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Median aperture of the fourth ventricle revisited

M. Ciołkowski[1, 2], M. Sharifi[1, 3], S. Tarka[4], B. Ciszek[1, 5]

[1]*Department of Descriptive and Clinical Anatomy, Medical University of Warsaw, Poland*
[2]*Department of Neurosurgery, Bielanski Hospital, Warsaw, Poland*
[3]*Department of Paediatric Otolaryngology, Medical University of Warsaw, Poland*
[4]*Department of Forensic Medicine, Medical University of Warsaw, Poland*
[5]*Department of Neurosurgery, Prof. Bogdanowicz Children's Hospital, Warsaw, Poland*

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Background: *The median aperture of Magendie is the largest of three openings of the fourth ventricle and thus it forms the main path for the outflow of the cerebrospinal fluid from the ventricle. The Magendie aperture connects the fourth ventricle with the cisterna magna and makes a natural corridor for neurosurgical approach and inspection of the ventricle and its floor. The purpose of this study was to give a contemporary anatomical view of this structure in the context of historical data.*
Material and methods: *The Magendie foramen was studied in 30 fixed specimens of human brainstems with cerebella. The microdissection technique was used. Measurements were taken with a microscope ocular ruler.*
Results: *The aperture is limited by the following structures: obex and gracile tubercles inferiorly, and tela choroidea with choroid plexus superolaterally. Obex tubercles usually have the form of a piece of neural tissue bridging two halves of the brainstem above the entrance to the central canal. Gracile tubercles together are 8.15 mm wide and the maximal width of the foramen is 6.53 mm. Tela choroidea attaches laterally at both sides to the inferior medullary velum. In most cases the right and left choroid plexus are connected to each other with a triangular membrane of tela choroidea, which protrudes through the median foramen and attaches to the vermis at a highly variable level.*
Conclusions: *We hope that the presented description of anatomical relations around the Magendie aperture, with its new measurements, will be helpful for those operating in the area and will explain some of the inaccuracies found in literature.* (Folia Morphol 2011; 70, 2: 84–90)

Key words: anatomy, choroid plexus, cisterna magna, foramen of Magendie, neurosurgical approach

INTRODUCTION

Ancient anatomists, who dissected human brains, like Herophilos, or those who dissected animal brains, like Galen, described in detail the floor of the fourth ventricle (e.g. *calamus scriptorius*) after pulling and raising the cerebellar vermis. However, the theory of animal spirit produced by the brain did not force them to look for communications of the ventricular system. At last, after many earlier presumptions, Domenico Cotugno described the watery fluid surrounding the spinal cord in 1764. In a series of elegant experiments and publications

Address for correspondence: M. Ciołkowski, Department of Descriptive and Clinical Anatomy, Centre of Biostructure Research, Medical University of Warsaw, Chałubińskiego 5, 02–004 Warsaw, Poland, tel/fax: +48 22 629 52 83, e-mail: maciej.ciolkowski@wum.edu.pl

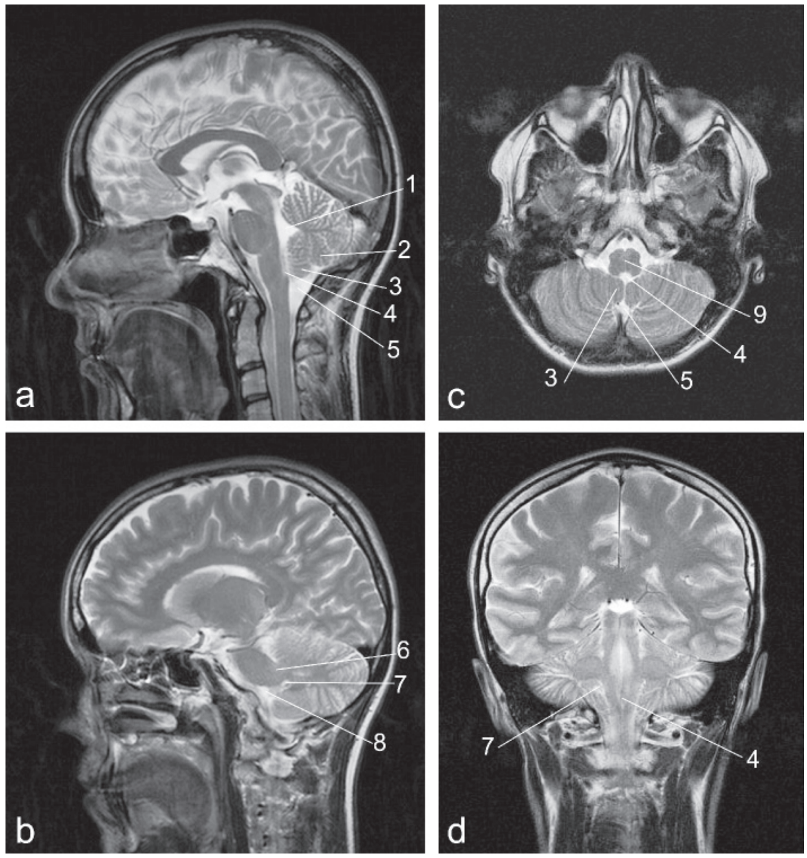

Figure 1. Magnetic resonance imaging of the head, T2 presentation. Sagittal (**A**, **B**), horizontal (**C**), and frontal (**D**) sections. The Magendie aperture is hardly visible in standard planes despite good resolution of images; 1 — fourth ventricle; 2 — pyramid of the cerebellar vermis; 3 — cerebellar tonsil; 4 — inferior angle of the rhomboid fossa; 5 — cisterna magna; 6 — middle cerebellar peduncle; 7 — aperture of Luschka; 8 — cerebello-pontine angle; 9 — medulla oblongata.

between 1825 and 1842 François Magendie proved the presence of the fluid, which he called "cephalo-spinal liquid or cephalo-rachidian, for those whose ear might be wounded by an hybridous word" [9]. He correctly described its vascular origin and its protective and physiological function. His name was given to the median aperture of the fourth ventricle, which he discovered, despite erroneously supposing that the fluid enters the ventricular system through it. "There should exist a communication between the exterior of the organ and its internal cavities — a communication, however, which had never been discovered. (...) And in fact, after examining the brains of several subjects, I at length found an opening of two or three lines in diameter, completely concealed by the lobe of the cerebellum, and forming a true entrance into the cavities of the brain" [10]. Finally, a description of the apertures of the fourth ventricle was completed in 1855 by Hubert von Luschka, who also attributed production of the fluid to the choroid plexus [3].

As the median aperture of the fourth ventricle is its largest opening and is located in the midline, the ventricle is relatively easily accessible through it. Brainstem lesions of the rhomboid fossa, cysts and tumours of the fourth ventricle and aqueduct, posterior vermis lesions can be approached through the Magendie foramen. Congenital or acquired malformations of the median aperture often lead to hydrocephalus. Although the normal or changed fourth ventricle can usually be well assessed in the imaging studies, its apertures are difficult to visualise due to their complicated spatial organisation (Fig. 1). The aim of this study was to present a microanatomical description of the median aperture of the fourth ventricle with regard to its clinical significance.

MATERIAL AND METHODS

The median aperture of the fourth ventricle was studied in 30 specimens of human brainstems with cerebella, 20 from males and 10 from females, aged from 24 to 88 years (mean age was 50 years with stan-

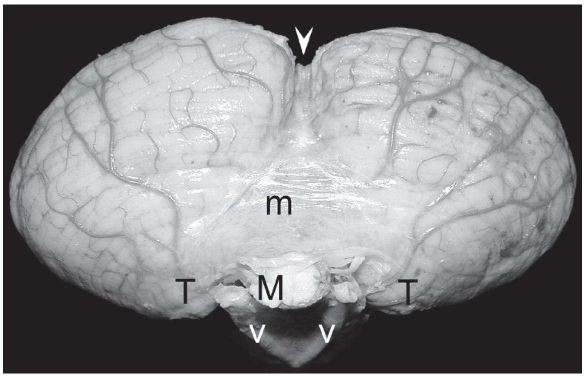

Figure 2. Posterior caudal view of the cerebellum and brainstem showing the arachnoidal cerebellomedullary membrane (m), which is closing the cisterna magna and separating it from the rest of the cerebellar vallecula (arrowhead); M — medulla oblongata; T — cerebellar tonsils; V — vertebral arteries.

dard deviation [SD] 16). The specimens were collected during routine forensic autopsies, from bodies without signs of previous neurosurgical interventions, any macroscopic malformations, or posttraumatic changes of the central nervous system. The arteries of the collected specimens were cannulated, flushed with water, and injected with coloured gelatine. The specimens were fixed in a 7% solution of formaldehyde for at least one month. The microdissection technique was used. Measurements were taken with a ruler in a microscope ocular, with 0.2 mm accuracy.

RESULTS

The median aperture of the fourth ventricle was seen in all cases after cutting the arachnoid membrane that posteriorly closes the cisterna magna. This membrane is usually relatively thick, opaque, extends between both cerebellar hemispheres, and is continuous with the spinal arachnoid mater (Fig. 2). It is also connected to the pia mater of the cerebellum with a variable number of trabeculae, some of which may be also anchored in the dura. The volume of the cisterna magna is mainly determined by the size of the cerebellar tonsils and the distance between them, as well by the size and shape of vermis (Fig. 3). In the studied specimens the smallest distance between cerebellar tonsils ranged from 2.0 to 8.4 mm, with mean value of 4.9 mm (detailed results of measurements are presented in Table 1). The shortest distance between the obex and vermis (usually the

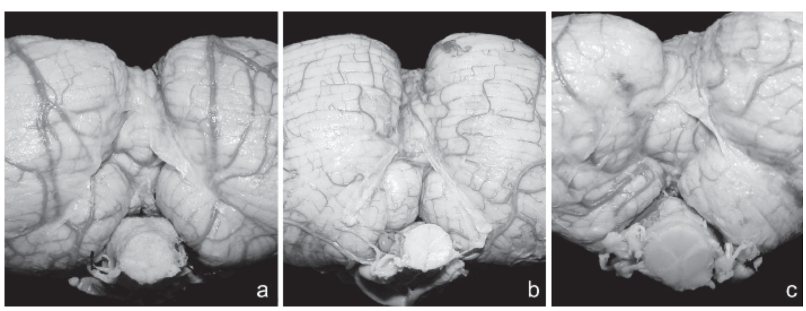

Figure 3. Different forms of the cisterna magna: high wide (**A**), high narrow (**B**), and low (**C**).

Table 1. Results of measurements taken in millimetres

Measurement	Range	Mean ± SD
Minimal distance between cerebellar tonsils	2.0–8.4	4.91 ± 1.77
Minimal distance between obex and vermis	2.0–13.0	6.35 ± 3.20
Width of left gracile tubercle	3.0–4.8	4.03 ± 0.52
Width of right gracile tubercle	3.2–5.0	4.12 ± 0.52
Width of Magendie foramen from left to midline	2.0–5.8	3.57 ± 0.89
Width of Magendie foramen from right to midline	0.8–4.6	2.95 ± 0.93
Total width of Magendie foramen	4.0–9.4	6.53 ± 1.54
Length of left caudal sagittal choroid plexus	0.2–14.0	6.61 ± 4.15
Length of right caudal sagittal choroid plexus	0.0–18.4	7.85 ± 5.55

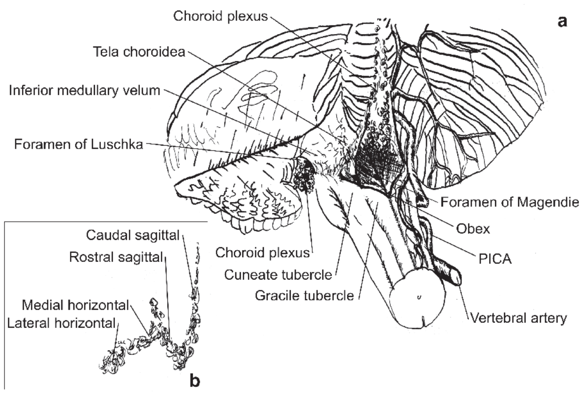

Figure 4. A. General appearance of the median aperture of the fourth ventricle after resection of the large part of the left cerebellar hemisphere. Posterior left view. The posterior inferior cerebellar artery (PICA) branching from the vertebral artery is shown on the right side; **B.** Left part of the choroid plexus of the fourth ventricle 'taken out' from the drawing above. Segments of plexus according to Sharifi et al. [17].

nodulus or uvula of vermis) was even more variable and ranged from 2.0 to 13.0 mm.

As the fourth ventricle can be compared to a tent, the median aperture appears as a rhomboid entrance to this tent. It is surrounded inferiorly by the gracile tubercles with the obex between them and superolaterally by the tela choroidea with the choroid plexus attached to the vermis (Fig. 4).

The obex is defined as a visible bridge over the opening of the central canal in the inferior pole of the rhomboid fossa. It was present in 21 (70%) cases as a band of nervous tissue, in 6 (20%) cases only as thickened band of leptomeninx, and was absent in 3 (10%) cases (Fig. 5).

On both sides of the posterior median sulcus of the medulla oblongata there are gracile tubercles at the superior ends of the gracile fascicles. Contrary to the more lateral cuneate and rare trigeminal tubercles they can be always easily distinguished. The mean width of the gracile tubercle in the examined specimens was 4.1 mm.

Rostral to the gracile tubercles, the surface of the dorsal medulla is covered with pia mater containing a net of blood vessels that ends sharply in the V-shaped border of the rhomboid fossa, which is lined with ependyma and has no visible vessels on its surface. The tip of the letter V leading to the central canal is usually covered with the obex, as mentioned above. The arms of the letter V are free right above the gracile tubercles and form the lower margin of the median aperture. Laterally they continue as a line of attachment for the posterior roof of the ventricle (taenia of the fourth ventricle). This posterior part of the roof consists of the paired inferior medullary velum and choroid membrane. Laterally it is limited by the lateral aperture of the fourth ventricle. The more medially we move, the more the nervous tissue of the inferior medullary velum disappears and we notice semi-translucent pial-ependymal choroid membrane. The free medial margin of the choroid membrane forms the upper margin of the median aperture. The angle between the lower and upper margins is the most lateral point of the median aperture. The width of the median aperture measured at this level ranged from 4.0 to 9.4 mm. The choroid membrane is usually (27 cases of 30) connected to the arachnoid membrane with a net of arachnoid trabeculae, of varying thickness. Perforations in the tela choroidea were noticed in 20 cases. In 4 cases on the left side and in 8 cases on the right (which makes in total 20%) the loop of the posterior inferior cerebellar artery was firmly attached to the tela choroidea by trabeculae. In these and other cases arterioles branching from the posterior inferior cerebellar artery may be incorporated in the choroid membrane (Fig. 6).

Two longitudinal arms of the choroid plexus of the fourth ventricle turn posteriorly and superiorly at the plane of median aperture and are delicately attached to the leptomeninx of the uvula or pyramid of vermis (actually to the arachnoid which is filling the vallecula, not directly to the pia). These arms of the choroid plexus were of equal length in 25 cases. The length of the caudal sagittal segments of the plexus ranged from 0 to 18.4 mm. Rarely their attachment was not symmetrical. There is a thin, narrow, triangular membrane of the tela choroidea preserved between both arms of the plexus. The choroid plexus is fixed to the vermis and to the arachnoid of the cisterna magna by arachnoid tracts, which are continuous with the plexus and variable in number and shape (Fig. 7).

DISCUSSION

The characteristic diamond-shaped appearance of the median aperture of the fourth ventricle was presented in detail. In 1853 Hirschfeld, contemporarily to Magendie, described the caudal roof of the fourth ventricle in the form of two fused "valves of Tarin", as the inferior medullary velum used to be referred to that time, which surrounded the "in-

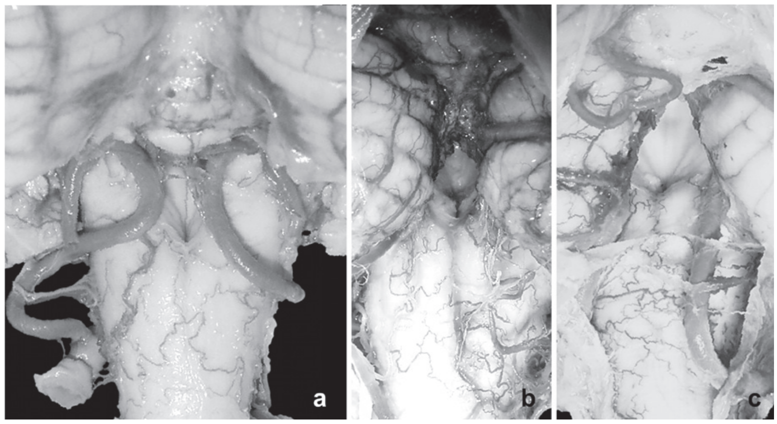

Figure 5. Variations of the inferior angle of the rhomboid fossa; **A.** Neural and leptomeningeal obex is hiding the entrance to the central canal; **B.** Only meningeal obex and posteromedian medullary vein; **C.** No obex present.

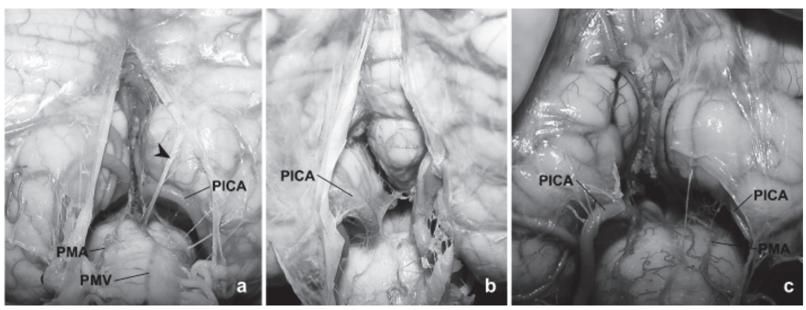

Figure 6. Vascular relationships around the median aperture of the fourth ventricle; **A.** Large caudal loops of both posterior inferior cerebellar arteries (PICA) meeting at midline, without attachment to the roof of the ventricle. Very rare bridging collateral (arrowhead) of the posteromedian medullary vein (PMV) is traversing the cisterna magna; **B.** Vertically oriented caudal loops of PICAs anchored by arachnoid laminae and trabeculae; **C.** Despite the fact that the right PICA is hypoplastic and is not in contact with ventricular roof, its branch — posterior medullary artery (PMA) is firmly attached to the tela choroidea.

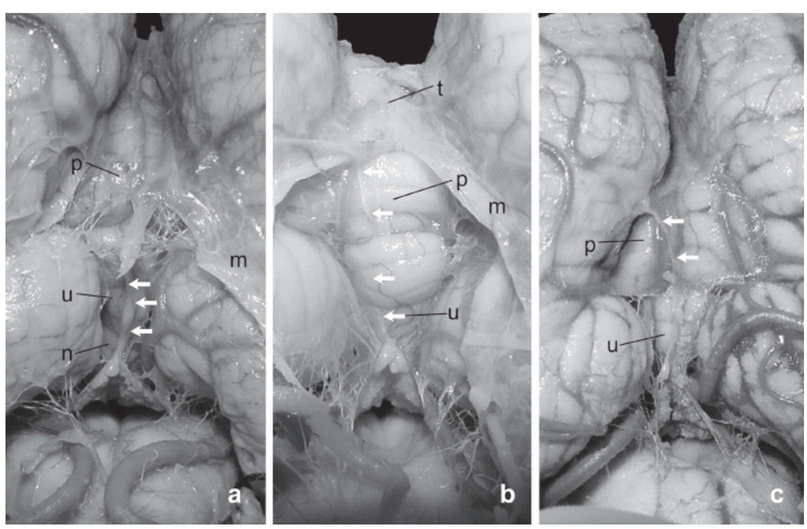

Figure 7. Different forms of the caudal sagittal segments of the choroid plexus of the fourth ventricle; **A.** Symmetrical segments continue as prominent tract/trabecula (arrows), which has falciform attachment to the cerebellomedullary membrane (m); **B.** A thinner tract is climbing the vermis to reach the left paramedian groove at the level of attachment of the cerebellomedullary membrane; **C.** Case of asymmetrical caudal segments of plexus with asymmetrical attachment of the trabecula; n — nodulus; u — uvula; p — pyramid; t — tuber of cerebellar vermis.

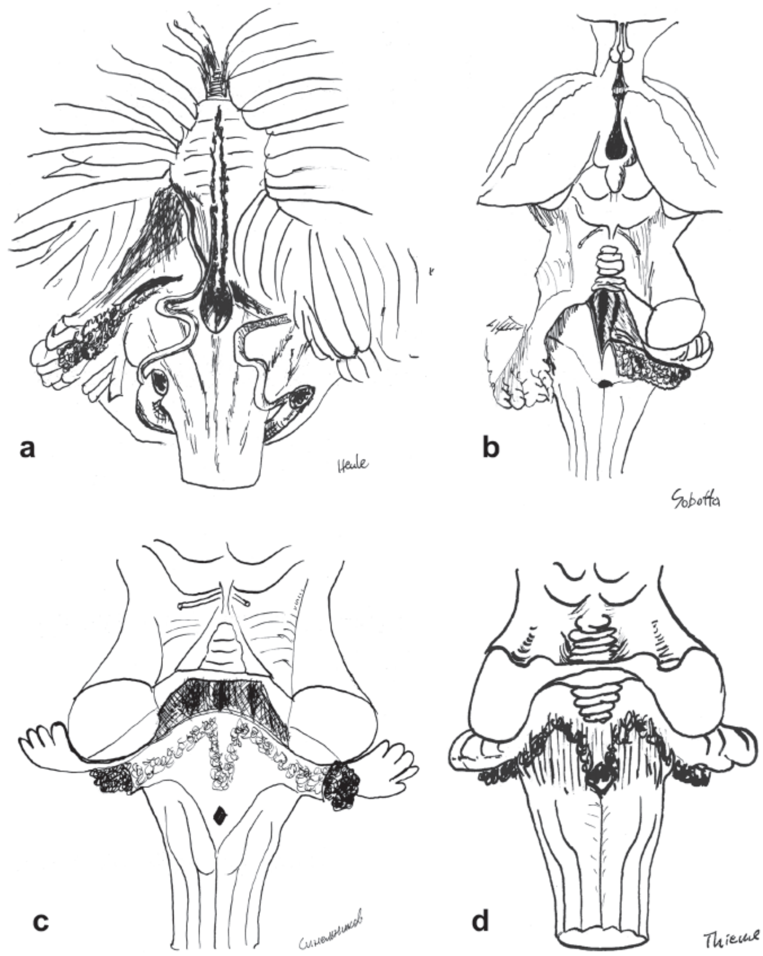

Figure 8. The median aperture of the fourth ventricle drawn from: **A.** J. Henle's anatomical textbook and atlas (from Polish edition of 1916) [5]; **B.** J. Sobotta's anatomical atlas — picture reproduced also in the most recent editions [19]; **C.** R.D. Sinelnikov's anatomical atlas [18]; **D.** The New Prometheus atlas of anatomy [16]. The oldest book seems to have the most adequate illustration.

termediate orifice" of the ventricle [6]. The description of the foramen borders by Key and Retzius [7], Blake [2], Rogers and West [15], Barr [1], Hewitt [4], and Rhoton [14] is similar to that of our study. Non-significant discrepancies between these papers may be explained by the use of adult and foetal specimens and observation of the Magendie foramen on histological sections performed at different angles. Nevertheless, even in some contemporary textbooks and atlases (Fig. 8) the median aperture appears as a small, round perforation in the caudal roof of the ventricle. Multiplied vision of a round aperture originates most probably from the original Magendie description: "The communication [of the fourth ventricle with the spinal subarachnoid space] is established by a round opening placed between the two posterior cerebellar arteries, which is two or three lines in diameter" [9]. Further he described its boundaries formed by blood vessels of the pia running to the "choroid plexus of cerebellum", "internal part of stria terminalis" on the sides and the "calamus scriptorius" inferiorly (after Clarke and O'Malley [3]). Teaching students with the use of incorrect illustrations may lead to erroneous statements about the insignificance of the Magendie foramen for the circulation of cerebro-spinal fluid.

Based on our knowledge from existing literature on studies of cerebrospinal fluid circulation, there are no detailed quantitative studies of the median aperture of the fourth ventricle. The only dimension given by Magendie is a "diameter of two or three lines", which makes about 4–6 mm [3]. It would be a slightly smaller opening than the one "admitting the point of the finger", as Rogers and West suggested [15]. Earlier, Key and Retzius described the variability of the foramen and its width between 5 and 8 mm [7], and Wilson, taking part in a contemporary discussion on the existence of the Magendie aperture, referred to these results [21]. Barr measured the width of the foramen to be on average 5 mm with a minimum of 1 mm [1].

The inferior pole of the rhomboid fossa is an important landmark of the median aperture. Here the obex, if present, hides the entrance to the central canal of the medulla. Wilson [20, 21] described types of the obex similar to those presented here based on histological studies.

Hewitt [4] wrote a paper in support of Barr's description of the Magendie foramen and noticed the presence of "the triangular fold containing the lower part of the choroid plexus and attached to the pia over the anterior end of the inferior vermis". His observations on the terminal part of the plexus and its variability are concurrent with ours.

The close relationship of the loop of the posterior inferior cerebellar artery (PICA) with the walls of the fourth ventricle are widely known and have been extensively studied especially in Rhoton's laboratory [8, 13]. Sharifi et al. [17] described branches of the PICA supplying the choroid plexus of the fourth ventricle running on the surface of the telo-velar roof of the ventricle. This anchoring of the PICA, also by medullary branches, may make any attempt to widen the Magendie foramen laterally very difficult during neurosurgical approaches to the ventricle through the cerebellomedullary fissure as proposed by Matsushima et al. [12].

Most anatomists are aware of the arachnoid membrane that posteriorly closes the cisterna magna [11]; however, its continuity with other cranial and spinal membranes, as well as its function in directing the flow of cerebro-spinal fluid flow, requires further studies.

The dimensions of the cerebellar tonsils and cisterna magna are highly variable and should always be individually assessed before planned intervention in the area of the Magendie foramen.

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REFERENCES

1. Barr ML (1948) Observations on the foramen of Magendie in a series of human brains. Brain, 71: 281–289.
2. Blake JA (1900) The roof and lateral recesses of the fourth ventricle, considered morphologically and embryologically. J Comp Neurol, 10: 79–108.
3. Clarke E, O'Malley CD (1996) The human brain and spinal cord. A historical study illustrated by writings from antiquity to the twentieth century. 2nd Ed. Norman Publishing, San Francisco.
4. Hewitt W (1960) The median aperture of the fourth ventricle. J Anat, 94: 549–551.
5. Henle J (1901) Grundriss der Anatomie des Menschen. 4th Ed. Friedrich Vieweng und Sohn, Braunschweig.
6. Hirschfeld L, Leveillé J-B (1853) Névrologie ou description et iconographie du système nerveux et des organes des sens de l'homme avec leur mode de préparation. J.-B. Baillière, Paris.
7. Key EAH, Retzius MG (1875) Studien in der Anatomie des Nervensystem und des Bindegewebes. Samson & Wallin, Stockholm.
8. Lister JR, Rhoton AL Jr, Matsushima T, Peace DA (1982) Microsurgical anatomy of the posterior inferior cerebellar artery. Neurosurgery, 10: 170–199.
9. Magendie F (1828) A physiological memoir upon the brain. From the French of M. Magendie by Joseph Gardner MD. Philadelphia.
10. Magendie F (1833) Précis elémentaire de physiologie. Troisième édition, corrigée, augmentée et ornée de six planches nouvelles. Méquignon-Marvis Père et fils, Paris.
11. Matsuno H, Rhoton AL, Peace D (1988) Microsurgical anatomy of the posterior fossa cisterns. Neurosurgery, 23: 58–80.
12. Matsushima T, Inoue T, Inamura T, Natori Y, Ikezaki K, Fukui M (2001) Transcerebellomedullary fissure approach with special reference to methods of dissecting the fissure. J Neurosurg, 94: 257–264.
13. Mussi ACM, Rhoton AL (2000) Telovelar approach to the fourth ventricle: microsurgical anatomy. J Neurosurg, 92: 812–823.
14. Rhoton AL (2000) Cerebellum and fourth ventricle. Neurosurgery, 47 (3 Suppl.): S7–S27.
15. Rogers L, West CM (1931) The foramen of Magendie. J Anat, 65: 457–467.
16. Schuenke M, Schulte E, Schumacher U (2007) Head and neuroanatomy. Thieme atlas of anatomy. Georg Thieme Verlag, Stuttgart.
17. Sharifi M, Ciołkowski M, Krajewski P, Ciszek B (2005) The choroid plexus of the fourth ventricle and its arteries. Folia Morphol, 64: 194–198.
18. Sinelnikov RD (1974) Atlas of human anatomy. Russian. 4th Ed. Medicina Publishers, Moscow.
19. Sobotta J (1938) Descriptive anatomie. 9. Auflage. J.F. Lehmanns Verlag, München/Berlin.
20. Wilson JT (1906) On the anatomy of the calamus region in the human bulb; with an account of a hitherto undescribed "nucleus postremus". Part I and II. J Anat Physiol, 40: 210–241, 357–386.
21. Wilson JT (1937) On the nature and mode of origin of the foramen of Magendie. J Anat, 71: 423–428.