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Original Article

The rule of five: A novel anatomical landmark for approaching cavernous sinus content

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ABSTRACT

Background: The main objective of this study is to enhance neurosurgeons' anatomical knowledge by providing specific anatomical references of the cavernous sinus (CS). However, it is essential to clarify that our study does not seek to establish an absolute intraoperative rule due to the inherent anatomical variability that must be considered.

Methods: Fifty-three cadaveric specimens were procured from the Forensic Institute (Bogotá) and subjected to dissection through an extradural approach. The measurements were taken in two distinct phases. The first phase involved the measurement of various anatomical structures in 25 specimens with respect to the anterior and posterior clinoids. The second phase, which was conducted 5 years later, involved the measurement of the distance between the foramen rotundum and the foramen ovale in 28 specimens using the L&W tools microcaliper.

Results: In 25 specimens, a perpendicular imaginary line was drawn from the lateral tip of the anterior clinoid to the floor of the medial fossa. This facilitated access to the Parkinson's triangle, which is located between the IV cranial nerve and the ophthalmic V1 nerve, revealing a constant distance of 5 mm between the lateral tip of the anterior clinoid and the IV cranial nerve. Furthermore, in 28 specimens, the mean distance from the foramen rotundum to the foramen ovale was found to be 1.3 cm bilaterally.

Conclusion: The rule of five is a valuable tool for comprehensively understanding the anatomy of the CS, providing a reference point for the different normal anatomical structures within the CS.

Keywords: Anatomy, Cavernous sinus, Cranial nerves, Microsurgical anatomy, Triangles

INTRODUCTION

The cavernous sinus (CS) is a complex and critical structure located at the base of the skull that houses several cranial nerves and blood vessels. Due to its central location and proximity to vital structures such as the internal carotid artery, the pituitary gland, and the optic chiasm, accessing the CS can be challenging and risky for neurosurgeons.[2] Even minor damage to these structures during surgery can result in severe and catastrophic consequences for the patient.[4]

Tumors and other pathologies affecting the CS can cause a variety of symptoms, including visual disturbances, diplopia, and cranial nerve palsies.[17] While such deformities may complicate surgical intervention, it is still crucial to understand the CS's normal anatomy to approach it safely and preserve neurovascular structures.

Several anatomical landmarks can guide neurosurgeons in approaching the CS safely, such as the anterior and posterior clinoid processes and the foramen rotundum and ovale.[8] However, the CS's microanatomy is complex and varies from person to person, making it challenging to approach surgically without causing damage to surrounding structures.

Technological advancements in high-resolution imaging and endoscopic techniques have improved the visualization of the CS's microanatomy, making surgical interventions more accurate and successful.[16] Nevertheless, understanding the normal anatomical relationships and landmarks of the CS is still fundamental to minimize surgical morbidity and optimize patient outcomes.

The primary objective of this study is to provide valuable insights into safe and reliable anatomical references, with the intention of strengthening the anatomical knowledge of neurosurgeons. However, it is important to clarify that our study does not claim to establish an intraoperative rule due to the anatomical variability that may exist.

MATERIALS AND METHODS

The study was approved by the Ethics Committee of the Forensic Institute of Bogotá following the principles of the Declaration of Helsinki. Dissections were performed on cadavers from the Institute of Forensic Medicine and Forensic Sciences, and specimens were selected based on specific criteria. Cadavers were chosen that had died within <4 h, had not died due to gunshot wounds to the head or blunt force trauma cranioencephalic, had not died due to hanging or strangulation, and had not died due to neurological causes or skull base fractures. In addition, cadavers with facial fractures were not included in the study.

The study was conducted in two phases, in the first phase, which was conducted earlier, measurements were taken on 25 cadaver specimens. Later, in the second phase, measurements were taken on 28 specimens. The reason for conducting the study in two phases was that during the first phase, there was an interest in measuring specific structures, and subsequently, the interest emerged in measuring the distance between the foramen rotundum and foramen ovale. However, due to the unavailability of cadavers, the study was delayed significantly.

The dissections were performed through a bicoronal incision, followed by craniotomy of the calvaria, including the pterional and temporal regions, and the brains were removed with a section of cranial nerves attached for full viewing.

To ensure accurate and precise measurements, all measurements were collected using the L&W tools microcaliper, a highly precise instrument capable of measuring with an accuracy of up to 0.01 mm.

In the first phase, the following measurements were taken on 25 cadaver specimens:

- Line perpendicularly joining the lateral tip of the anterior clinoid process with the floor of the middle fossa
- Triangle found 5 mm from the line mentioned above
- Length of the edges of the superior triangle, Parkinson's triangle, and anterolateral triangle
- Distance from the lateral tip of the anterior clinoid process to the medial aspect of the internal carotid artery as it passes from the region subclinoid to supraclinoid
- Anteroposterior distance from the lateral tip of the clinoid process anterior to oculomotor porus
- For the distance from the posterior clinoid process to the origin of the Dorello's canal, five specimens were used out of the 25 specimens chosen
- Transverse and anteroposterior diameters of the skulls studied (measured between the intracranial face on one side and the intracranial face on the other side)
- In five specimens, measurements were made between the posterior clinoid process and Dorello's canal.

In the second phase, the following measurements were taken on 28 specimens:

- Distance between the foramen rotundum to the foramen ovale.

The measurements were recorded on three separate occasions, and the mean value of each measurement was taken as the true value. In addition, all measurements collected in both phases were recorded in an Excel program, which facilitated the calculation of means and allowed for the detection of any differences among the measurements of each structure. This method provided a convenient and efficient way to visualize the data and generate graphs and charts, enabling a more comprehensive presentation of the results.

RESULTS

The dissection of 25 specimens [Table 1] revealed that only four specimens (14%) exhibited the superior triangle at 5 mm from the lateral tip of the anterior clinoid process, while the remaining specimens exhibited Parkinson's triangle (86%). The trunk of the meningohypophyseal, the C3 portion of the intracavernous internal carotid artery, and the sixth cranial nerve were found whenever Parkinson's triangle was accessed and identified, as extensively described in the first part of the study. When the superior triangle was present, the rear edge width of the triangle was <4.1 mm, with an average of 3.47 mm, and the height of the middle fossa from the lateral tip of anterior clinoid process averaged 13.89 mm.

The measurements of Parkinson's triangle were as follows: the fourth cranial nerve (side a) measured 12.53 mm,

Table 1: Anatomical findings at 5 mm from the lateral tip of the anterior clinoid process, measured perpendicular to the floor of the middle fossa and its correlation with the triangle found with that measurement.

Specimen	Distance Clinoids process A 5 mm	Base width parkinson's triangle in mm	Findings		
			Meningo pituitary	C3	V1 cranial nerve
1	PT	6	Yes	Yes	Yes
2	PT	6	Yes	Yes	Yes
3	PT	7	No	Yes	No
4	PT	7.5	Yes	Yes	Yes
5	PT	3.6	Yes	Yes	Yes
6	PT	4.4	Yes	Yes	Yes
7	PT	6.12	Yes	Yes	Yes
8	PT	6.35	Yes	Yes	Yes
9	PT	4.3	Yes	Yes	Yes
10	PT	6.3	Yes	Yes	Yes
11	PT	5.65	Yes	Yes	Yes
12	PT	4.74	Yes	Yes	Yes
13	PT	5.82	Yes	Yes	Yes
14	PT	6.54	Yes	Yes	Yes
15	PT	5.45	Yes	Yes	Yes
16	PT	6.89	Yes	Yes	Yes
17	PT	6.75	Yes	Yes	Yes
18	PT	4.8	Yes	Yes	Yes
19	PT	4.58	Yes	Yes	Yes
20	PT	5.34	Yes	Yes	Yes
21	PT	5.45	Yes	Yes	Yes
22	ST	3.2	No	Yes	No
23	ST	3.4	No	Yes	No
24	ST	3.4	No	Yes	No
25	ST	4.1	No	Yes	No

PT: Parkinson's triangle, ST: Superior triangle, C3: Horizontal segment internal carotid artery, V1: The first branch of the trigeminal (ophthalmic branch)

V-1 cranial nerve (side b) measured 10.07 mm, and the width (side c) measured 5.3 mm. The cranial nerves were measured using a perpendicular line to the floor of the middle fossa that falls from the lateral tip of the anterior clinoid process as a reference, and their length was measured until they intersected with other cranial nerves to form the triangles.

Moreover, the average distance from the medial aspect of the anterior clinoid process to the medial aspect of the emergence of the internal carotid artery from subclinoid to supraclinoidea was 8.93 mm [Table 2]. In Phase 1, the distance between the posterior clinoid process and Dorello's canal was measured in five specimens and found to be 1.34 cm on the left side and 1.3 cm on the right side [Table 3]. Finally, the average distance between the foramen rotundum and foramen ovale was 5.75 mm on the right side and 5.92 mm on the left side in the 28 specimens evaluated.

Furthermore, the measurements of the anteroposterior and transversus axis of the skull were taken without the thickness of the diploe, providing a comparison parameter [Table 2].

CS triangles

The photographs of the anatomical dissections provide a comprehensive view of the microsurgical anatomy of the CS. Figure 1 depicts the distinct triangles described around the CS, while Figure 2 illustrates the posterior superior and medial compartment of the right CS with its diverse structures. In addition, Figure 3 shows the interrelationships between the cranial nerves, revealing various anatomical landmarks and nerve structures that can be easily damaged if not accurately identified.

Figure 4 displays the vascular trunks supplied by the right internal carotid artery of intracavernous trajectory, specifically the meningohypophyseal trunk and the inferolateral trunk. The triangles present in the lateral wall of the right CS are described in Figure 5.

The fourth cranial nerve and Parkinson's triangle are vertically positioned approximately 5 mm from the lateral tip of the anterior clinoid process, while the foramen rotundum is located approximately 5 mm away from the fourth cranial nerve. In addition, there is a consistent distance of

Table 2: Reference of all the morphological aspects in mm of the dissected specimens.

	Δ Found at 5 mm	Parkinson´s Triangle (IV a, c, V1 b)	Superior Triangle (III a, c, IV)	Anterolateral Triangle (a V1, b V2)	Distance internal carotid and anterior Clinoid Process	Distance AP points anterior clinoid process to porus oculomotor	Distance from posterior clinoid process is to Dorello's canal	Distance Anterior Clinoid process to Medial Fossa	Transverse Diameter of Skull	AP skull
1	Parkinson Δ	a =16.4 b = 14 c = 6	a= 6.6 b= 16.4 c = 11.1	a = 14 b = 21	8.5	6.3	18.0	16.1	18	20
2	Parkinson Δ	a = 11.1 b = 11.4 c = 6	a= 9.6 b= 11.12	a = 11.4 b = 16.3	10.7	5	18.3	15	18	20
3	Parkinson Δ	a= 11.8 b= 12.4 c = 7	a= 7 b= 11.8 c = 5	a=12.4 b=8.85	9	6.5	13	12	16	22
4	Parkinson Δ	a= 12 b= 11.3 c =7.5	a = 9.4 b = 12 c = 4	a=11.3 b=10	11.7	6	14.9	13	16	22
5	Parkinson Δ	a= 12.2 b= 7.2 c = 3.6	a= 6.4 b= 12.2 c = 6.5	= 7.2 = 11	9.7	3.2	18	12.5	17	19
6	Parkinson Δ	a= 12 b=6.4 c= 4.4	a =6.5 b = 12 c= 6.6	a = 6.4 b = 13.4	7.4	5.3	15.5	15.4	17	19
7	Parkinson Δ	a= 15.5 b= 13.89 c = 6.12	a = 8.12 b = 15.5 c= 7.649	= 13.8 =12.2	6.95	5.45	13.92	14.7	20	21
8	Parkinson Δ	a= 20 b= 13.21 c = 6.35	a= 4 b= 20 c = 8.64	a =13.21 b=10.65	6.6	6.12	16.50	16.5	20	21
9	Parkinson Δ	a= 12 b=11 c=4.3	a=7.3 b=13 c=4.3	a=11 b=12	6.5	4.7	16.7	17.8	18	20
10	Parkinson Δ	a=16 b=7.8 c=6.3	a=5.8 b=16 c=3.76	a=7.8 b=12.34	7.8	4.56	12	12.3	18	20
11	Parkinson Δ	a=13 b=7.96 c=5.65	a=6.54 b=13 c=4.08	a=7.96 b=11.67	6.54	5.64	11.3	16.5	17	15
12	Parkinson Δ	a=11.89 b=8.92 c=4.74	a=6.78 b=11.89 c=3.67	a=8.92 b=10.45	7.1	7.2	12.34	12.2	17	15
13	Parkinson Δ	a=10.89 b=6.89 c=5.82	A=5.78 b=10.89 c=4.34	a=6.89 b=11.801	8.7	4.12	12.12	13.4	19	18

(Contd...)

Table 2: *(Continued)*.

	Δ Found at 5 mm	Parkinson´s Triangle (IV a, c, V1 b)	Superior Triangle (III a, c, IV)	Anterolateral Triangle (a V1, b V2)	Distance internal carotid and anterior Clinoid Process	Distance AP points anterior clinoid process to porus oculomotor	Distance from posterior clinoid process is to Dorello's canal	Distance Anterior Clinoid process to Medial Fossa	Transverse Diameter of Skull	AP skull
14	Parkinson Δ	a=9.12 b=9.32 c=6.54	A=8.98 b=9.12 C=3.78	a=9.32 b=13.23	6.7	4.1	17.5	14.2	19	18
15	Parkinson Δ	a=11.89 b=7.67 c=5.45	A=7.45 b=11.89 c=4.74	a=7.67 b=11.98	11.5	6.3	16.3	15	12	15
16	Parkinson Δ	a=12.67 b=8.43 c=6.89	a=9.16 b=12.67 c=5.89	a=8.43 b=13.67	10.6	5.5	14	14.2	12	15
17	Parkinson Δ	a=12.14 b=9.87 c=6.75	a=8.67 b=12.14 c=4.32	a=9.87 b=12.34	7.4	5.3	11.3	11.5	15	19
18	Parkinson Δ	a=10.76 b=9.56 c=4.8	a=7.567 b=10.76 c=4.01	a=9.56 b=13.45	8.1	4	16	13.3	15	19
19	Parkinson Δ	a=13.56 b=9.65 c=4.58	a=6.78 b=13.56 c=3.89	a=9.65 b=12.34	9.3	5	14.2	13.23	16	19
20	Parkinson Δ	a=9.89 b=9.08 c=5.34	a=9.45 b=9.89 c=4.23	a=9.08 b=11.78	8.7	5.1	12	14	16	19
21	Parkinson Δ	a=13.32 b=7.89 c=5.45	a=12.34 b=13.32 c=3.24	a=7.89 b=10	11.34	5.4	15	15.1	15	20
22	Superior Δ	a=10.3 b=9.88 c=3.2	a=7.89 b=10.3 c=6.59	a=9.88 b=8.87	12.7	3.2	12.2	13.2	15	20
23	Superior Δ	a=8.98 b=10.65 c=3.4	a=9.67 b=8.98 c=7.45	a=10.65 b=11.34	10.1	4.1	13	12.3	17	21
24	Superior Δ	a=12 b=14.2 c=3.4	a=9.2 b=12 c=7.2	a=14.2 b=13	9.2	5.4	15.1	12.5	17	21
25	Superior Δ	a=14 b=13.4 c=4.1	a=8.3 b=14 c=6.5	a=13.4 b=15	10.5	6	17.2	11.5	18	20

Δ: Triangle, AP: Anteroposterior, III cranial nerve, V1 cranial nerve (ophthalmic branch), V2 cranial nerve(maxillary branch), IV: Trochlear nerve; c: Tentorial border between the porus oculomotorius and the porus trochlear, the base of the edge of the tentorium between the two nerves (IV and V1)

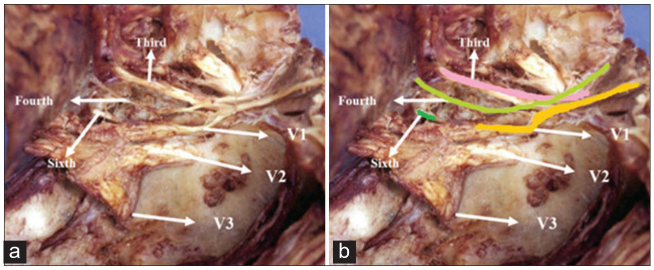

Figure 1: (a and b) Main anatomical repairs present in the cavernous sinus. The image shows the relationship of the differente cranial nerves with each other a) Sixth cranial nerve, fourth cranial nerve, third cranial nerve, V1 cranial nerve, V2 cranial nerve, V3 cranial nerve. b) sixth cranial nerve, fourth cranial nerve, third cranial nerve, V1 cranial nerve, V2 cranial nerve, V3 cranial nerve.

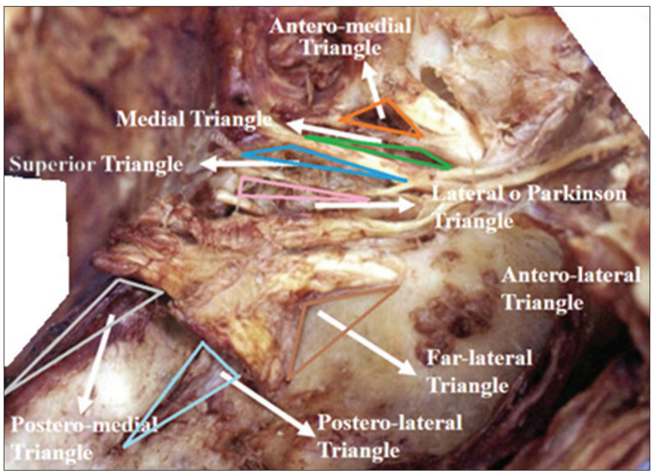

Figure 2: Main triangles described in the cavernous sinus. Parkinson's triangle is the largest of all the triangles but in the figure, it looks smaller due to the projection.

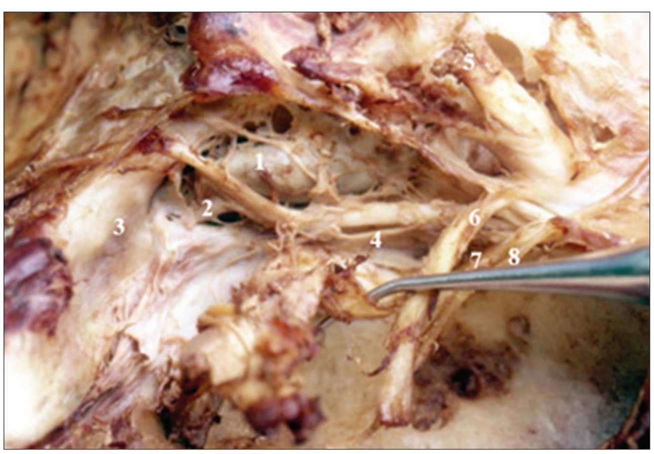

Figure 3: Superior posterior and medial compartments of the right cavernous sinus. 1-Medial compartment (Cavernous internal carotid artery), 2-Posterior compartment, 3-Membrane of anterior foramen lacerate, 4-VI cranial nerve, 5-Optic nerve, 6-III cranial nerve, 7-IV cranial nerve, and 8-V-1 cranial nerve retracted with the dissector forward.

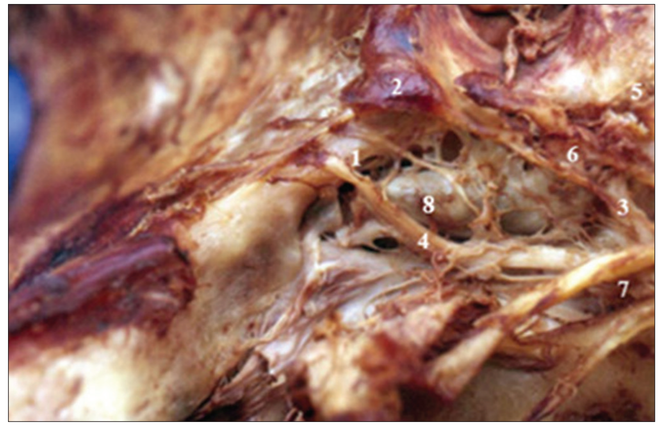

Figure 4: Vascular trunks dependent on the intracavernous A. Right internal carotid intracavernous. 1-Meningo-hypophyseal trunk area, 2-Area of the Meningeal branch Dorsal, 3-Area of the inferolateral trunk, 4-VI cranial nerve, 5-Supraclinoid segment, 6-Subclinoid segment, 7-III, IV and V-1 retracted cranial nerve, and 8-Intracavernous internal carotid artery.

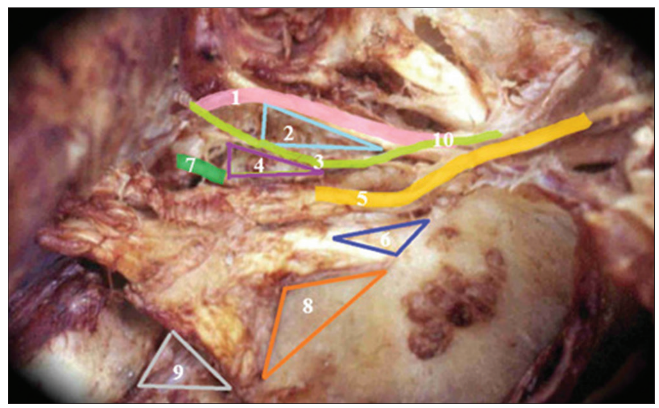

Figure 5: Triangles of the lateral wall of the cavernous sinus right. 1-III cranial nerve, 2-Superior triangle, 3-IV cranial nerve, 4-Parkinson triangle, 5-V-1, 6-Anterolateral triangle, 7-Sixth cranial nerve, 8-Extreme lateral Triangle, 9-Glassock's triangle, and 10-Crossing of the IV cranial nerve over the III cranial nerve.

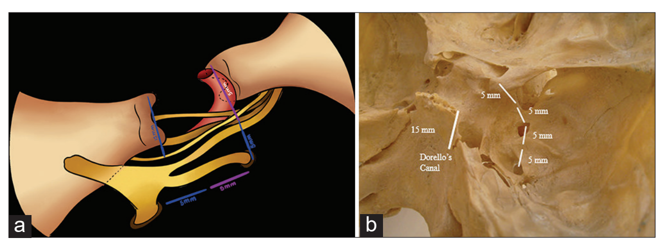

Figure 6: The rule of five stablishes that 5 mm from the clinoid process in most cases is the Parkinson's triangle, 5 mm from this triangle is the rotundum foramen, and 5 mm from this last is the foramen ovale. (a) It shows the nerve relationships of the foramen rotundum and foramen ovale. V2 exits through the foramen rotundum and V3 exits through the foramen ovale, and the VI cranial nerve passes through Dorello's canal, (b) represents the rule of five and its bone relationship.

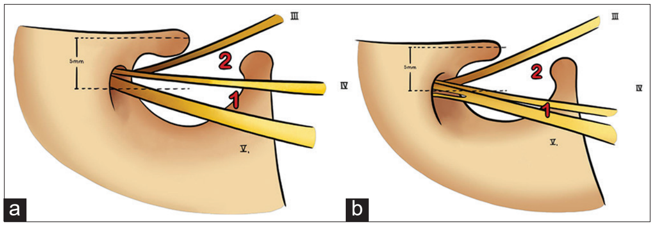

Figure 7: Relation between Parkinson's triangle area (1) versus superior triangle (2) to 5 vertical mm from the lateral tip of the clinoid process. (a) In 86% of the cases, the Parkinson's triangle is located 5 mm from the anterior clinoid process, (b) The remaining 14% is the superior triangle. (a and b) III cranial nerve, IV cranial nerve and V1 cranial nerve.

Table 3: Measurements between posterior clinoid and Dorello's canal in five fresh corpses.

Skull 1	LS:1.5CM	RS:1.5CM
Skull 2	LS:1.2CM	RS:1.1CM
Skull 3	LS:1.2CM	RS:1.2CM
Skull 4	LS:1.5CM	RS:1.5CM
Skull 5	LS:1.3CM	RS:1.2CM

LS: Left side, RS: Right side.

approximately 5 mm from the foramen rotundum to the ovale. Moreover, Dorello's canal, through which the sixth cranial nerve passes, is situated 15 mm posteriorly from the posterior clinoid process, as outlined in Table 3. These consistent distance relationships among the structures serve as the fundamental basis of the "rule of five."

DISCUSSION

Our study highlights the significance of acquiring a comprehensive understanding of the topographic anatomy of the CS to enhance the anatomical knowledge of neurosurgeons. However, it is important to note that our findings do not serve as an intraoperative anatomical rule due to the potential deformations of the CS caused by various pathologies.[5,6,7,9-13]

This study introduced the rule of five, which emphasizes the precise localization of various anatomical structures within the CS. These structures include the fourth cranial nerve (upper limit of Parkinson's triangle), Parkinson's triangle, the foramen rotundum, the foramen ovale, and Dorello's canal through which the sixth nerve passes. The location of these structures is determined with reference to specific bony landmarks.

The "Rule of five" [Figure 6] establishes that the fourth cranial nerve, serving as the upper limit of Parkinson's triangle, is vertically positioned approximately 5 mm from the lateral tip of the anterior clinoid process. In addition, the foramen rotundum (greater round) is located approximately 5 mm away from the fourth cranial nerve, while maintaining a consistent distance of approximately 5 mm between the foramen rotundum and the ovale.

Furthermore, it has been found that the III cranial nerve is situated approximately 10 mm from the IV cranial nerve. However, some studies, including the one conducted by Watanabe *et al*., have found the distance to be around 9.6 ± 3.6 mm.[15] Another method to locate the IV cranial nerve is through the previously mentioned "rule of five" and/or by tracking the free edge of the tentorium.[1,3,10,14]

Similarly, this study has determined that Dorello's canal, through which the sixth cranial nerve passes, is positioned 15 mm posteriorly from the posterior clinoid process.

The location of Parkinson's triangle can be determined by utilizing the anterior clinoid process as a reference point. By drawing an imaginary line perpendicular to the foramen rotundum from the lateral tip of the anterior clinoid process, the triangle can be assessed. Research findings indicate that in 86% of cases, Parkinson's triangle is situated 5 mm away from the lateral tip of the anterior clinoid process, while only 14% exhibit the superior triangle [Figure 7]. The detection of the superior triangle at a distance of 5 mm from the lateral tip of the anterior clinoid process indicates an unusually small area for Parkinson's triangle.

Parkinson's triangle plays a crucial role in neurosurgery, as it serves as an important landmark for accessing CS. The upper boundary of Parkinson's triangle is defined by the fourth cranial nerve, and its identification is imperative to avoid damage during surgical procedures, which can result in impaired eye movement. Furthermore, this triangle is also relevant to other structures such as the oculomotor nerve and the posterior cerebral artery, making it a valuable reference point for various neurosurgical interventions.[1,3,10,14]

Strengths

This research presents significant contributions to our understanding of the anatomical landmarks within the CS through the utilization of a simple and practical "rule of five." The identification of Parkinson's triangle, which facilitates the localization of the thinner cranial nerve (fourth cranial nerve), along with the foramen rotundum, foramen ovale, and Dorello's canal, serves as a valuable reference for obtaining detailed knowledge of the CS.

Furthermore, the research emphasizes the importance of recognizing normal anatomical structures, despite the fact that various tumors and abnormalities can distort the CS's normal structure. This approach provides a point of reference during surgical interventions, which can help minimize complications and reduce patient morbidity.

Limitations and future research

Regarding the limitations of this study, it is paramount to acknowledge that pathologies causing significant deformations of the CS were not considered. Therefore, the parameters established in this research solely serve as an anatomical reference, and their surgical applicability is limited due to the inherent variability of the CS, the potential deformations caused by pathologies, and the necessity of clinoidectomy in surgical approaches.

Further investigations may also consider variations in the transverse and anteroposterior diameters of the skull, as these factors can impact the heights and distances of specific portions within the cranial vault. Such studies could enhance the current research by accounting for deformities in the normal anatomy of the CS, thus providing surgeons with a more comprehensive understanding of the challenges posed by various pathologies. These considerations may facilitate the development of more refined and effective surgical interventions in the future.

CONCLUSION

This study anatomically dissects the CS to enhance the knowledge of neurosurgeons and facilitate the acquisition of CS-specific expertise among trainee neurosurgeons. It is important to note that the primary objective of this research is not to offer surgical guidance, but rather to establish a comprehensive reference for comprehending the intricate normal anatomy of the CS.

Declaration of patient consent

The Institutional review board (IRB) permission obtained for the study.

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Nil.

Conflicts of interest

There are no conflicts of interest.

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