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ANATOMICAL SIGNIFICANCE OF THE CONCEPT OF THE CONFLUENS OF THE SUBARACHNOID SPACE. IMPLICATIONS IN FORENSIC INVESTIGATION

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Abstract: The existence of a large number of unsolved issues concerning topografic and structural anatomy of the accumulation (the confluens) and draining (the cistern) compartments of the cerebrospinal fluid from within the subarachnoid space required the analysis of the determining factors that lie at the basis of nomenclature, localization and evaluation of the latter in the sites of the cerebral fossae. The investigation was carried out on 10 brains, 6 taken from adult corpses aged between 45 and 60 years of age and 4 from newborn corpses free from acute, chronic or posttraumatic lesions. Multifactorial anatomy analysis, of the geometric form, its spatial orientation and limitation was carried out on the compartmenting structures. (the confluents and the cisterns), as well as on the arterial and vein vascular structures grouped into 4 cerebral fossae : the rostral cerebral fossa, the basal cerebral fossa, the dorsal cerebral fossa and the caudal cerebral fossa permanently in biunivocal correspondence with the cranial fossae. We believe that the existence of arteries in the cerebral fossae ensures the rhythmicity of the pulsations upon the compartmental structures, the draining of the cerebrospinal fluid into the subarachnoid space. It is equally important to approve that the accumulation compartments of the cerebrospinal fluid should be called confluents of the subarachnoid space, its acceptance in the International Anatomic Terminology repairing a historic error regarding this concept. The results of our study have important implications both in forensic neuropsychiatry as well as in investigation neurosurgery with the view of carrying out the punctures of the confluens.

Keywords: subarachnoid space, the confluent of subarachnoid space, cisterns of the subarachnoid space, forensic and neurosurgical investigation.

INTRODUCTION

The morphological study of the subarachnoid spaces is of special interest in topographic and functional evaluation of the confluens and cisterns of the cerebrospinal fluid and on the latter's implications in forensic investigation, on the one hand and, in neurosurgery on the other. The concept of confluens, presented by François Magendie (1825)[1] to term the expanded intervals in the subarachnoid space, is present in French literature as "Les confluens du Magendie". This concept was taken over by Charpy (1853)[2], but later abandoned by all schools involved in the working out of the International Anatomic Terminology (Table 1). Hubert von Luschka (1855)[3] supported the concept of confluens of the subarachnoid space, but re-termed it subarachnoid sinuses. Gustav M. Retzius (1842 - 1919)[4] takes up this issue but completely minimizes the anatomic and functional differences between the confluens compartments and the drainage cisterns, naming them both as les citerns (Eponym: Les Citerns du Retzius). It is neurosurgeon Henry Duret's merit (1920)[5] to have termed the two entities according to their anatomic and functional status, i.e., the accumulation compartments as les lacs (the confluens), pre-existent in French literature as les confluents du Magendie, but never accepted in any International Anatomic Terminology, and the drainage compartments as "les fluves", later called the cisternae subarachnoidae (Table 1).

The study of the confluens of subarachnoid space, in the context of their localization in the cerebral fossae, renders evident the cerebrospinal acccumulation sites, as well as the diffusion of brain hemorrhages on the one hand, and the election sites for collecting the fluids from these confluence sites, on the other.

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The aim of the present study is to shed light on cerebrospinal fluid accumulation compartments (the confluens) and drainage (the cisterns) as well as on their relations with the neighboring vascular structures.

The objective is the anatomic, topographic and structural analysis of the cerebral fossae as sites and evaluation of the confluens of the subarachnoid space.

MATERIALS AND METHOD

For the anatomic, topographic and structural analysis of the cerebral fossae and for the evaluation of spatial distribution of branches of the internal carotid artery and basilar artery we used 10 brains of which 6 were taken from adult corpses aged between 45 and 60 and 4 from newborn corpses, free from acute, chronic or posttraumatic lesions.

After minute washing in tap water for 4 hours the fixation of the anatomic samples was done in two stages, i.e. the first step in 10% formaldehide solution buffered with calcium carbonate, pH = 7.2 was used for 3 days, followed by a second fixation stage in 5% buffered formaldehide solution, pH = 7.2 for 3 months.

The anatomic analysis of localization and relations within the cerebrals fossae was carried out by studying the basal faces of the midbrain and forebrain for the rostral cerebral fossa and the basal cerebral fossa (Fig. 1), on the one hand as well as by studying the medial sagittal sections, through the rhomencephalon for the dorsal cerebral fossa and the caudal cerebral fossa (Fig. 3). The images were taken by macrophotography on Camera Canon Eos 1Ds and Macro-Ultrasonic Lens EF 100 mm F/1,8. The processing of the images was done on Adobe Photoshop C 55.1 (64Bit).

RESULTS

The substantiation on anatomic bases of the concept of confluens of the subarachnoid space was achieved by evaluating 4 loci of the so-called cerebrals fossae, i.e. the rostral cerebral fossa, the basal cerebral fossa, the dorsal cerebral fossa and the caudal cerebral fossa (Table 2).

A. Topographic and structural anatomy of the rostral cerebral fossa

On examining the basal face of the telencephalon we identified the rostral cerebral fossa situated pre-chiasmatically, in median sagittal plane.

The geometrical form resembles a triangular pyramid frustum with convex faces spatially limited and directed as follows: the small base face is orientated towards the rostrum up to the transverse cerebral fissure of Bichat; the large base face is orientated caudally up to the optic chiasma; the lateral faces are orientated towards the gyrus rectus while the basal face is orientated towards the rostrum where it is limited by arachnoid bridging (Fig. 1). The arachnoid bridging is a structure passing from the chiasmatic cistern to the cistern of lamina terminalis which we termed "intercistern arachnoid trabecule"and is made up of 3 parts, i.e. prechisamatic part, transchiasmatic part and retrochiasmatic part.

Table 1. Variability of compartmental terminology of the subarachnoid space in international anatomical terminology

International anatomical terminology	Terminological variation		
	Subarachnoid space	Draining compartment	Accumulation compartment
1	2	3	4
FAT(1892) ***(7)*** French Anatomical Terminology	***ESPACE*** *Sous Arachnödies*	***CANAUX*** *Les Citerns du Retzius,1842;* ***Les fluves du Duret, 1920***	***CONFLUENTS*** *Les Confluents du Magendie, 1825; Les Citerns du Retzius 1842* ***Les lacs du Duret, 1920***
BNA (1895) (*8*) Basel Nomina Anatomica	***CAVUM*** *SubArachnoideale*	***CISTERNA*** *SubArachnoideales*	NO
JNA (1936) ***(9)*** Jena Nomina Anatomica	***CAVUM*** *LeptoMeningicum*	*Cisternae LeptoMeningicae*	NO
PNA (1955) ***(10)*** Paris Nomina Anatomica	***CAVUM*** *SubArachnoideale*	*Cisternae SubArachnoideae*	NO
IAT (1998) ***(11)*** International Anatomical Terminology	***SPATIUM*** *SubArahnoideum Synonym: Spatium LeptoMeningeum*	*Cisternae SubArachnoideae*	NO
TNA (2016) ***(6)*** Terminologia Neuro Anatomica	***SPATIUM*** *SubArahnoideum*	*Cisternae SubArachnoideae*	NO

Table 2. Topofraphic and structural anatomy of the subbarachnoid space

CONFLUENTS (1 + 6)						CISTERNS (7 and 8)	
Terminology Fat (1892) și Current term (2022)	**Localization**	**Geometrical form**	**Spatial orientation and delimitation**	**Content**	**Drainage**	**Denomination in TNI (2016)**	**Affluents**
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**
ANTERIOR CONFLUENT ***Current term:*** **ROSTRAL CONFLUENT**	**ROSTRAL CEREBRAL FOSSA** Rostral with reference to the optic chiasma	Triangular pyramidal frustum and convex faces	**Small base face is** orientated rostrally towards the transverse cerebral fissure of Bichat. The large base face is orientated caudally towards the optic chiasma. **Lateral faces** towards the gyrus rectus. The basal face towards the arachnoid bridging	A1 Segment of anterior cerebral artery; Anterior perforating arteries	Basal confluent	***CISTERN OF LAMINA TERMINALIS***	***CISTERN OF LATERAL FOSSA***
INFERIOR CONFLUENT ***Synonym: CENTRAL CONFLUENT*** ***Current term:*** **BASAL CONFLUENT**	**BASAL CEREBRAL FOSSA** Rostral with reference to the optic chiasma	Quadrilateral form and convex faces	**He rostra The rostral side** towards the Optic chiasma. **The caudal side towards** the Ponce. **The lateral side** towards the medial faces of the temporal lobe. **Divisions:** 1).Chiasmatic part; 2).Interpeduncular part; 3).Prepontine part.	Cerebral vascular Circle ; Proximal part of the Sylvian fissure Liliequist membrane ***(12)***	Rostral Confluent;	***CHIASMATIC CISTERN*** ***INTERPEDUNCULAR CISTERN*** ***PREPONTINE CISTERN***	***CISTERN OF LATERAL FOSSA ;***
SUPERIOR CONFLUENT ***Current term:*** **DORSAL CONFLUENT**	**DORSAL CEREBRAL FOSSA** Caudal with reference to the tentorium cerebelli	Rhomboendron (parallelopiped made up of 6 parallelograms)	**The rostral face** towards Quadrigeminal plate. **The dorsal face** towards the Splenium of corpus callosum. **The caudal face** towards the Vermis of cerebellum **The lateral faces** towards the Interpeduncular cistern. **The basal face** towards the tentorium cerebelli	P4 Segment of posterior cerebral artery; Quadrigeminal artery; IX; Vena Galien; Pineal gland	Basal confluent via Interpeduncular cistern	***QUADRIGEMINAL CISTERN*** ***Synonyms : Superior cistern; Cistern of great cerebral vein***	***AMBIENS CISTERN***
POSTERIOR CONFLUENT ***Current term:*** **CAUDAL CONFLUENT**	**CAUDAL CEREBRAL FOSSA** Basal with reference to the tentorium cerebelli	Quadrillateral pyramid frustum and convex faces	**The small face base** is orientated rostrally towards the median aperture (Magendi) **The large face base** is orientated caudally towards the transverse cerebral fissure of Bichat. **The basal face** towards the dorsal face of the Medulla oblongata. **The dorsal face** towards the lower face of the vermis of cerebelli. **The lateral faces** towards the Amygdaloid body	Inferior posterior cerebelli artery	Basal confluent	***POSTERIOR CEREBELLO-MEDULLARY CISTERN.*** ***Synonym: Cisterna magna***	***FOURTH VENTRICLE VIA MEDIAN APERTURE;*** ***INTERPEDUNCULAR CISTERN.***

The rostral cerebral fossa contains the cistern of lamina terminalis, with it's affluent, the cistern of lateral fossa which is drained into the basal confluent. The dissection of the vascular structures of the rostral cerebral fossa enabled the visualization of the following arteries: the anterior cerebral artery, anterior communicating artery, recurrent artery of Heubner (TNA, 2016, Latin [6]: arteria striata longa), medial frontobasal artery and polar frontal artery as branches of the post-communicating part of the anterior cerebral artery and, last but not least, of the median callosal artery as branch of the anterior communicating artery of the anterior cerebral artery. We also identified the anterior cerebral vein (Fig. 2).

B. Topographic and structural anatomy of the basal cerebral fossa

The basal cerebral fossa was easily visualized in median sagittal plane on the base of the midbrain and the forebrain, caudally from the optic chiasma.

The geometric forms resembles a quadrillateral form with convex sides orientated and spatially limited as follows, i,.e. the rostral side is orientated towards the optic chiasma; the caudal side is orientated towards the ponce while the laterals are orientated towards the medial faces the temporal lobe (Fig. 1). The structural heterogeneity of this fossa relief led to a triple division, as follows:

a). The chiasmatic part that is limited towards the rostrum by the optic chiasma; laterally from the uncus of the hippocampal gyrus, by the optic nerve and the distal segment of n. oculomotorius; dorsally by the tuber cinereum of the hippothalamus while caudally by the diencephalic part of the Liliequist's membrane (Fig. 1 B1);

b). Interpeduncularis part was identified as a space situated between the cerebral peduncles and limited rostrally by the chiasmatic part through the tangent plane to the mammillary body and caudally by a frontal plane through the subarachnoidian part of the oculomotor nerves (Fig. 1 B2);

c). The prepontine part situated at the caudal extremity of the basal cerebral fossa is limited caudally by the pons and basally by a small indentation (Clivus) that marks the basilar part of the occipital bone and rostrally makes connection to the sphenoid bone (Fig.1B3).

The basal cerebral fossa has 3 cisterns, i.e.: the chiasmatic cistern, the interpeduncular cistern and the prepontine cistern. Its affluent is the cistern of lateral fossa and drains into the rostral confluent.

The dissection of vascular structures from the basal fossa enabled the visualization of the blood vessels that make up the cerebral circle (Fig. 2B).

C. Topographic and structural anatomy of the dorsal cerebral fossa

The dorsal cerebral fossa was identified in median sagittal plane, caudally from the tectum of the midbrain.

The geometrical form resembles a rhomboedron, i.e. a parallelopiped with 6 parallelopipedic faces orientated and limited as follows: the rostral face is orientated towards the quadrigeminal plate; the dorsal face is orientated towards the splenium of the corpus callosum; the caudal face is orientated towards the vermis of the cerebellum; lateral faces are orientated towards the cerebral peduncles, while the basal face is orientated towards the incisura of the tentorium cerebelli (Fig. 3A).

The dorsal cerebral fossa contains the quadrigeminal cistern (Synonym – Superior cistern or Cistern of great cerebral vein), its affluent is the ambient cistern and drains into the basal confluent via the Interpeduncular cistern.

The dissection o the dorsal cerebral fossa enabled the visualization of the pre-communicating part of the posterior cerebral artery, the Quadrigeminal artery, Vena Galien, IX nerve and the Pineal gland (Fig.3A).

D. Topographic and structural anatomy of the caudal cerebral fossa

The caudal cerebral fossa was identified at the base of the tentorium cerebelli. Its geometric form is a quadrilateral pyramid frustum with convex faces orientated and spatially limited as follows: the small base is rostrally orientated towards the median aperture (Magendie); the large base face is orientated caudally towards the transverse cerebral fissure of Bichat; the base face is orientated towards the dorsal face of the medulla oblongata; the dorsal face is orientated towards the lower face of the vermis of cerebelli while the lateral faces are orientated towards the amygdalod body (Fig. 3B).

The caudal cerebral fossa contains the posterior cerebellomedullary cistern (Synonym: Cisterna magna) whose afluents are the fourth ventricle via the median and lateral apertures and the interpeduncular cistern and drains into the basal confluent. The dissection of the vascular space enabled the visualization of the inferior posterior artery.

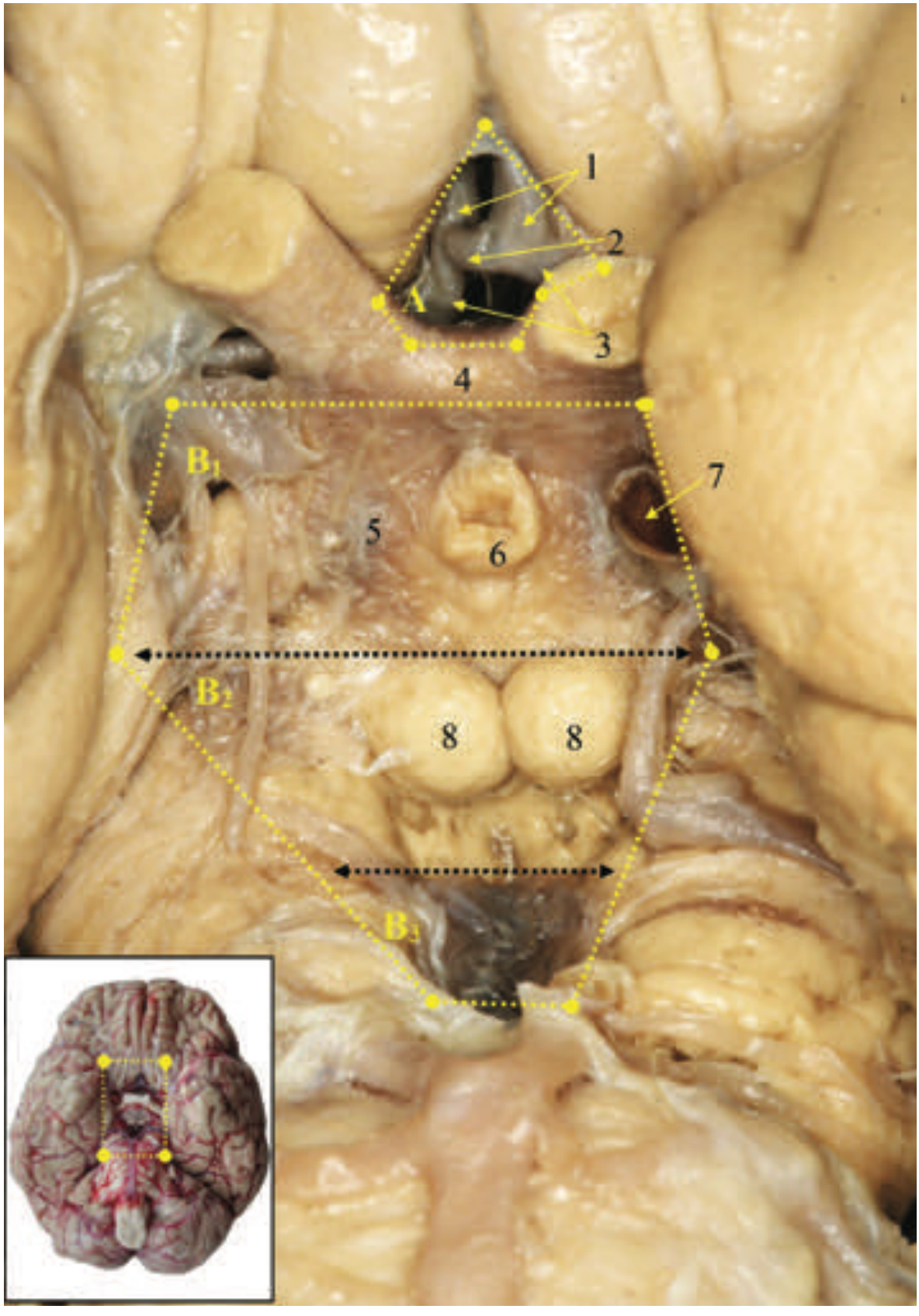

Figure 1. Spatial limitation of the cerebral fossae at the level of the basal face of the midbrain and forebrain: *A. Rostral cerebral fossa. B. Basal cerebral fossa* : B1-Chiasmatic part; B2-Interpeduncularis part B3- Prepontine part.1. Postcommunicating part of the anterior cerebral artery 2. Anterior communicating artery 3. Precommunicating part of the anterior cerebral artery 4. Optic chiasma 5.Tuber cinereum 6. Infundibulum 7. Internal carotid artery 8. Mammillary body.

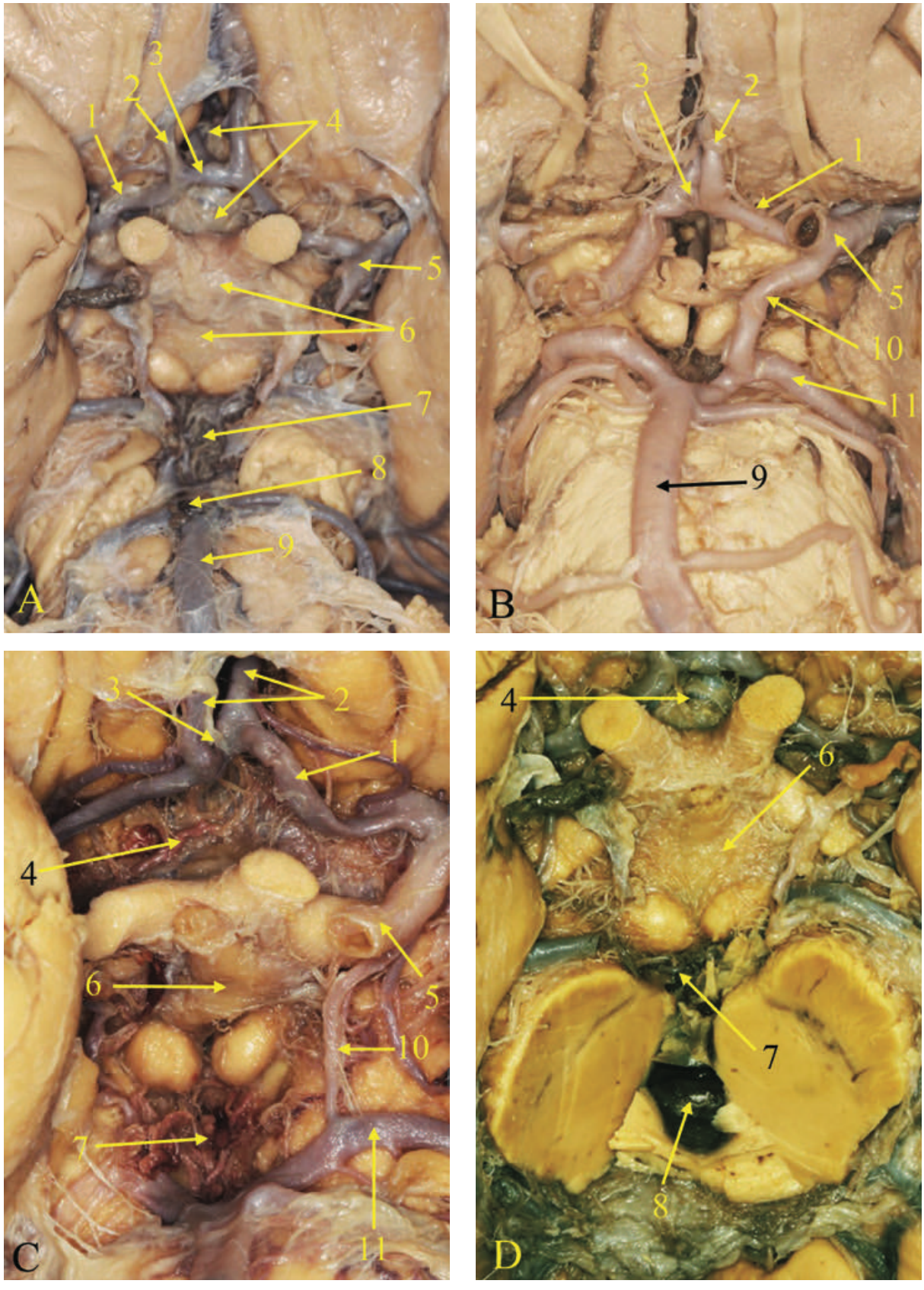

Figure 2. Dissection of the branches of the internal carotid artery and basilar artery. 1. Precommunicating part of the anterior cerebral artery 2. Postcommunicating part of the cerebral artery 3. Anterior communicating artery 4. Rostral cerebral fossa 5. Internal carotid artery 6. Chiasmatic part of the basal cerebral fossa 7. Interpeduncular part of the basal cerebral fossa 8. Prepontin part of the basal cerebral fossa 9. Basilar artery 10. Posterior communicating artery 11. Posterior cerebral artery.

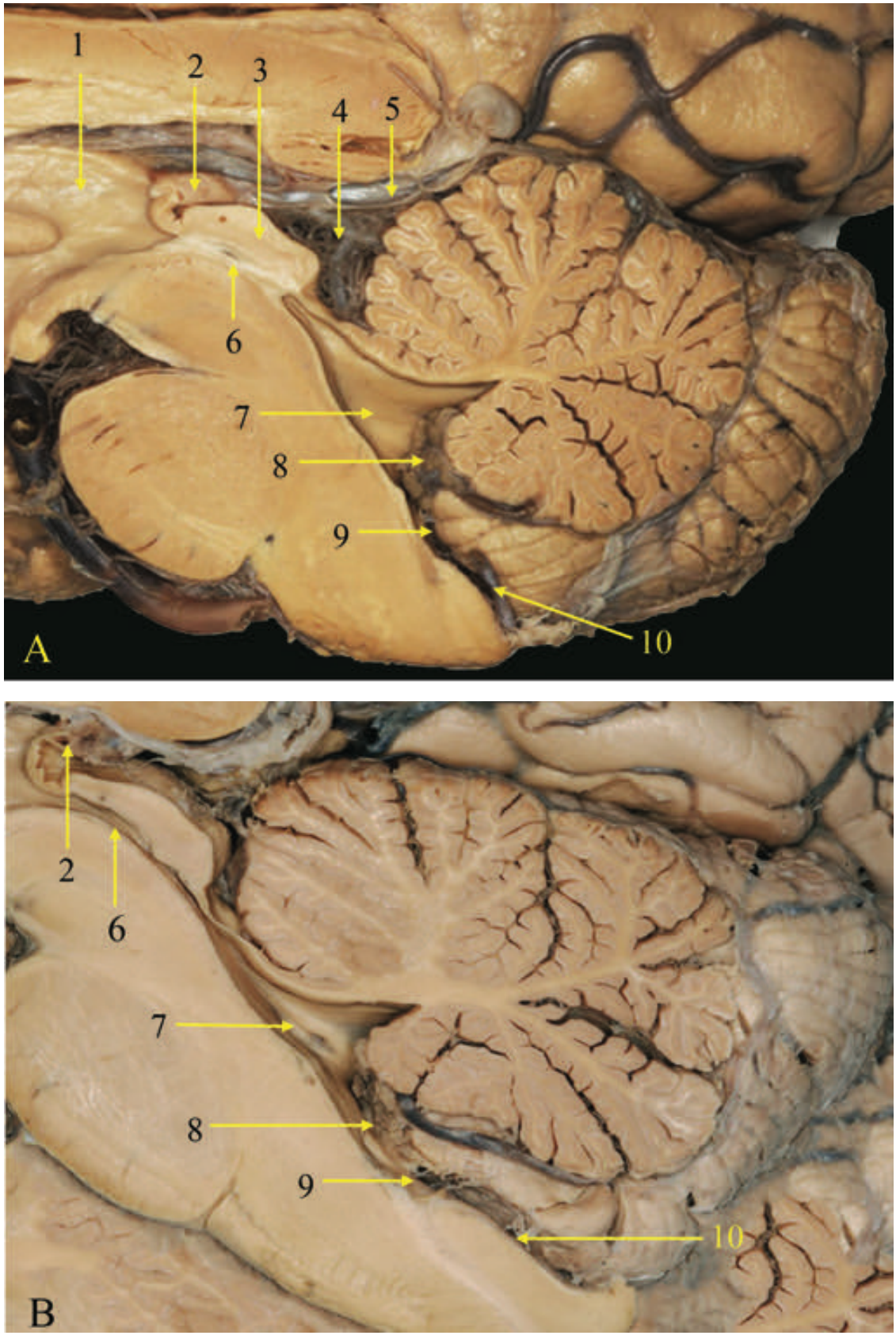

Figure 3. Median sagittal section through the midbrain and rhombencephalon. Localization, orientation and spatial limiting of the dorsal cerebral fossa (A) şi caudal cerebral fossa (B). 1. Third ventricle 2. Pineal body 3. Quadrigeminal plate 4. Dorsal cerebral fossa 5. Great cerebral vein (Galien) 6. Aqueduct of midbrain 7. Rhomboid fossa of the fourth ventricle 8. Choroid plexus of fourth ventricle 9. Median aperture of fourth ventricle (Magendie) 10. Caudal cerebral fossa.

DISCUSSION

Deciphering the morphology of accumulation (The confluens) and draining (The cisterns) compartments of the cerebrospinal fluid into the subarachnoid spaces is difficult because of the existence of several issues associated to: 1) the absence of a unitary concept to name these compartments; 2) the diverse terms existing in the International Anatomic Terminology; 3) uncertainty regarding localization, geometry, spatial limits and content of the cerebrals fossae; 4) terming and localizing these compartments and, last but not least, 5) the complete absence of correlations between the cerebrals fossae and the cranial fossae to be used for the localization and limiting of the compartments of the subarachnoid spaces.

Our anatomic study is based on the evaluation of the cerebral fossae as localization of these compartments. Special interest was payed to the localization and relations between the confluents and the vascular structures at this level.

The anatomic and functional knowledge of the confluents of subarachnoid spaces is of utmost importance in forensic neuropathology as well as in neurosurgical explorations by puncture in order to collect cerebrospinal fluid.

CONCLUSIONS

1. Anatomic, multifactorial, topographic and structural evaluation of the subarachnoid spaces brings more details on the circulation of the cerebrospinal fluid.

2. It is important to admit the term confluens for the accumulation compartments and introduce the term in the International Anatomic Terminology, the correction of a historic error.

3. The analysis of the spatial organization of the cerebral fossae in direct correlation with the cranial fossae enables the evaluation of the factors that admit the cerebral diffusion in traumatisms of the skull with fracture at the cranial base.

4. Due to the presence of arteries in the cerebral fossae their pulsating rhythmicity gives force to the cerebrospinal fluid to flow into the subarachnoid space.

Conflict of interest

The authors declare that they have no conflict of interest.

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