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Clinical and surgical relevance of ipsilateral occurrence of the ossified interclinoid ligament and carotico-clinoid foramen in the juvenile sphenoid bone

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Abstract: This study is an illustrative case of the ipsilateral ossification of the dural folds stretched between the clinoid processes found in the juvenile sphenoid bone. Thereby, occurred inconstant bony formations are termed as the interclinoid bridge and the carotico-clinoid foramen.
Both structures are of clinical meaning if surgical operations are performed in the sellar region.

Keywords: interclinoid ligament, carotico-clinoid foramen, sella turcica bridging, sphenoid bone.

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Introduction

The dural folds stretched in the periclinoidal region of the sphenoid bone also termed as ligaments can ossify in various degree due to heterotopic condensation of the bony tissue. In consequence solid bridges arise within the dura mater of the sellar region. Depending on the extend of ossification they appear as trabecula or lamina and usually form complete or incomplete connections between the clinoid processes (anterior, middle, and posterior) of the sphenoid bone. The so-called sellar bridges may develop between the anterior and posterior clinoid processes, either between the anterior and middle clinoid process or can occur simultaneously, demonstrating various patterns of interconnection: complete, incomplete or contact [1]. Presence of the sellar bridges alter regional anatomy of the sphenoid bone because the space limited by the clinoid processes is converted into the foramina called the anterior interclinoid foramen (commonly known as the carotico-clinoid foramen) and the posterior interclinoid foramen (less frequently described in the anatomical literature).

Ossification of the interclinoid ligament may form a bony bridge of varying size and shape (lamina or trabecula) which can join completely or incompletely the anterior and posterior clinoid processes. Such a bony bridge limits laterally the space between medial aspect of the pituitary fossa, and jointly with the ossified carotico-clinoid ligament located anteriorly demarcate the interclinoid foramen posteriorly [2–4]. The posterior interclinoid foramen usually appears as irregular space, approximately pyramidal in shape, which is occupied by the contributions of the intercavernous sinus or tributaries to the circular sinus [5, 6].

The sellar bridges and the resultant foramina are closely related to the clinically important neurovascular structures (II, III, VI cranial nerves, internal carotid artery, cavernous and intercavernous sinuses), and the pituitary gland, as well. These anatomical relationships are considered in details prior performing surgery in cases of the paraclinoid aneurysms, and the meningiomas involving the carotico-clinoid ligament together with the internal carotid artery while it passes through the carotico-clinoid foramen [7–9].

It is also noteworthy that the interclinoid ligament is the landmark structure for identification of the oculomotor nerve due to its close proximity from the lateral side. Hence this ligamentous structure, along with the oculomotor membrane forms partially the roof (superior wall) of the cavernous sinus. Actually, the interclinoid ligament bisects its superior wall, and thus delineate the border between the carotid trigone located anteromedially and the oculomotor trigone located posterolaterally [10].

In turn, carotico-clinoid ligament consists of a varying number of fibrous bundles stretched between anterior clinoid process, middle clinoid process, the upper portion of medial wall of the cavernous sinus and continues with the proximal ring. According to Truong *et al.* [11] the carotico-clinoid ligament is the strongest and most constant ligament (identified in 97.5% of cases) among the parasellar ligaments.

Ossification of the carotico-clinoid ligament converts it to a bony bar which limits posteriorly the carotid grove in the place where the internal carotid artery runs between the anterior and middle clinoid processes. As a result the internal carotid artery passes through the carotico-clinoid foramen or canal, where it can be compressed or tightened by the ossified carotico-clinoid ligament. This may happened in particular if the caliber of the internal carotid artery is larger than the diameter of the carotico-clinoid foramen, moreover such coincidence increases probability of headache, noticed by Ozdoğmuş *et al.* [4].

Thereby, occurrence of the carotico-clinoid foramen gained clinical significance, and draw an attention of anatomists and surgeons. It is noteworthy that early written reports of this foramen are dated on 18th and 19th centuries [12]. Actually, the first one comes from a Scottish surgeon and anatomist Alexander Monro Primus, later described also by a German physician and anatomist Friedrich Gustav Jakob Henle [13, 14]. They both noticed that the clinoid processes could be occasionally joined by the bony bridges, thus form the carotico-clinoid foramen. Therefore, two eponyms of the carotico-clinoid foramen exist: foramen of Henle or foramen of Monro [15].

The aim of this study is to illustrate anatomical features of coexisting interclinoid and carotico-clinoid bridges found in the osteological material dated on the 18th century. As it was aforementioned the existence of these bony formations were described in the anatomical literature of that time, however without a graphic documentation. Hereby, we demonstrate such a specimen along with a short comment on the neurosurgical issues related to the ossification of the dural folds attached to the clinoid processes of the sphenoid bone.

Materials and Methods

Anatomical variants of the sphenoid bone were studied using dry bone samples housed in the Department of Anatomy of the Jagiellonian University Medical College. One of the samples revealed outstanding morphological features related to the sellar region due to the bony connections found ipsilaterally between the clinoid processes: anterior, middle and posterior (Fig. 1).

The sphenoid bone derived from incomplete and disarticulated skull of an infant being of age 8–9 years at death, whose fragmented skeleton dated on the 18th century was explored during archaeological excavations conducted in Kraków (Poland) in the year of 2020. The sphenoid bone was partially destroyed, however, the sella turcica, the clinoid processes (anterior, middle, posterior) and the ossified dural folds attached

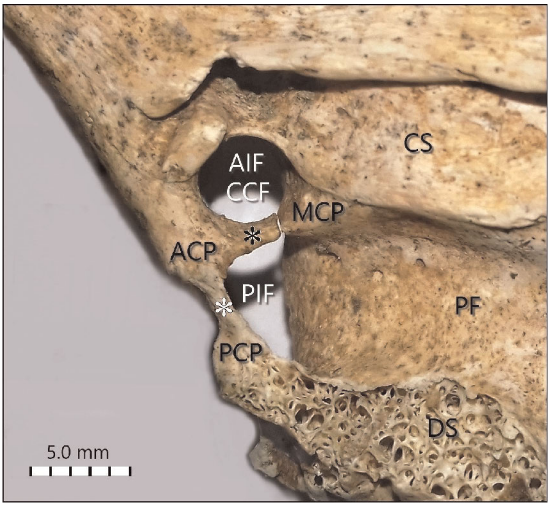

Fig. 1. Unilateral coexistence of the bony bridges (marked by black and white asterisks) formed between the clinoid processes: anterior (ACP), middle (MCP) and posterior (PCP); AIF — anterior interclinoid foramen (CCF — carotico-clinoid foramen), PIF — posterior interclinoid foramen, CS — chiasmatic sulcus, PF — pituitary fossa, DS — dorsum sellae

to them were well preserved, thereby these structures were subjected to the morphometrical analysis. For this purpose, the bone specimen was photographed using a digital camera. Resultant image files demonstrating ossified dural folds and corresponding foramina: the carotico-clinoid and interclinoid were uploaded to the ImageJ software (https://imagej.nih.gov/ij/) in order to perform measurements of these structures, according to the algorithms developed by Rasband [16] and presented by Abramoff *et al.* [17]. The following size and shape descriptors were used to characterize the carotico-clinoid and posterior interclinoid foramen:

- Size of the cross-sectional area and the perimeter of each foramina.
- Feret's diameter (maximum caliper) which is the longest distance between any two points along the selection boundary.
- Circularity, roundness, and aspect ratio.

Circularity is the measure of the object elongation. As the value approaches 0.0, it indicates an increasingly elongated shape. Roundness is the measure of how closely the shape of an object approaches a perfect circle. In turn, aspect ratio is defined as the length of longest Feret's diameter over length of the shortest Feret's diameters. All size and shape descriptors were estimated using binarized version of the digital image of the examined ossified dural folds and related foramina (Fig. 2). The segmented shape of the interclinoid foramina is dependent on the camera position towards the sample to be photographed (front, rear projection or angular). In order to minimize this detrimental effect (object distortion) we positioned the digital camera lens perpendicularly to the cross-section of the interclinoid foramina. Hence, we performed measurements on three separate images yielding mean values of the size and shape parameters characterizing quantitatively the foramina (carotico-clinoid and posterior interclinoid).

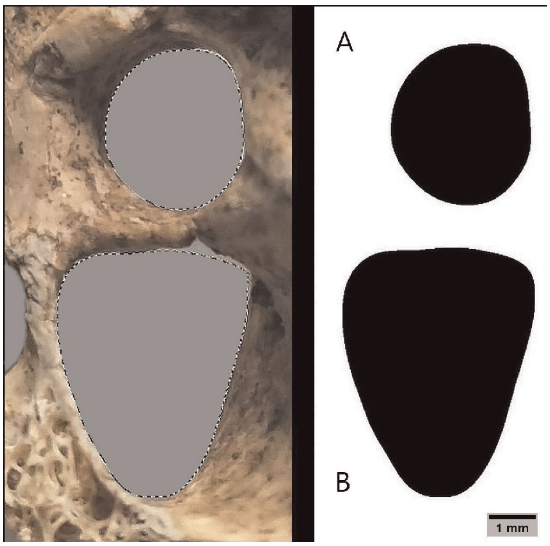

Fig. 2. Close up of the examined sample and binarized images of the lumen cross-sectional shape segmented for the (A) — anterior interclinoid (carotico-clinoid) and (B) — posterior interclinoid foramina subjected to the morphometric analysis. The outline of each foramen is marked with dashed line.

The length and width of the ossified interclinoid and carotico-clinoid ligaments were measured on the native digital images (without segmentation) because binarized images do not allow to perceive the interface between the tip of the clinoid process and the ossified dural fold. Thereby, the length of each bony bar was measured between the tips of the relevant clinoid processes, whereas the width was measured across the middle part of the bony bar (Fig. 3).

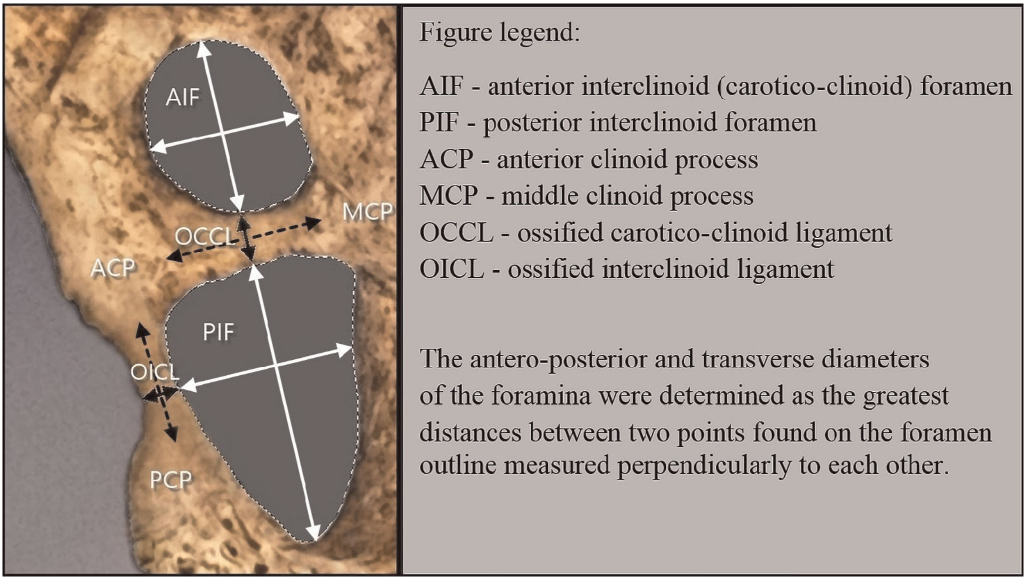

Fig. 3. A schematic drawing of the linear measurements of the anterior (carotico-clinoid) and posterior interclinoid foramina (white arrows), and the bony bars (black arrows) resulted from ossification of the interclinoid and carotico-clinoid dural fold.

Results

Delicate bony bridges located between the right clinoid processes: anterior, middle and posterior were identified as the ossified interclinoid ligament, and the ossified carotico-clinoid ligament. The interclinoid ligament was completely ossified, and firmly joined the anterior clinoid process with the posterior clinoid process. In turn, the carotico-clinoid ligament was almost completely ossified, however a very narrow cleft disrupted its contact with the middle clinoid process which is well pronounced. Nevertheless, this bony bridge apparently formed a partition which served as passage for the clinoidal segment of the internal carotid artery (Fig. 1).

Indeed, the space limited laterally by the anterior clinoid process, posteriorly by the bony bridge, further by the middle clinoid process and medially by the lateral aspect of the sphenoid body was circular in shape, thus termed carototico-clinoid foramen.

In contrast, the space located posteriorly to the ossified carotico-clinoid ligament, laterally limited by the ossified interclinoid bridge, and medially by the lateral aspect of the sphenoid body was approximately triangular in shape. Due to its location between the anterior, posterior and middle clinoid processes was defined as the interclinoid foramen.

The values of the morphometrical parameters support visual assessment of the interclinoid foramina appearance indicating significant difference in their size and shape (Table 1).

Table. 1. Parameters of the anterior interclinoid (carotico-clinoid) foramen (AIF) and posterior interclinoid foramen (PIF). Perimeter, antero-posterior diameter (APD), transverse diameter (TD), Feret's diameter (FerD) are measured in millimeters. Area in square millimeters. Shape factors: aspect ratio (Ar), circularity (Circ) and roundness (Round) are dimensionless quantities.

	Area	Perimeter	APD	TD	FerD	Ar	Circ	Round
AIF	14.1	14.0	4.5	4.0	4.6	1.7	0.9	0.9
PIF	28.8	21.9	7.1	5.4	7.3	1.4	0.8	0.7

The posterior interclinoid foramen is much bigger and more elongated comparing to the anterior interclinoid (carotico-clinoid) foramen which is almost circular in shape and has approximately two-fold lesser cross-sectional area. In turn, the carotico-clinoid bridge and interclinoid bridge are of similar width but they vary considerably in length (Table 2).

Table. 2. Measurements of the bony bridges: carotico-clinoid (CCB) and interclinoid (ICB).

	Length [mm]	Width [mm]
CCB	5.1	1.2
ICB	3.1	1.0

Discussion

The vast majority of information about the anatomical features of the sellar bridges and resultant foramina (interclinoid and carotico-clinoid) comes from observations performed on the skulls of adult individuals of both sexes, which derive from distinct populations [18].

It must be noted that similar findings come also from the fetal, infant and juvenile skulls [19, 20], however information on their incidence and morphometric features are scanty compared to the adult subjects. The sellar bridges can develop during prenatal life, nevertheless the reasons of their formations remained unclear and were explained by the developmental anomalies of the sphenoid bone. In other cases the sellar bridges develop over time of the post-natal life, and can be evident at the 6 years of age or in later periods [21].

Regional ossification of the fibrous tissue of the dura mater described Augier [22], and Hochstetter [23] who showed precartilaginous connections between the anterior and posterior clinoid process. In turn, Lang [24] suggested that the formation of the sellar bridges derives from the cartilaginous tissue and not from the ossification of the dura mater. Ossified dural folds connecting the anterior and middle clinoid processes, elsewhere the anterior and posterior clinoid processes were identified in the skulls of fetuses and children [23]. A bilateral formation of the carotico-clinoid foramen was already observed in a 30-week fetus. Also the interclinoid foramina were found bilaterally in a 36-week fetus [19]. Similarly, Clarke *et al.* [25] found in the skull of the fetus (approximated gestational age: 23–27 weeks) bilaterally present the sellar bridges being the cartilaginous formations of the interclinoid ligament with progressive ossification. Also Lang [24] reported existence of the sellar bridges and carotico-clinoid foramina in the embryos and newborn infants.

Several authors indicated that occurrence of the sellar bridges and the carotico-clinoid foramina seems to be correlated both in young and adult subjects. Kim *et al.* [26] found, that an interosseous bridge was associated with a carotico-clinoid foramen in all examined human crania. Gibelli *et al.* [27] established that patients without sella turcica bridging usually did not show ossified carotico-clinoid ligament, and that observation appeared to be statistically significant. In turn, Clarke *et al.* [25] noticed that coexistence of the ossified interclinoid and carotico-clinoid ligaments was the most common combination of the ossified dural folds among examined patients. Rennert *et al.* [28] found both ossified carotico-clinoid ligament and ossified interclinoid ligament in the 3 years old patient.

Our study presents coexistence of the ossified interclinoid and carotico-clinoid ligaments, along with completely formed foramina (carotico-clinoid and posterior interclinoid) located at the sphenoid bone of a young individual being of age 8–9 years. In turn, Mallik *et al.* [29] described a skull of an adult male individual (age between 30–40 years), where found both ossified interclinoid and carotico-clinoid ligaments and resultant carotico-clinoid foramen, as well. Coexisting the interclinoid bridge and the carotico-clinoid foramen were also found by Boyan *et al.* [30] at one of the skulls of Turkish adults, however of unknown age and sex.

A similar case of coexistence of the carotico-clinoid foramen and sella turcica bridges in a female skull reported Ray and Gupta [31]. They observed that from the right anterior clinoid process a single bony bar extended posteriorly and bifurcated into the carotico-clinoid bar which joined the middle clinoid process, and the interclinoid bar which joined the posterior clinoid process. The osseous connection between anterior and middle clinoid processes formed the carotico-clinoid foramen which was round in shape.

Furthermore, unique cases of coexisting bony bridges between the anterior, middle and posterior clinoid processes along with accompanied foramina (carotico-clinoid and posterior clinoid) were reported by Daimi and Alsaffar [32] and Priya *et al.* [33]. They found triple bony bridges which were formed bilaterally due to ossification of the dural folds attached to the clinoid processes. Interestingly, Priya *et al.* [33] perceived a bony connection between the middle clinoid process and the lateral border of dorsum sellae, what is an uncommon finding among reported ossifications of the dural ligaments.

To sum up, the anatomical variants of the sellar bridges regarding their localization are usually classified as [34–36]:

type I — bridge between the anterior and middle clinoid processes,
type II — bridge between the anterior, middle and posterior clinoid processes,
type III — bridge between the anterior and posterior clinoid processes,
type IV — bridge between the middle and posterior clinoid processes.

In the human sphenoid bones the sellar bridges exist as the separated ossified dural folds (interclinoid or carotico-clinoid), either jointly in the combination (interclinoid and carotico-clinoid), and rarely all three clinoid processes are connected by the ossified dural folds. All of these anatomical variants can occur unilaterally or bilaterally and manifest complete or incomplete bridging between clinoid processes.

A meta-analysis performed by Cuschieri *et al.* [37] regarding occurrence of the sellar bridges revealed that their mean prevalence was higher (26.5%) than previously reported (4.6–11.1%), and was most prevalent in Europe. However, higher prevalence of sella turcica bridges can be found in patients with dental anomalies (eg.: altered direction of dental eruption), either afflicted with craniofacial deviations [38–41].

Aforementioned observations and views find support mostly in case reports coming from distinct human population. So far, few studies have been dedicated to analyze sellar bridges and related bony structures using large series of dry human skulls or radiographic images of living subjects who demonstrated normal and aberrant anatomy of the sella turcica [21, 42, 43]. Thus, further studies are still necessary to reveal the whole spectrum of sellar bridges, and fully understand reasons of simultaneous ossification of the dural folds attached to the clinoid processes, hence to determine the factors which may govern the unilateral or bilateral formation of the sellar bridges, and formation of the complete or incomplete carotico-clinoid foramina being of various diameter.

Ozdoğmuş *et al.* [4] found similar range of the diameters of the complete carotico-clinoid foramina for the right and left side (4.05–5.63 mm, and 4.43–5.98 mm). In turn, the diameters of the carotico-clinoid foramina resulted from incomplete ossification of the corresponding ligament revealed a ranged 3.92–5.85 mm on the right and 4.30–5.60 mm on the left. The authors did not find significant correlations between sex, age, side and the frequency of complete and incomplete ossification of the carotico-clinoid ligaments, when studied normal subjects. In turn, Freire *et al.* [44] found that mean values range from 5.18 to 5.35 mm, depending on the side (right or left) and the sex of the examined adult subjects.

The appearance of the carotico-clinoid foramen identified in our sample if compare to the illustrative literature data, shows that formation of this foramen has been completed, in spite of juvenile age. For instance, Zdilla *et al.* [45] found that the area enclosed within the left carotico-clinoid foramen was 16.8 mm^2, and its maximum diameter measured 4.6 mm. In our sample corresponding values were measured as 14.1 mm^2 for the cross-sectional area, and 4.5 mm for the antero-posterior diameter or 4.6 mm for the Feret's diameter. These authors also found that the carotico-clinoid foramen was for the most part circular. We also observed that such geometrical feature was characteristic for this foramen in our sample, and its similarity to the circle was supported by the values of shape factors. Both the size and shape of the carico-clinoid foramen is contrasting to the geometrical features of the posterior interclinoid foramen (Table 2). Unfortunately we did not find similar data in available literature allowing for efficient comparing size and shape parameters of both foramina.

Measured diameters of the carotico-clinoid foramen (4.5 × 4.0 mm) seem to be big enough to freely transmit the internal carotid artery which cavernous and clinoid segments have their diameters commonly found to be around 4 mm, would be of the diameters commonly found to be in order of 4 mm. According to Baz *et al.* [46] the average diameter of the clinoid segment of the internal carotid artery assessed for adult subjects of both sexes were 4.27 mm (± 0.45). Theoretically, this segment may be encompassed by the carotico-clinoid foramen. Hence, these authors did not find significant correlation between age and the diameter of the internal carotid artery. Therefore, we think that in our case the course of the internal carotid artery through the carotico-clinoid foramen was not disturb, and the ossified carotico-clinoid ligament did not compress the wall of the artery.

Neurosurgical implications

Surgical treatment of aneurysms, tumors, and other basicranial lesions is based on detailed visualization of the bony and neurovascular structures located in the sellar and parasellar regions.

So far, many authors have raised the issue of clinical relevance of detailed knowledge about the sellar and parasellar regions in effective and safe surgical management in this cranial region.

Variability of the bony structures, their adhesion to the cranial nerves, and the blood vessels force an accurate preoperative recognition of the topography for the best planning surgical strategy [4].

Current neurosurgery offers minimally invasive approach to the sellar region (transnasal, transphenoidal) and usage of endoscopes along with the radiographic imaging allows to perceive tiny bony structures. According to Nutik [47] removed anterior clinoid process increases about 6 mm the field of observation of the internal carotid artery. Nevertheless, endoscopic exploration and surgical approach to the paraclinoid and parasellar regions can be limited by the occurrence of the accessory bony structures in this cranial regions [8, 9, 48].

The ossified interclinoid ligament forming a bony junction between the anterior and posterior clinoid processes can hinder their resection during the clinoidectomy, likewise clipping of the aneurysms or removal of other lesion located in the paraclinoid region [49, 50].

In turn, osseous bridging between the anterior and middle clinoid processes may cause performance of the middle clinoidectomy more difficult than commonly, due to necessity of cutting bony bar being the ossified carotico-clinoid ligament, which adhere to the wall of the internal carotid artery. If this ligament ossifies completely forms an osseous ring which encompasses clinoid segment the internal carotid artery. Then surgical removal of the middle clinoid may be required, elsewhere only its reduction is sufficient [7, 11].

The sellar bridges and the carotico-clinoid foramen create difficulties for retraction and mobilization the cavernous portion of the internal carotid artery, and increase a risk of its rapture, especially while clinoid and paraclinoid aneurysms or clinoid meningiomas are subjected for surgical treatment [51–54]. Thus, routine neurosurgical operations performed around the sella turcica, such as extradural clinoidectomy, may require some modification or even be contraindicated. In such cases Zhao *et al.* [9] claim stepwise disconnections of the bony structures are of paramount importance to avoid injury of the internal carotid artery and other neurovascular structures, as well.

Surgical significance of the anatomical obstacles chiefly depends on the size, number, and type of the bony bridges (complete or incomplete) connecting the clinoid processes, either the extend of anterior clinoid pneumatization [48]. Therefore, if the interclinoid bridges are present then the surgical approach to the paraclinoid and parasellar region is recommended to be performed with precaution, in order to avoid accidental destruction of the neurovascular structures.

Actually, we demonstrated ossifications of the dural folds found in the juvenile sphenoid bone, whereas most of published case reports relate to adult subjects. Regarding neurosurgical operations like the clinoidectomy performed on children, presentation of cases demonstrating anatomical variation of the sellar region in the children skulls enrich knowledge about anatomical obstacles which can be encountered in pediatric patients. Thereby, such ossified dural folds should be also considered as potential restrictions in the pediatric endonasal and transsphenoidal approaches used in the skull base surgery [55, 56].

It should be noted that despite the dural ossifications, surgical endonasal approaches to the sellar region in the pediatric patients are more often restricted by other anatomical features like relatively small piriform aperture, the nare-sellar distance which is significantly different in both sexes, degree and pattern of pneumatization of the sphenoid sinus and its volume which increases with age [57, 58]. Morphometrical analysis of the children skulls appears important for safe drilling in the vicinity of the sella turcica, either tracing optimal surgical corridors that allow endoscopic access to the lesions of the cranial base.

Limitations of the study

Morphometric analysis was performed on the digital images of the interclinoid foramina obtained only from a singular sample. Thereby, calculated values are characteristic only for the particular case of the juvenile sphenoid bone having ossified dural folds (interclinoid and carotico-clinoid) and related foramina (carotico-clinoid and posterior interclinoid). Due to the incomplete preservation of the sphenoid bone (lack of the right clinoidal and parasellar regions) we were not able investigate if similar ossifications occurred on contralateral side, and fully compare our observations to the similar cases presented in the literature.

Conclusions

Previous and contemporary reports certify that simultaneous ossification of the dural folds can occur at different stages of life, including fetal, infant and adult periods. Close proximity of the ossified interclinoid and carotico-clinoid ligaments to the neurovascular structures can be a risk factor while the surgical management is performed in the sellar or parasellar region. Therefore, precise preoperative imaging of the sellar region is indispensable to avoid or minimalize surgical complications due to necessity of dissecting bony bridges connecting the clinoid processes.

Conflict of interest

The authors declare no conflict of interest nor any financial interest associated with the current study.

References

1. *Neiss A.*: Die sellabrücke, eine erscheinungsform des foramen caroticoclinoideum. Rofo. 1956; 84 (1): 70–72. doi: 10.1055/s-0029-1212788.
2. *Keyes J.E.L.*: Observations on four thousand optic foramina in human skulls of known origin. Arch Ophthalmol. 1935; 13 (4): 538–568.
3. *Natsis K., Piagkou M., Lazaridis N., Totlis T., Anastasopoulos N., Constantinidis J.*: Incidence and morphometry of sellar bridges and related foramina in dry skulls: Their significance in middle cranial fossa surgery. J Craniomaxillofac Surg. 2018; 46 (4): 635–644. doi: 10.1016/j.jcms.2018.01.008.
4. *Ozdoğmuş O., Saka E., Tulay C., Gürdal E., Uzün I., Cavdar S.*: The anatomy of the carotico-clinoid foramen and its relation with the internal carotid artery. Surg Radiol Anat. 2003; 25 (3–4): 241–246. doi: 10.1007/s00276-003-0111-4.
5. *Kaplan H.A., Browder J., Krieger A.J.*: Intercavernous connections of the cavernous sinuses. The superior and inferior circular sinuses. J Neurosurg. 1976; 45 (2): 166–168. doi: 10.3171/jns.1976.45.2.0166.
6. *Narayan R.K., Asghar A., Ghosh S.K.*: Ossification around intercavernous sinus: An osteological finding that can complicate trans-sphenoidal surgery. Morphologie. 2020; 104 (347): 280–286. doi: 10.1016/j.morpho.2020.06.005.
7. *Fernandez-Miranda J.C., Tormenti M., Latorre F., Gardner P., Snyderman C.*: Endoscopic endonasal middle clinoidectomy: anatomic, radiological, and technical note. Neurosurgery. 2012; 71 (2 Suppl Operative): ons233-9; discussion ons239. doi: 10.1227/NEU.0b013e3182690b6b.
8. *Sharma A., Rieth G.E., Tanenbaum J.E., Williams J.S., Ota N., Chakravarthi S., Manjila S., Kassam A., Yapicilar B.*: A morphometric survey of the parasellar region in more than 2700 skulls: emphasis on the middle clinoid process variants and implications in endoscopic and microsurgical approaches. J Neurosurg. 2018; 129 (1): 60–70. doi: 10.3171/2017.2.JNS162114.
9. *Zhao X., Labib M.A., Avci E., Preul M.C., Baskaya M.K., Little A.S., Nakaji P.*: Navigating a carotico-clinoid foramen and an interclinoidal bridge in the endonasal endoscopic approach: an anatomical and technical note. J Neurol Surg B Skull Base. 2021; 82 (5): 534–539. doi: 10.1055/s-0040-1715470.
10. *Umansky F., Valarezo A., Elidan J.*: The superior wall of the cavernous sinus: a microanatomical study. J Neurosurg. 1994; 81 (6): 914–920. doi: 10.3171/jns.1994.81.6.0914.
11. *Truong H.Q., Lieber S., Najera E., Alves-Belo J.T., Gardner P.A., Fernandez-Miranda J.C.*: The medial wall of the cavernous sinus. Part 1: Surgical anatomy, ligaments, and surgical technique for its mobilization and/or resection. J Neurosurg. 2018; 131 (1): 122–130. doi: 10.3171/2018.3.JNS18596.
12. *Hyrtl J.*: Lehrbuch der Anatomie des Menschen. 14 Aufl. Braumuller. Wien. 1878.
13. *Monro A.*: The anatomy of the human bones and nerves: with an account of the reciprocal motions of the heart, and a description of the human lacteal sac and duct. Edinburgh. 1741.
14. *Henle J.*: Handbuch der systematischen Anatomie des Menschen. Knochenlehre. Braunschweig; F. Vieweg, 1855.
15. *Zdilla M.J.*: The erroneous eponym of the carotico-clinoid foramen of Henle: attribution is due to Alexander Monro (primus). Anatomy. 2017; 11 (2): 104–106.
16. *Rasband W.S.*: ImageJ, U.S. National Institutes of Health, Bethesda, Maryland, USA. 1997–2018. https://imagej.nih.gov/ij/.
17. *Abramoff M.D., Magalhaes P.J., Ram, S.J.*: Image Processing with ImageJ. Biophotonics International. 2004; 11 (7): 36–42.
18. *Muhammed F.K., Abdullah A.O., Rashid Z.J., Pusic T., Shbair M.F., Liu Y.*: Morphology, incidence of bridging, and dimensions of sella turcica in different racial groups. Oral Radiol. 2019; 35 (2): 127–134. doi: 10.1007/s11282-018-0328-x.
19. *Kier E.L.*: Embryology of the normal optic canal and its anomalies. An anatomic and roentgenographic study. Invest Radiol. 1966; 1 (5): 346–362. doi: 10.1097/00004424-196609000-00023.

20. *Zdilla M.J.*: The caroticoclinoid foramen in fetal and infantile orbitosphenoid, presphenoid, and sphenoid bones: developmental and neurosurgical considerations. J Neurosurg Pediatr. 2018; 23 (3): 390–396. doi: 10.3171/2018.9.PEDS18481.
21. *Axelsson S., Storhaug K., Kjaer I.*: Post-natal size and morphology of the sella turcica. Longitudinal cephalometric standards for Norwegians between 6 and 21 years of age. Eur J Orthod. 2004; 26 (6): 597–604. doi: 10.1093/ejo/26.6.597.
22. *Augier M.*: Squelette céphalique. In: Poirier P., Charpy A. eds. Traité d´anatomie humaine. Masson, Paris. 1931.
23. *Hochstetter F.*: Über die Taenia interclinoidea, die Commissura alicochlearis und die Cartilago supracochlearis des menschlichen Primordialkraniums. Gegenbaurs Morph Jahrb. 1940; 84: 220–243.
24. *Lang J.*: Structure and postnatal organization of heretofore uninvestigated and infrequent ossifications of the sella turcica region. Acta Anat (Basel). 1977; 99: 121–139. doi: 10.1159/000144840.
25. *Clarke E., Golberg M., Smędra A., Mazur M., Mazurek A., Balawender K., Barszcz K., Żytkowski A.*: Bilateral caroticoclinoid foramen and unilateral abducens nerve canal found on the fetal skull — Case report. Transl Res Anat. 2022; 29: 100224. https://doi.org/10.1016/j.tria.2022.100224.
26. *Kim J.M., Romano A., Sanan A., van Loveren H.R., Keller J.T.*: Microsurgical anatomic features and nomenclature of the paraclinoid region. Neurosurgery. 2000; 46 (3): 670–682. doi: 10.1097/00006123-200003000-00029.
27. *Gibelli D., Cellina M., Gibelli S., Panzeri M., Oliva A.G., Termine G., Sforza C.*: Sella turcica bridging and ossified carotico-clinoid ligament: Correlation with sex and age. Neuroradiol J. 2018; 31 (3): 299–304. doi: 10.1177/1971400917751036.
28. *Rennert R.C., Brandel M.G., Steinberg J.A., Martin J.R., Gonda D.D., Fukushima T., Day J.D., Khalessi A.A., Levy M.L.*: Surgical relevance of pediatric anterior clinoid process maturation for anterior skull base approaches. Oper Neurosurg (Hagerstown). 2021; 20 (3): E200–E207. doi: 10.1093/ons/opaa374.
29. *Mallik S., Sawant V.G.*: Bilateral "carotico-clinoid foramen" with "sella turcica bridge" — a case report. Anat Physiol. 2015; 5 (006): 2161–2940.
30. *Boyan N., Ozsahin E., Kizilkanat E., Tekdemir I., Soames R., Oguz O.*: Surgical importance of the morphometry of the anterior clinoid process, optic strut, caroticoclinoid foramen, and interclinoid osseous bridge. Neurosurg Q. 2011; 21 (2), 133–136. https://doi.org/10.1097/WNQ.0b013e31820f1929.
31. *Ray B., Gupta N.*: Caroticoclinoid foramen with interclinoid osseous bar. Clin Anat. 2006; 19 (8): 732–733. doi: 10.1002/ca.20430.
32. *Daimi S.R.H., Alsaffar R.A.M.*: Rare case of bilateral coexistence of caroticoclinoid foramen, inter-clinoid bar and posterior clinoid foramen in a dry human skull. J Evolution Med Dent Sci. 2020; 9 (1): 60–62.
33. *Priya A., Narayan R.K., Ghosh S.K., Kumar P.*: Morphometry and morphological analysis of carotico-clinoid foramen: an anatomical study with clinical implications. Folia Morphol (Warsz). 2023; 82 (1): 108–118. doi: 10.5603/FM.a2021.0128.
34. *Archana R., Anita R., Jyoti C., Punita M., Rakesh D.*: Incidence of osseous interclinoid bars in Indian population. Surg Radiol Anat. 2010; 32: 383–387. doi: 10.1007/s00276-009-0582-z.
35. *Peker T., Anil A., Gülekon N., Turgut H.B., Pelin C., Karaköse M.*: The incidence and types of sella and sphenopetrous bridges. Neurosurg Rev. 2006; 29 (3): 219–223. doi: 10.1007/s10143-006-0018-8.
36. *Skrzat J., Mróz I., Marchewka J.*: Bridges of the sella turcica — anatomy and topography. Folia Med Cracov. 2012; 52 (3–4): 97–101.
37. *Cuschieri A., Cuschieri S., Zammit C.*: Sella turcica bridging: a systematic review. Surg Radiol Anat. 2022; 44 (3): 381–389. doi: 10.1007/s00276-021-02873-9.
38. *Arcos-Palomino I., Ustrell-Torrent J.M.*: Association between sella turcica bridging and altered direction of dental eruption: A case-control study. J Clin Exp Dent. 2019; 11 (10): e913–e920. doi: 10.4317/jced.56165.
39. *Becktor J.P., Einersen S., Kjaer I.*: A sella turcica bridge in subjects with severe craniofacial deviations. Eur J Orthod. 2000; 22 (1): 69–74. doi: 10.1093/ejo/22.1.69.
40. *Leonardi R., Barbato E., Vichi M., Caltabiano M.*: A sella turcica bridge in subjects with dental anomalies. Eur J Orthod. 2006; 28 (6): 580–585. doi: 10.1093/ejo/cjl032.

41. *Kucia A., Jankowski T., Siewniak M., Janiszewska-Olszowska J., Grocholewicz K., Szych Z., Wilk G.*: Sella turcica anomalies on lateral cephalometric radiographs of Polish children. Dentomaxillofac Radiol. 2014; 43 (8): 20140165. doi: 10.1259/dmfr.20140165.
42. *Nikolova S., Toneva D., Zlatareva D., Fileva N.*: Osseous bridges of the sphenoid bone: frequency, bilateral and sex distribution. Biology (Basel). 2023; 12 (4): 492. doi: 10.3390/biology12040492.
43. *Touska P., Hasso S., Oztek A., Chinaka F., Connor S.E.J.*: Skull base ligamentous mineralisation: evaluation using computed tomography and a review of the clinical relevance. Insights Imaging. 2019; 10 (1): 55. doi: 10.1186/s13244-019-0740-8.
44. *Freire A.R., Rossi A.C., Prado F.B., Groppo F.C., Ferreira Caria P.H., Botacin P.R.*: Caroticoclinoid foramen in human skulls: incidence, morphometry and its clinical implications. Int J Morphol. 2011; 29 (2): 427–431.
45. *Zdilla M.J., Cyrus L.M., Lambert H.W.*: Carotico-clinoid foramina and a double optic canal: a case report with neurosurgical implications. Surg Neurol Int. 2015; 6: 13. doi: 10.4103/2152-7806.150456.
46. *Baz R.A., Scheau C., Niscoveanu C., Bordei P.*: Morphometry of the entire internal carotid artery on CT angiography. Medicina (Kaunas). 2021; 57 (8): 832. doi: 10.3390/medicina57080832.
47. *Nutik S.L.*: Removal of the anterior clinoid process for exposure of the proximal intracranial carotid artery. J Neurosurg. 1988; 69 (4): 529–534. doi: 10.3171/jns.1988.69.4.0529.
48. *Suprasanna K., Kumar A.*: Surgically relevant bony anatomical variations in paraclinoid aneurysms-three-dimensional multi-detector row computed tomography-based study. J Neurosci Rural Pract. 2017; 8 (3): 330–334. doi: 10.4103/jnrp.jnrp_416_16.
49. *Inoue T., Rhoton A.L. Jr., Theele D., Barry M.E.*: Surgical approaches to the cavernous sinus: a microsurgical study. Neurosurgery. 1990; 26: 903–932. doi: 10.1097/00006123-199006000-00001.
50. *Ota N., Tanikawa R., Miyazaki T., Miyata S., Oda J., Noda K., Tsuboi T., Takeda R., Kamiyama H., Tokuda S.*: Surgical microanatomy of the anterior clinoid process for paraclinoid aneurysm surgery and efficient modification of extradural anterior clinoidectomy. World Neurosurg. 2015; 83 (4): 635–643. doi: 10.1016/j.wneu.2014.12.014.
51. *Linskey M.E., Sekhar L.N., Hirsch W.L., Yonas H., Horton J.A.*: Aneurysms of the intracavernous carotid artery: natural history and indications for treatment. Neurosurgery. 1990; 26 (6): 933–937.
52. *Javalkar V., Banerjee A.D., Nanda A.*: Paraclinoid carotid aneurysms. J Clin Neurosci. 2011; 18 (1): 13–22. doi: 10.1016/j.jocn.2010.06.020.
53. *Yasuda A., Campero A., Martins C., Rhoton A.L. Jr, de Oliveira E., Ribas G.C.*: Microsurgical anatomy and approaches to the cavernous sinus. Neurosurgery. 2005; (1 Suppl): 4–27. doi: 10.1227/01.neu.0000144208.42171.02.
54. *Erturk M., Kayalioglu G., Govsa F.*: Anatomy of the clinoidal region with special emphasis on the caroticoclinoid foramen and interclinoid osseous bridge in a recent Turkish population. Neurosurg Rev. 2004; 27 (1): 22–26. doi: 10.1007/s10143-003-0265-x.
55. *Kim Y.H, Lee J.Y., Phi J.H., Wang K.C., Kim S.K.*: Endoscopic endonasal skull base surgery for pediatric brain tumors. Childs Nerv Syst. 2019; 35 (11): 2081–2090. doi: 10.1007/s00381-019-04335-5.
56. *Tatreau J.R., Patel M.R., Shah R.N., McKinney K.A., Wheless S.A., Senior B.A., Ewend M.G., Germanwala A.V., Ebert C.S. Jr, Zanation A.M.*: Anatomical considerations for endoscopic endonasal skull base surgery in pediatric patients. Laryngoscope. 2010; 120 (9): 1730–1737. doi: 10.1002/lary.20964.
57. *Zhan R., Xin T., Li X., Li W., Li X.*: Endonasal endoscopic transsphenoidal approach to lesions of the sellar region in pediatric patients. J Craniofac Surg 2015; 26 (6): 1818–1822. doi: 10.1097/SCS.0000000000001946.
58. *Banu M.A., Guerrero-Maldonado A., McCrea H.J., Garcia-Navarro V., Souweidane M.M., Anand V.K., Heier L., Schwartz T.H., Greenfield J.P.*: Impact of skull base development on endonasal endoscopic surgical corridors. J Neurosurg Pediatr. 2014; 13 (2): 155–169. doi: 10.3171/2013.10.PEDS13303.