VIA MEDICA

ORIGINAL ARTICLE

Folia Morphol.
Vol. 83, No. 1, pp. 176–181
DOI: 10.5603/FM.a2023.0004

ISSN 0015–5659
eISSN 1644–3284
journals.viamedica.pl

Occurrence of the ossification of petrosphenoid ligament: a retrospective radiologic study from computed tomographic images

Bhagath Kumar Potu[1], Fatemah Hamad Al-Khamis[2], Hebah Husain Taher[2], Abdulrahman Abdulreheim[3]

[1]*Department of Anatomy, College of Medicine and Medical Sciences, Arabian Gulf University, Manama, Kingdom of Bahrain*
[2]*College of Medicine and Medical Sciences, Arabian Gulf University, Manama, Kingdom of Bahrain*
[3]*Medical Imaging Department, Mubarak Al-Kabeer Hospital, Jabriya, Kuwait*

[Received: 20 October 2022; Accepted: 21 December 2022; Early publication date: 17 January 2023]

Background: *Various ligaments present in the skull base are of clinical and surgical importance. One among them, is the petrosphenoid ligament (PSL). PSL may ossify either in a partial or complete form and forms the roof of Dorello's canal underneath which the abducens nerve passes. Studies argued both protective and adverse effects of the ossified PSL. Hence, the incidence of PSL ossification has become a relevant subject in clinical practice to radiologists, neurologists and neurosurgeons for understanding its potential role in abducens nerve compression.*

Materials and methods: *We have undertaken this study to investigate the incidence of PSL ossification from multidetector computed tomography (MDCT) images of the patients who had been referred to the Medical Imaging Department of Mubarak Al-Kabeer Hospital in Kuwait. We retrospectively assessed a total of 200 patients' head CT scans (400 petroclival regions) between January 2021 and June 2022 in which 59% were males (n = 118) and 41% were females (n = 82) aged between 18 and 91 years.*

Results: *A total of 37 patients (26 male, 11 female) aged between 18–84 years were presented with ossification of PSL. Among these 37 patients, 28 patients were presented with unilateral ossified PSL, and 9 patients were presented with bilateral ossified PSL, amounting to the total of 46 ossified PSL from 400 CT images of the petroclival regions (11.5%). The genderwise and sidewise occurrence of the PSL ossification seen in different age groups were not statistically significant ($p > 0.05$). Among all the ossified cases, there was no patient presented with abducens nerve palsy.*

Conclusions: *We believe our results provide baseline data in the region for understanding PSL ossification and its impact on the abducens nerve palsy.* (Folia Morphol 2024; 83, 1: 176–181)

Keywords: petrosphenoid ligament, ossification, multidetector computed tomography, abducens nerve palsy

Address for correspondence: Dr. Bhagath Kumar Potu, Department of Anatomy, College of Medicine and Medical Sciences, Arabian Gulf University, Manama, Kingdom of Bahrain, e-mail: potubk@agu.edu.bh

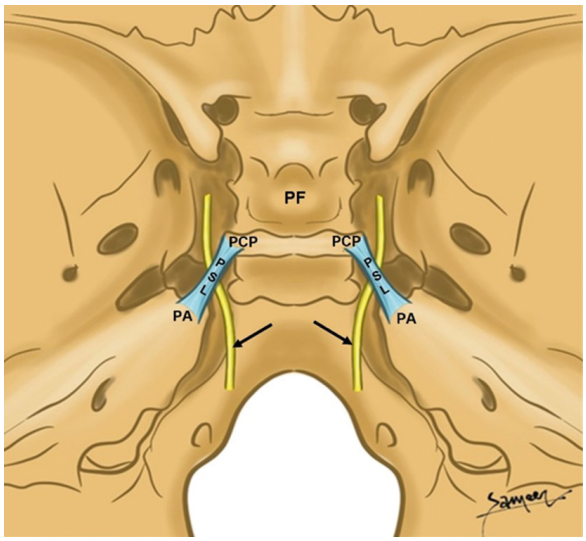

Figure 1. Schematic diagram showing the extent of petrosphenoid ligament (PSL); PF — pituitary fossa; PCP — posterior clinoid process; PA — petrous apex. Arrows showing the abducens nerve.

INTRODUCTION

Various ligaments present in the skull base are of clinical and surgical importance. One among them is the petrosphenoid ligament (PSL). As early as in the year 1859; Gruber [10] first described this ligament as a sphenopetrosal ligament that extends between the petrous apex and the accessory clinoid process of the sphenoid bone. Subsequently, in further studies, it is often referred to as the ligament of Gruber [18, 27]. Later on, Dorello [7] explored this region and found that the ligament constitutes the roof of the sphenopetrosal passageway to the abducens nerve as well as to the inferior petrosal sinus. This passage is named after Dorello as, Dorello's canal [7]. Several studies followed, reported that the abducens nerve usually [6, 8], but not in all the cases [21, 30], passes below the PSL, which is located between the petrous apex and the posterior clinoid process (Fig. 1) [12]. The available morphometric data on PSL length suggests that the average length may vary from 8–14 mm and its average width measured at the midsection ranges from 1–2 mm. The Dorello's canal, which is situated below the PSL, near the tip of petrous bone is as narrow as 5–6 mm in width with 1–2 mm height, respectively [12, 21, 25].

In some cases, the PSL may ossify either in a partial or complete form and form a bony bridge connecting the apex of the petrous bone with the sphenoid bone. Such bony bridge forms an osseous foramen, which is a normal feature seen in nonhuman primates, but not in human beings. Up to date, the incidence of PSL ossification has been found to be in a range of 1–25% from the studies reported from various populations [12, 14, 16, 20, 28]. Studies argued both protective and adverse effects of the ossified PSL. A few studies have proposed that the ossified PSL might pose an increased risk of injury to the abducens nerve in the petroclival region causing abducens nerve palsy [21, 25, 28]. Contrary to these findings, a study also proposed the protective effects of PSL in guarding the abducens nerve [20]. Hence, the incidence of PSL ossification has become a relevant subject in clinical practice to radiologists, neurologists and neurosurgeons for understanding its potential role in abducens nerve compression. Although few anatomical studies determined the characteristic features of ossified PSL, radiological studies evaluating the incidence of PSL ossification are scarce in the available literature. To the best of our knowledge, no computed tomography (CT) imaging study has been performed in Kuwait region to assess the ossification of PSL. Therefore, we have undertaken this study to investigate the incidence of PSL ossification from the multidetector computed tomography (MDCT) images.

MATERIALS AND METHODS

Subjects

In this study, we retrospectively assessed a total of 200 patients' head CT scans (400 petroclival regions), who were referred to the Medical Imaging Department of Mubarak Al-Kabeer Hospital in Kuwait. Patients' CT scan data were reviewed using the "Centricity Universal Viewer" system at Mubarak Al-Kabeer Hospital from January 2021 till June 2022. The age of patients evaluated was in the range of 18–91 years. The mean age of the patient was 54.8 ± 18.3. CT images presenting artefacts and images with history of tumour and fractures of the petroclival region were excluded. This study was approved by the Ministry of Health, Kuwait (No: 1794/2021) as well as the Institutional Research and Ethics Committee, College of Medicine and Medical Sciences, Arabian Gulf University (Project number: E01-PI-10-21).

Assessment of PSL ossification from MDCT images

Scans were obtained using 64-row CT Scanner (GE Healthcare, Chicago, IL, USA). The image parameters were: rotation time = 1.0 s, slice thickness = 0.65 mm, effective mAs [Milli-Ampere seconds] = 150–300

Table 1. Genderwise distribution of petrosphenoid ligament ossification

Gender	Extent		Total
	Partial	Complete	
Male	24	2	26
Female	11	0	11
Total	35	2	37

Table 2. Sidewise distribution of petrosphenoid ligament ossification

	Side of ossification	Gender	
		Male	Female
Partial	Left	9	3
	Right	8	7
	Bilateral	7	1
Complete	Left	0	0
	Right	1	0
	Bilateral	1	0

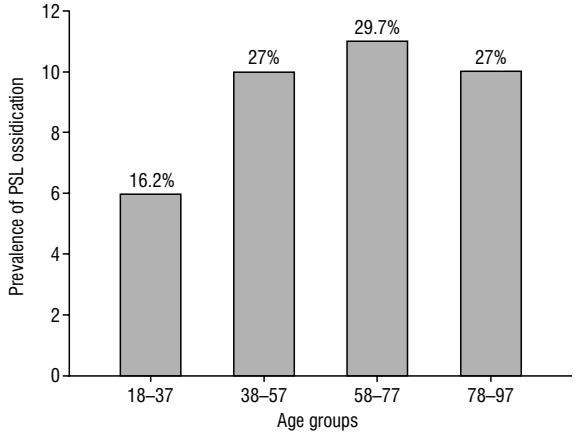

Figure 2. Age distribution of petrosphenoid ligament (PSL).

and 140 kV dose. The images were observed and assessed carefully on high-resolution monitors at bone window settings (W: 3077, C: 570). Axial slices of the skull base above the uppermost portion of the petroclival region were assessed in a craniocaudal direction to look for an ossification of the PSL. If PSL ossification was observed as an uninterrupted hyperdense extension from the petrous apex to posterior clinoid process, we defined it as a complete ossification. Any hyperdense, incomplete bony ridge in the course of PSL was noted, we defined it as a partial ossification. Age related demographics of the patients were recorded for detailed evaluation to see whether there is any association between the age and frequency of the ossification. The medical records of patients with PSL ossification were also assessed to investigate whether the cases of PSL ossified cases are associated with abducens nerve palsy.

Statistical analysis

Data were analysed using IBM SPSS v.24 (IBM Corp., Armonk, NY, USA). Descriptive statistics were used to analyze the prevalence of PSL among age groups and sex. Data were presented as percentages. Chi-square test was performed to see whether any significant influence of sex and side on occurrence of the ossification of PSL and the significant association between the age and occurrence of the ossification of PSL. The level of significance was set at $p < 0.05$.

RESULTS

In our study of 200 patients, 59% were males (n = 118) and 41% were females (n = 82). Patients were divided into groups according to age with each group spanning 20 years. A total of 400 CT images of petroclival regions were assessed to analyze the extent of PSL ossification.

A total of 37 patients (26 male, 11 female) aged between 18–84 years were presented with ossification of the PSL. The overall prevalence of PSL ossification was 18.5% and it was seen in all age groups.

Among these 37 patients, 28 patients were presented with unilateral ossified PSL, and 9 patients were presented with bilateral ossified PSL, amounting to the total of 46 ossified PSL from 400 CT images of the petroclival regions assessed (11.5%) (Table 1). The genderwise, sidewise, and partial to complete occurrence of the PSL ossification were shown in Table 2. The age distribution of all subjects with occurrence of PSL ossification were presented in Figure 2. With regards to the extent of ossification, we found completely ossified PSL in 2 male patients (1 on the right side and 1 bilaterally) (Tables 1, 2; Fig. 3A). Of 35 partially ossified cases (24 male, 11 female), 15 were on the right side, 12 were on the left side and 8 were bilateral (Tables 1, 2; Fig. 3B). Figure 4A, B show the unilateral ossification of PSL on the right and left sides. Figure 5A, B are the volume rendered three-dimensional CT images showing bilateral partial and unilateral partial ossification of the PSL. There was no statistically significant association between gender, side, age groups and occurrence of the PSL ($p > 0.05$).

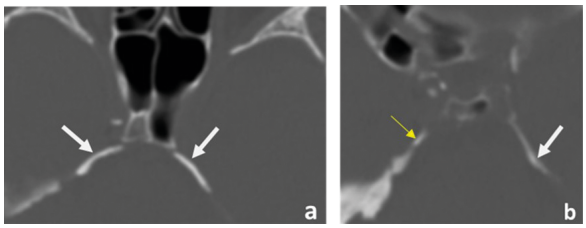

Figure 3. Bilateral ossification of petrosphenoid ligament (PSL); **A.** Axial computed tomography image showing bilateral complete ossification of PSL (white arrows) in a 52-year-old male; **B.** Axial computed tomography image showing partially ossified PSL on the right side (thin yellow arrow) and completely ossified PSL on the left side (thick white arrow) in a 68-year-old male.

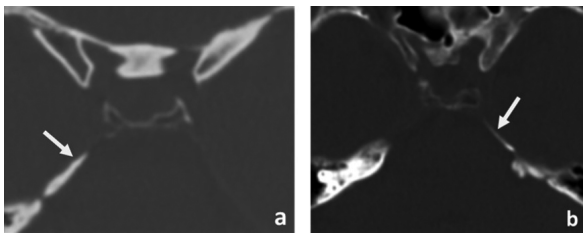

Figure 4. Unilateral partial ossification of petrosphenoid ligament (PSL); **A.** Axial computed tomography image showing unilateral ossification of PSL on the right side (white arrow) in a 26-year-old female; **B.** Axial computed tomography image showing unilateral ossification of PSL on the left side in a 59-year-old male (white arrow).

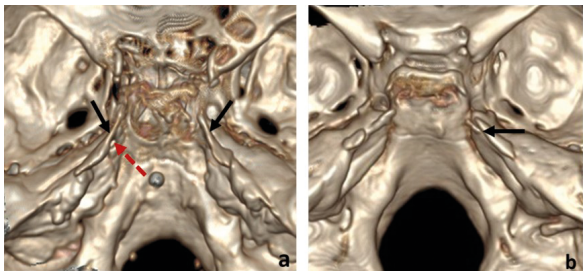

Figure 5. Volume rendered three-dimensional computed tomography images of ossified petrosphenoid ligament (PSL); **A.** Postero-superior view of the skull base showing bilateral partial ossification of PSL (black arrows) in a 68-year-old male. Dotted red arrow showing the petrous apex; **B.** Postero-superior view of the skull base showing partially ossified PSL on the right side (black arrow) in a 26-year-old female.

Based on the data reviewed, there was no patient registered with abducens nerve palsy among all the ossified cases.

DISCUSSION

To the best of our knowledge, this is the first study to report the prevalence of PSL ossification from CT scans of the skull bases in Kuwait region. Our study found 46 ossified PSL from 400 CT images of the petroclival regions assessed (11.5%). The incidence of ossified PSL was found to range from 1 to 12% in different radiological and anatomical studies. However, in one study [14], results are different in which ossified PSL was found to be 25% (5 out of 20 specimens). A recent radiological study conducted on 240 CT images found 26 ossified PSL (19 unilateral, 7 bilateral) and identified that in bilateral cases, 14.3% were completely ossified and 85.7% were partially ossified. In unilateral cases, 26.3% were completely ossified and 73.7% were partially ossified [26]. A study by Tsitsopulos et al. [27] confirmed that PSL was ossified in 10% of cases. Ozgur and Esen [20] in their study from 523 CT images (1046 petroclival regions) found 61 ossified PSL (31 unilateral, 15 bilateral) of which 6.5% were on the right side and 5.1% were on the left side. They identified that 38 (3.6%) ligaments were partially ossified, whereas 23 (2.2%) ligaments were completely ossified. In addition to these radiological findings, very few gross anatomical studies are existing in the literature. A gross anatomical study conducted on 134 skulls observed 7 ossified PSL [1]. Peker et al. [22] in a sample of 80 subjects, reported these ossifications occurring at the incidence of 7.6% on the right side and 10.1% on the left side, respectively. A few anatomical studies have also reported a completely ossified bilateral PSL [1, 13, 19, 22, 29] and to a lesser extent, partially ossified unilateral PSL from their sample [24]. In addition to these, few reports have also discussed the atypical attachments of PSL to the posterior genu of the cavernous internal carotid artery in a male cadaver [31], and to the dorsum sellae in a fetal skull [5]. Ossification of the skull base ligaments could be attributed to factors, such as genetics, metabolic abnormalities and mechanical stress [26]. It is clear from our study results that the ossification of PSL is a common finding in all the age groups and the incidence of ossification is found to be increasing in all the age groups from 18–77 years.

Apart from ossification, partial to complete calcification of PSL is also described in the literature. Inal et al. [13] conducted a CT study on 130 skull bases and reported that the partial calcifications of the PSL were found to be 9.8% on both right and left sides and complete calcifications at the incidence of 2.3% on right and 2.9% on left sides, respectively. There were no statistically significant differences seen between PSL calcification in males and females on the right and left sides, respectively. In addition to these

radiological findings, a few anatomical studies were also conducted to assess the calcification of PSL. Icke et al. [12] have noted a small number of calcified PSL at the incidence of 5% in 2 of 40 cases studied, followed by Destrieux et al. [6] examined 16 human cadaver heads and found only 1 calcified PSL (6.25%).

The anatomical relationship of PSL with Dorello's canal has become an important aspect in clinical practice, particularly in skull base surgeries [8, 9], dealing with the pathologies of petroclival region [15]. The association of ossified PSL with hypoplasia of the Dorello´s canal [3, 4], has explained the mechanism of abducens nerve palsy in several pathological conditions caused by the infection and inflammation of the petrous apex [2]. Contrary to these adverse findings, studies also claimed that the ossified PSL may act as an important anatomical landmark, shielding the abducens nerve by limiting the petrous drilling in skull base surgeries [11] and may protect the structures passing through Dorello's canal as commonly seen in nonhuman primates [17, 23]. A study by Ozgur and Esen [20] supported this hypothesis and revealed that the complete or partial ossification of PSL was not associated with abducens nerve palsy as in our study.

Our results also suggest that the abducens nerve palsy may be mostly related to the hypoplastic Dorello's canal and the position of nerve within Dorello's canal, rather than the ossification of PSL alone. Studies confirmed that the passage of abducens nerve through Dorello's canal is not constant. It may travel in the lateral 1/3rd, middle 1/3rd or, rarely, medial 1/3rd of the canal [4, 20, 25]. In any of these cases, the abducens nerve can be entrapped when the narrow segment of the canal corresponds to the course of the abducens nerve.

CONCLUSIONS

In conclusion, our study confirms the efficiency of MDCT in identifying the ossification of PSL. We believe that these results provide baseline data in the region for understanding PSL ossification and its impact on the abducens nerve palsy. Our study has some limitations, are that: this study contained smaller samples and the complete clinical data on the radiological imaging and surgical correlation was not available. Although CT provides information about the ossified PSL, magnetic resonance imaging may be useful in future to determine the precise relationship between the ossified PSL and abducens nerve.

Conflict of interest: None declared

REFERENCES

1. Aggarwal B, Gupta M, Kumar H. Ossified ligaments of the skull. J Anat Soc India. 2012; 61(1): 37–40, doi: 10.1016/s0003-2778(12)80010-4.
2. Ambekar S, Sonig A, Nanda A. Dorello's canal and Gruber's ligament: historical perspective. J Neurol Surg B Skull Base. 2012; 73(6): 430–433, doi: 10.1055/s-0032-1329628, indexed in Pubmed: 24294562.
3. Barges-Coll J, Fernandez-Miranda JC, Prevedello DM, et al. Avoiding injury to the abducens nerve during expanded endonasal endoscopic surgery: anatomic and clinical case studies. Neurosurgery. 2010; 67(1): 144–154, doi: 10.1227/01.NEU.0000370892.11284.EA, indexed in Pubmed: 20559102.
4. Chua C, Cooper LL, Wei XC, et al. Recurrent sixth nerve palsy associated with a hypoplastic Dorello's canal. J AAPOS. 2011; 15(4): 392–394, doi: 10.1016/j.jaapos.2011.03.015, indexed in Pubmed: 21907125.
5. Clarke E, Golberg M, Smędra A, et al. Bilateral caroticoclinoid foramen and unilateral abducens nerve canal found on the fetal skull: case report. Transl Res Anat. 2022; 29: 100224, doi: 10.1016/j.tria.2022.100224.
6. Destrieux C, Velut S, Kakou M, et al. A new concept in Dorello's canal microanatomy: the petroclival venous confluence. J Neurosurg. 1997; 87(1): 67–72, doi: 10.3171/jns.1997.87.1.0067.
7. Dorello P. Considerazioni sopra la causa della paralisi transitoria dell' abducente nelle flogosi dell' orecchio medio. In: Ferrari G (ed.). Atti della Clinica Oto-Rino-Laringoiatrica. Tipografia del Campidoglio, Roma 1905: 209–217.
8. Duque PJ, Barco RJ, Mendoza ZJ. Dorello´s Canal or Abducens Nerve Canal: Constancy or Inconstancy? Int J Morphol. 2017; 35(1): 233–235, doi: 10.4067/s0717-95022017000100038.
9. Ezer H, Banerjee AD, Thakur JD, et al. Dorello's canal for laymen: a lego-like presentation. J Neurol Surg B Skull Base. 2012; 73(3): 183–189, doi: 10.1055/s-0032-1311753, indexed in Pubmed: 23730547.
10. Gruber W. Beitrage zur anatomie des keilbeins und schlafenbeins. In: Richter HE, Winter A (ed.). Schmidt's Jahrbucher der in-und Auslandischen. Gessamten Medicin, Anatomie und Physiologie. Verlag Von Otto Wigard, Leipzig 1859: 40–41.
11. Iaconetta G, Tessitore E, Samii M. Duplicated abducent nerve and its course: microanatomical study and surgery-related considerations. J Neurosurg. 2001; 95(5): 853–858, doi: 10.3171/jns.2001.95.5.0853.
12. Icke C, Ozer E, Arda N. Microanatomical characteristics of the petrosphenoidal ligament of gruber. Turk Neurosurg. 2010; 20(3): 323–327, doi: 10.5137/1019-5149.jtn.2921-10.0.
13. Inal M, Muluk NB, Burulday V, et al. Investigation of the calcification at the petroclival region through multi-slice computed tomography of the skull base. J Craniomaxillofac Surg. 2016; 44(4): 347–352, doi: 10.1016/j.jcms.2016.01.018, indexed in Pubmed: 26922483.
14. Joo W, Yoshioka F, Funaki T, et al. Microsurgical anatomy of the abducens nerve. Clin Anat. 2012; 25(8): 1030–1042, doi: 10.1002/ca.22047, indexed in Pubmed: 22334502.
15. Kshettry VR, Lee JH, Ammirati M. The Dorello canal: historical development, controversies in microsurgical

anatomy, and clinical implications. Neurosurg Focus. 2013; 34(3): E4, doi: 10.3171/2012.11.FOCUS12344, indexed in Pubmed: 23451716.
16. Liu XD, Xu QW, Che XM, et al. Anatomy of the petrosphenoidal and petrolingual ligaments at the petrous apex. Clin Anat. 2009; 22(3): 302–306, doi: 10.1002/ca.20771, indexed in Pubmed: 19173250.
17. Marom A. A new look at an old canal. Skull Base. 2011; 21(1): 53–58, doi: 10.1055/s-0030-1263282, indexed in Pubmed: 22451800.
18. Nathan H, Ouaknine G, Kosary IZ. The abducens nerve. Anatomical variations in its course. J Neurosurg. 1974; 41(5): 561–566, doi: 10.3171/jns.1974.41.5.0561, indexed in Pubmed: 4417502.
19. Ozer E, Icke C, Arda N. Microanatomical study of the intracranial abducens nerve: clinical interest and surgical perspective. Turk Neurosurg. 2010; 20(4): 449–456, doi: 10.5137/1019-5149.JTN.3303-10.1, indexed in Pubmed: 20963693.
20. Özgür A, Esen K. Ossification of the petrosphenoidal ligament: multidetector computed tomography findings of an unusual variation with a potential role in abducens nerve palsy. Jpn J Radiol. 2015; 33(5): 260–265, doi: 10.1007/s11604-015-0410-9, indexed in Pubmed: 25749833.
21. Ozveren MF, Erol FS, Alkan A, et al. Microanatomical architecture of Dorello's canal and its clinical implications. Neurosurgery. 2007; 60(2 Suppl 1): 1–7, doi: 10.1227/01.NEU.0000249229.89988.4D, indexed in Pubmed: 17297359.
22. Peker T, Anil A, Gülekon N, et al. The incidence and types of sella and sphenopetrous bridges. Neurosurg Rev. 2006; 29(3): 219–223, doi: 10.1007/s10143-006-0018-8, indexed in Pubmed: 16528575.
23. Rusu MC, Vrapciu AD, Rădoi PM, et al. Concomitant completely ossified trigeminal pore and Dorello's canal. Folia Morphol. 2023; 82(1): 187–189, doi: 10.5603/fm.a2022.0007, indexed in Pubmed: 35099042.
24. Skrzat J, Mróz I, Spulber A, et al. Ossification of the petrosphenoid ligament: a case study. Folia Med Cracov. 2017; 57(2): 87–94, indexed in Pubmed: 29121040.
25. Tomio R, Toda M, Sutiono AB, et al. Grüber's ligament as a useful landmark for the abducens nerve in the transnasal approach. J Neurosurg. 2015; 122(3): 499–503, doi: 10.3171/2014.10.JNS132437, indexed in Pubmed: 25380109.
26. Touska P, Hasso S, Oztek A, et al. 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, indexed in Pubmed: 31115710.
27. Tsitsopoulos PD, Tsonidis CA, Petsas GP, et al. Microsurgical study of the Dorello's canal. Skull Base Surg. 1996; 6(3): 181–185, doi: 10.1055/s-2008-1058643, indexed in Pubmed: 17170976.
28. Tubbs RS, Sharma A, Loukas M, et al. Ossification of the petrosphenoidal ligament: unusual variation with the potential for abducens nerve entrapment in Dorello's canal at the skull base. Surg Radiol Anat. 2014; 36(3): 303–305, doi: 10.1007/s00276-013-1171-8, indexed in Pubmed: 23877841.
29. Umansky F, Elidan J, Valarezo A. Dorello's canal: a microanatomical study. J Neurosurg. 1991; 75(2): 294–298, doi: 10.3171/jns.1991.75.2.0294, indexed in Pubmed: 2072168.
30. Wysiadecki G, Orkisz S, Gałązkiewicz-Stolarczyk M, et al. The abducens nerve: its topography and anatomical variations in intracranial course with clinical commentary. Folia Morphol. 2015; 74(2): 236–244, doi: 10.5603/FM.2015.0037, indexed in Pubmed: 26050813.
31. Żytkowski A, Clarke E, Musiał A, et al. Atypical attachment of the petrosphenoidal (petroclival) ligament to the posterior genu of the cavernous internal carotid artery: case report. Transl Res Anat. 2022; 27: 100185, doi: 10.1016/j.tria.2022.100185.