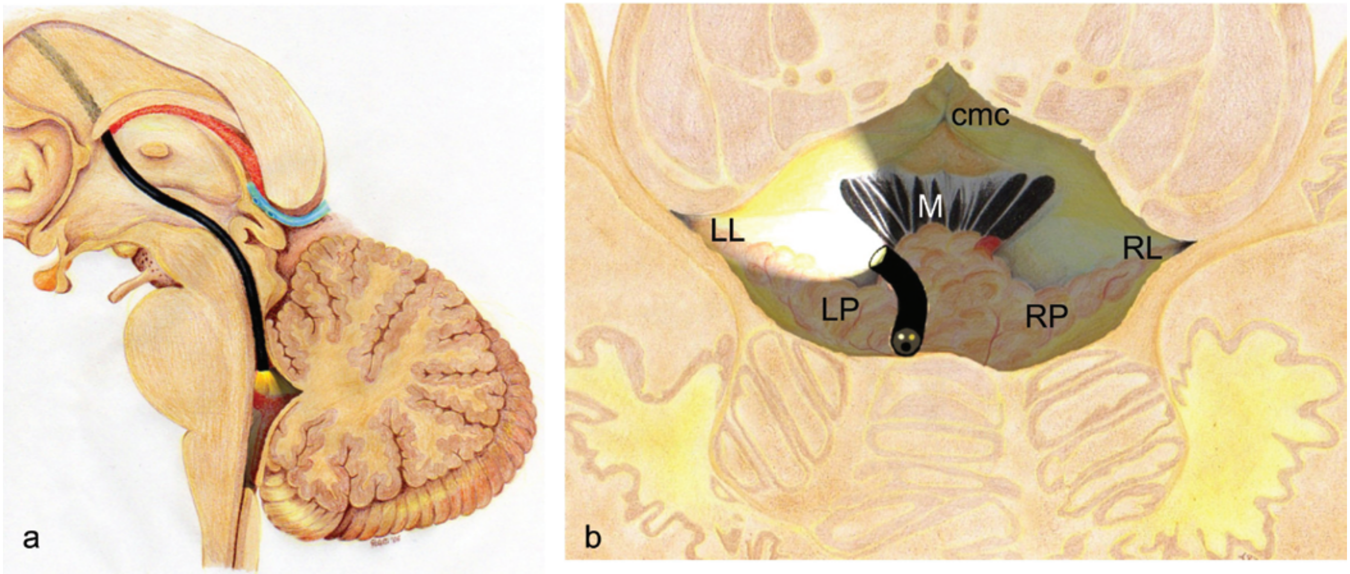

FIG. 1. Artist's drawings showing the trajectory to the fourth ventricle. The endoscopic view is perpendicular to the inferior triangle. cmc = centromedullary canal; LL = left Luschka foramen; LP = left plexus; M = foramen of Magendie; RL = right Luschka foramen; RP = right plexus.

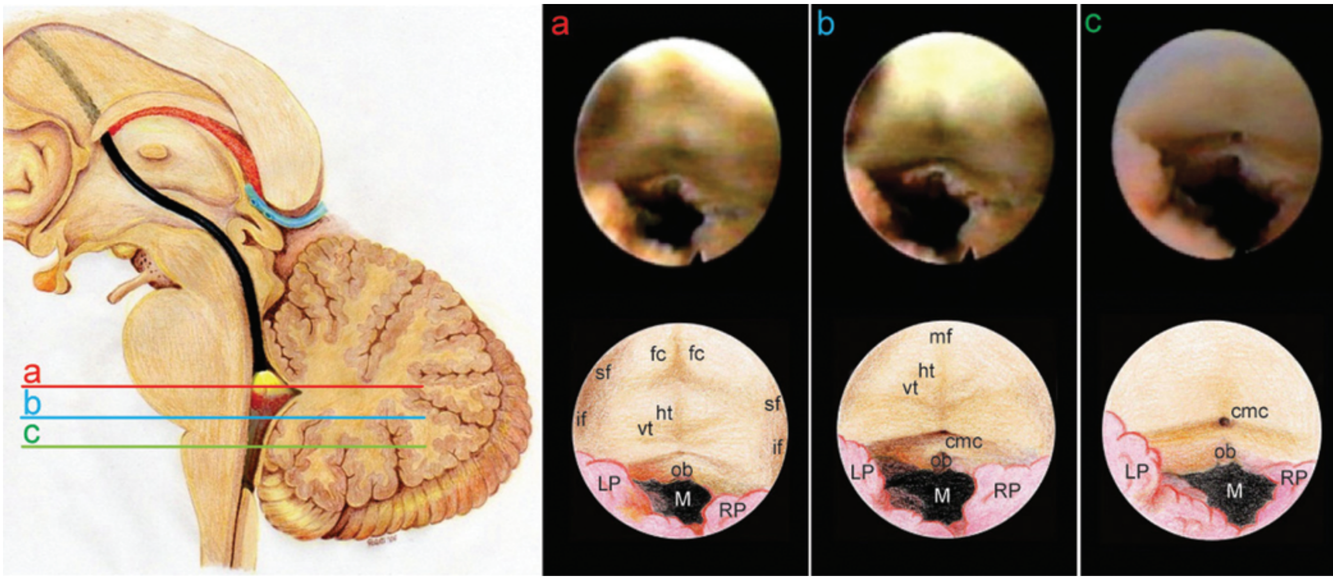

Fig. 2. Artist's drawing showing orientations of endoscopic views of the inferior triangle. Letters (a–c) correspond to the endoscopic views and anatomical drawings in the *right* panel. at = acoustic tubercle; fc = facial colliculus; ht = hypoglossal triangle; if = inferior fovea; mf = median fissure; ob = obex; sf = superior fovea; T = taeniae; vt = vagal triangle.

ing to some authors) is due to the inferior colliculi. Ventrally, a trace of a sulcus is visible continuing in the fourth ventricle.

Roof of the Fourth Ventricle

Once the rhomboid fossa is reached, the superior velum medullare is immediately faced because this structure is on the trajectory of the tip of the scope. The velum, however, is obliquely positioned and therefore the scope may be gently advanced by sliding it along the velar wall. In that way the tip of the scope navigates along the roof of the fossa rhomboidea far from the brainstem. The fastigium can be inspected with gentle down-stirring movements; the inferior velum medullare is so smooth that the vermian structures (nodule) become clearly visible, particularly when the ventricle is dilated. Paired on the midline, the longitudinal portions of the choroid plexus are soon visible and often well separated. According to the description by Rhoton,[15] the choroid plexus of the fourth ventricle may be compared with 2 inverted symmetrical L-shaped fringes that arise on the ventricular surface of the tela choroidea and are located on each side of the midline on the roof of the ventricle (Figs. 2 and 4). Thus the double plexi are conjoined in the medial line and located in the roof of the ventricle. The horizontal portion of the plexi starts at the level of the foramen of Magendie, and then they deviate in opposite directions along the lateral

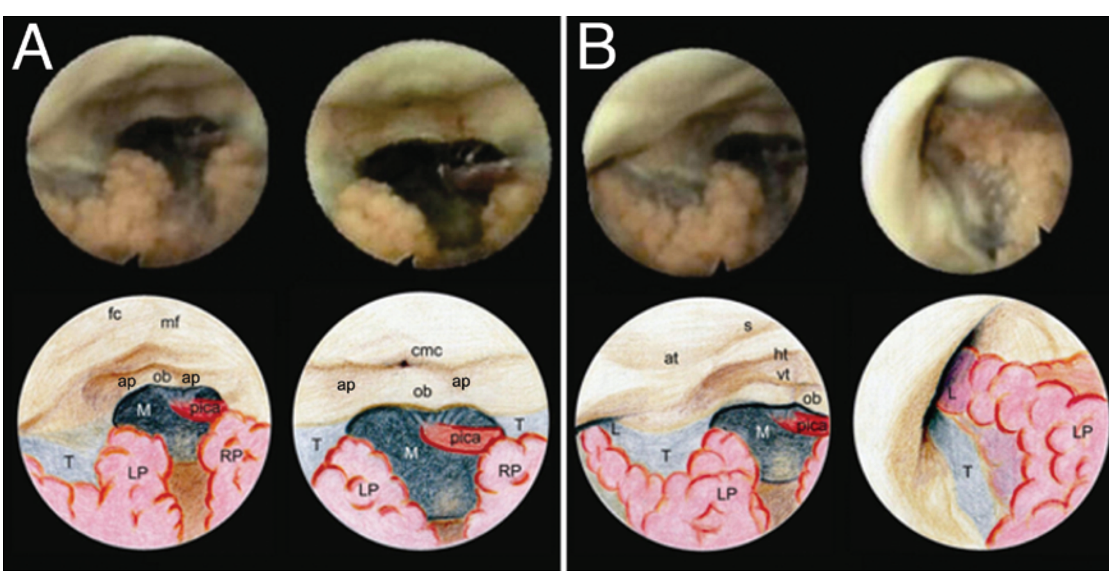

Fig. 3. Endoscopic views and anatomical drawings of the fourth ventricle. ap = area postrema; L = foramen of Luschka; s = acoustic striae.

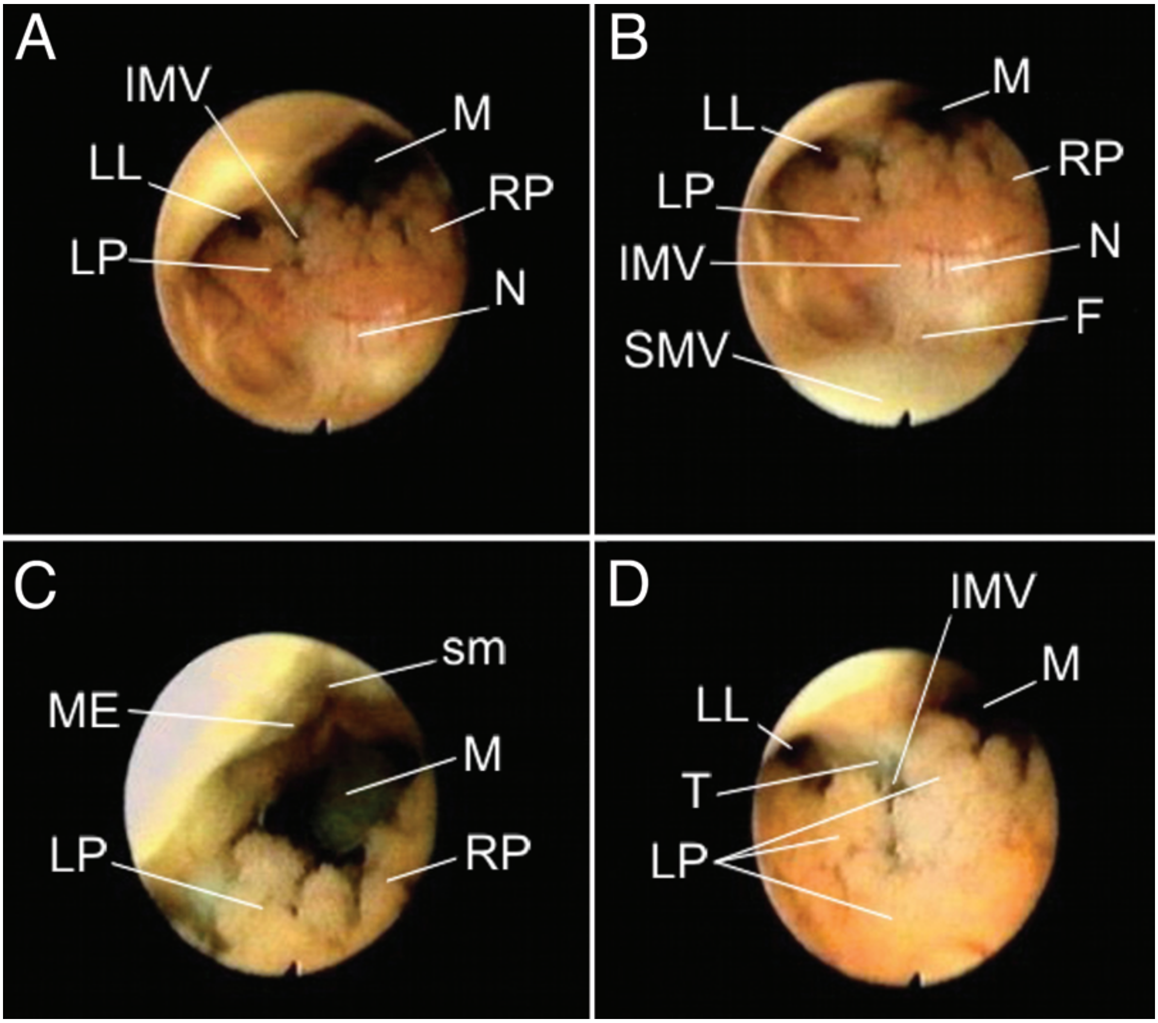

FIG. 4. Endoscopic views of the lateral recess (A and B), Magendie region (C), and global view of the inferior triangle (D). F = fastigium; IMV = inferior medullary velum; ME = median eminence; N = nodule; sm = sulcus medianus; SMV = superior medullary velum.

recesses, parallel to the telovelar junction until the foramen of Luschka, where they emerge in the cerebellopontine angles.

Floor of the Fourth Ventricle and the Inferior Triangle

The floor of the fourth ventricle (fossa rhomboidea) has a symmetrical rhomboid shape, and it is classically divided into 3 parts: 1) a superior or pontine, 2) an intermediate or junctional, and 3) an inferior or medullary part. Generally the anatomical structures of the inferior triangle (also called calamus scriptorius) offer the best endoscopic images because the edges of the rhomboid fossa are lifted up by tela choroidea and therefore the view of the endoscopic tip turns from parallel to perpendicular and straight (Figs. 2–4). If the inferior triangle resembles an ink pot (calamus), the tip of the flexible scope may lay on resembling a pen. It must be added that once the tip of the scope has reached the inferior part of the fourth ventricle, it can be freely stirred from one side to the other without danger of damaging the aqueduct, because the maneuver is simply done by spinning the instrument.

Identifications of anatomical structures are summarized in Table 2. The following anatomical structures of the fourth ventricle were identified in all cases: fastigium, median sulcus, superior and inferior medullary vela, inferior fovea, vermian inferior structures, hypoglossal triangle, vagal triangle, area postrema, choroid plexus, obex, canalis medullaris, lateral recess, foramina of Luschka and Magendie, and PICAs. The median eminence, striae medullaris, auditory tubercle, facial colliculus, and inferior fovea were seen in the majority of cases; the superior fovea and sulcus limitans could sometimes be clearly identified; whereas the locus caeruleus could never be seen. We therefore were able to identify clearly and consistently, on the whole, 20 anatomical landmarks (Table 2).

Discussion

Although experiences with endoscopic exploration of the fourth ventricle have seldom been reported,[1,4,6,8,12,16,19] and therefore this issue does not represent an absolute

TABLE 2
List of endoscopically identified anatomical landmarks

Landmark	Endoscopic Visualization
aqueduct	
aditus ad aqueductum cerebri	clear
first stricture	clear
ampulla	clear
second stricture	clear
sulcus ventralis	frequent
roof of the 4th ventricle	
superior medullary velum	clear
fastigium	clear
choroid plexus	clear
floor of the 4th ventricle	
superior triangle	
locus caeruleus	never
median sulcus	clear
sulcus limitans	rare
median eminence	frequent
superior fovea	rare
facial colliculus	frequent
junctional part	
striae medullaris	frequent
auditory tubercle	frequent
inferior triangle	
inferior fovea	clear
hypoglossal triangle	clear
vagal triangle	clear
area postrema	clear
inferior medullary velum	clear
vermian inferior structures	clear
canalis medullaris	clear
lateral recess	clear
foramen of Luschka	clear
foramen of Magendie	clear
obex	clear
PICAs	clear

novelty, to our knowledge no investigator has focused on the endoscopic identification of the structures encountered during fourth ventricle navigation. Many theoretical objections to the transaqueductal navigation of the fourth ventricle could be raised, but in practice it proves relatively easy and harmless; the clinical aspects of the approach have been discussed elsewhere.[9,11] In many cases the exploration of the fourth ventricle was an important part of the diagnostic or therapeutic procedure. For example, in intraventricular hemorrhages, colloid cysts, or craniopharyngioma, the fourth ventricle must be cleaned of blood or colloid/cholesterol residues. In the 3 cases of intraventricular tumors, the lesion was located just inside the fourth ventricle, which was reached to obtain a biopsy. In cases of a trapped fourth ventricle, we used endoscopy to implant a ventriculoperitoneal shunt with a single catheter inserted, under visual control, into the fourth ventricle. As for hydrocephalus, which accounts for the majority of cases, in all instances the navigation through the aqueduct was part of our routine procedure when dealing with possible intraventricular pathological entities. We started to explore the fourth ventricle systematically in cases of normal-pressure hydrocephalus after our first exploration unexpectedly revealed closure of the outlets.[10] This observation demonstrated the utility of a full exploration of the fourth ventricle with flexible endoscopes to exclude unpredicted blockages or stenoses of the outlets not revealed on the MR imaging study. This procedure was thereafter routinely included in all our operations, and indeed some other cases of unexpected closure were seen, allowing us to avoid in some instances a ventriculoperitoneal shunt, because hydrocephalus due to outlet closure is a blocked hydrocephalus that can be treated with third ventriculocisternostomy.

In an anatomical endoscopic description one should be aware not only that, as outlined before, the posterior stirring of the endoscopic tip turns the videoendoscopic images upside down, but also that the advancement of the scope in the fourth ventricle is parallel to the floor; therefore the brainstem is mostly viewed at an angle and not perpendicularly as in microsurgery (Figs. 2–4). These general aspects account for the particularities of this type of endoscopic navigation. The upper two-thirds of the ventricle are inspected with parallel light, suitable to enhance even a small inequality of the surface of the floor, as for example in the median fissure, median eminence, and particularly the colliculi and related fossae. Conversely, the best panoramic view results for the inspection of the inferior third part of the ventricle (inferior triangle), where we assert a remarkable superiority of the vision compared with the classic microsurgical description. The visual control of the structures encompassed from one of the foramina of Luschka to the opposite one (thus the inferior edges of the triangle) can be described. The more external parts of the inferior triangle come to an end through the lateral recess in the funnel-like foramen of Luschka, coming out with their fringes of choroidal plexus into the pontocerebellar cistern. The contours of the foramen of Luschka are delimited by the lateral portion of the acoustic area and by the cranial nerve VIII and inferior cerebellar peduncles. All the structures surrounding the foramen of Magendie are prime sites for neuroendoscopy, which can give details superior to microsurgery. The very end of the foramen of Luschka may be inspected only in conditions of a dilated fourth ventricle. Orientation toward the foramen of Luschka is always led by the horizontal portion of the choroid plexus. The latter may be so abundant as to fill up the foramina themselves like clusters of grapes in a cornucopia.[15] The calamus scriptorius constitutes the apex of the inferior triangle enclosing important landmarks such as the hypoglossal trigona, vagal trigona, and area postrema, which are distinctly seen, together with the centromedullary canal, and can always be examined with great accuracy.

According to many neuroanatomists,[15,20] beneath the inferior fovea and between the trigonum hypoglossi and the lower part of the area acustica, there is a triangular dark field, the ala cinerea, which corresponds to the sensory nucleus of the vagus and glossopharyngeal nerves. The lower end of the ala cinerea is crossed by a narrow translucent ridge, the funiculus separans, and between this funiculus and the clava is a small tongue-shaped area, the area postrema. Sections show that the funiculus separans is formed by a strip of thickened ependyma, and the area postrema by loose, highly vascular, neuroglial tissue containing nerve cells of moderate size. This succinct and well-known description of the inferior triangle has a superb counterpart in the endoscopic views. The area postrema is noticed because it shows as a pale orange spot compared with the white structures around it, whereas we could never visualize the aforementioned funiculus separans. The canalis centromedullaris was found endoscopically in all cases, whereas in microsurgical approaches this structure is veiled posteriorly by the obex itself (Figs. 2 and 3). At its inferior end the calamus scriptorius is called the obex, and is usually covered by a subtle band of tissue. The obex is a landmark not so precisely delimited; Milhorat and Miller[13] considered it to be the band of gelatinous tissue connecting the clava at the inferior pointed end of the fossa rhomboidea, constituting there a minipouch according to the Latin word "obex." Therefore, the obex should be considered more of an anatomical region than a structure. Most of the calamus area shapes the contour of the foramen of Magendie with its aspect of a smoothed triangular shape. The other sides of the foramen of Magendie are represented by cerebellar tonsils and the PICAs (Fig. 2).

Conclusions

Neuroendoscopy offers a quite different perspective on the anatomy of the fourth ventricle and, compared with the microsurgical description, it seems to provide a superior and detailed visualization, particularly of the structures located in the inferior triangle. Most of the structures of the inferior triangle, in fact, such as the median sulcus, inferior medullary velum with the vermian inferior structures, choroidal plexus, auditory tubercle, inferior fovea, hypoglossal triangle, vagal triangle, area postrema, obex, canalis medullaris, recessus lateralis, foramen of Luschka, foramen of Magendie, and PICAs can all be easily identified during endoscopy.

Disclaimer

The authors do not report any conflict of interest concerning the materials or methods used in this study or the findings specified in this paper.

References

1. Anandh B, Mohanty A, Sampath S, Praharaj SS, Kolluri S: Endoscopic approach to intraventricular cysticercal lesions. **Minim Invasive Neurosurg 44:**194–196, 2001
2. Barkhof F, Kouwenhoven M, Scheltens P, Sprenger M, Algra P, Valk J: Phase-contrast cine MR imaging of normal aqueductal CSF flow. Effect of aging and relation to CSF void on modulus MR. **Acta Radiol 35:**123–130, 1994
3. Bergsneider M: Endoscopic removal of cysticercal cysts within the fourth ventricle. Technical note. **J Neurosurg 91:**340–345, 1999
4. Cinalli G, Spennato P, Savarese L, Ruggiero C, Aliberti F, Cuomo L, et al: Endoscopic aqueductoplasty and placement of a stent in the cerebral aqueduct in the management of isolated fourth ventricle in children. **J Neurosurg 104:**21–27, 2006
5. Flyger G, Hjelmquist U: Normal variations in the caliber of the human cerebral aqueduct. **Anat Rec 127:**151–162, 1957
6. Fritsch MJ, Kienke S, Manwaring KH, Mehdorn HM: Endoscopic aqueductoplasty and interventriculostomy for the treatment of isolated fourth ventricle in children. **Neurosurgery 55:**377–379, 2004
7. Fukushima T, Ishijima B, Hirakawa K, Nakamura N, Sano K: Ventriculofiberscope: a new technique for endoscopic diagnosis and operation. Technical note. **J Neurosurg 38:**251–256, 1973
8. Gawish I, Reisch R, Perneczky A: Endoscopic aqueductoplasty through a tailored craniocervical approach. **J Neurosurg 103:**778–782, 2005
9. Longatti P, Basaldella L, Feletti A, Fiorindi A, Billeci D: Endoscopic navigation of the fourth ventricle. Technical note and preliminary experience. **Neurosurg Focus 19(6):**E12, 2005
10. Longatti P, Fiorindi A, Feletti A, Baratto V: Endoscopic opening of the foramen of Magendie using transaqueductal navigation for membrane obstruction of the fourth ventricle outlets. Technical note. **J Neurosurg 105:**924–927, 2006
11. Longatti PL, Martinuzzi A, Fiorindi A, Maistrello L, Carteri A: Neuroendoscopic management of intraventricular hemorrhage. **Stroke 35:**e35–e38, 2004
12. Matula C, Reinprecht A, Roessler K, Tschabitscher M, Koos WT: Endoscopic exploration of the IVth ventricle. **Minim Invasive Neurosurg 39:**86–92, 1996
13. Milhorat TH, Miller JI: The Obex is not synonymous with the upper end of the central canal. **Pediatr Neurosurg 21:**112, 1994
14. Mohanty A: Endoscopic options in the management of isolated fourth ventricles. Case report. **J Neurosurg 103:**73–78, 2005
15. Rhoton AL Jr: Cerebellum and fourth ventricle. **Neurosurgery 47 (3 Suppl):**S7–S27, 2000
16. Sansone JM, Iskandar BJ: Endoscopic cerebral aqueductoplasty: a trans-fourth ventricle approach. **J Neurosurg 103:**388–392, 2005
17. Schroeder HW, Gaab MR: Endoscopic aqueductoplasty: technique and results. **Neurosurgery 45:**508–515, 1999
18. Tanriover N, Ulm AJ, Rhoton AL Jr, Yasuda A: Comparison of the transvermian and telovelar approaches to the fourth ventricle. **J Neurosurg 101:**484–498, 2004
19. Toyota S, Taki T, Oshino S, Hashiba T, Oku Y, Hayakawa T, et al: A neuroendoscopic approach to the aqueduct via the fourth ventricle combined with suboccipital craniectomy. **Minim Invasive Neurosurg 47:**312–315, 2004
20. Williams PL, Banniser LH (eds): **Gray's Anatomy: The Anatomical Basis of Medicine and Surgery**, **ed 39.** New York: Churchill Livingstone, 2004
21. Woollam DH, Millen JW: Anatomical considerations in the pathology of stenosis of the cerebral aqueduct. **Brain 76:**104–112, 1953

Manuscript submitted July 1, 2007.
Accepted November 5, 2007.
Address correspondence to: Andrea Martinuzzi, M.D., Ph.D., "E. Medea" Scientific Institute, Via Costa Alta 37, 31015 Conegliano (TV) Italy. email: andrea.martinuzzi@cn.lnf.it.