

Anatomical and morphometric evaluation of the foramen transversarium of cervical vertebrae

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ÖZET

Servikal Vertebraların Foramen Transversarium'larının Anatomik Ve Morfometrik Olarak Değerlendirilmesi

Servikal vertebraların processus transversus'larında bulunan foramen transversarium vertebra cervicalis'de varyasyonel durumlar olan double foramen transversarium sıklığını ortaya koymak, foramen transversarium'un boyutlarını, şekil farklılıklarını ve bu durumların neden olabileceği klinik belirtileri vurgulamaktır. Gülhane Tıp Fakültesi Anatomi Anabilim Dalı laboratuvarında mevcut 82 servikal vertebra üzerinde çalışma yapıldı. Tüm vertebralar üzerindeki foramen transversarium'ların farklılıkları kaydedildi. Tüm vertebralarda foramen transversarium mevcuttu. 82 servikal vertebra'nın 18 tanesinde double foramen transversarium görüldü. Bunların içinde 6 vertebra'da tek taraflı, 12 vertebra'da iki taraflı double foramen transversarium bulundu. Tek taraflı olanlardan 1 tanesi sağ tarafta, 5 tanesi sol tarafta idi. En fazla yuvarlak tipte foramen transversarium görüldü. Sağ tarafta bulunan foramen transversarium'ların ön-arka ve medial-lateral çapları sırasıyla 5,7 mm ve 6,5 mm; sol tarafta bulunan foramen transversarium'ların ön-arka ve medial-lateral çapları sırasıyla 5,5 mm ve 6,6 mm idi. Bu çalışmada double foramen transversarium sıklığı % 21,95 olarak bulunmuştur. Double foramen transversarium iki taraflı olması tek taraflı double foramen transversarium'dan iki kat fazla olduğu görülmüştür. Bu varyasyonun klinisyenler tarafından bilinmesi önemlidir. Foramen transversarium'lardaki morfolojik farklılıklar, C7 hariç bu açıklıklardan geçen a.vertebralis'deki kan akımının etkilenmesine bağlı nörolojik durumlara yol açması açısından önem arz etmektedir.

Anahtar Kelimeler: *Vertebrae cervicales, çift foramen transversarium, aksesuar foramen transversarium, Morfometri.*

SUMMARY

The purpose of this study is to reveal the incidence of double foramen transversarium constituting variational conditions at the foramen transversarium vertebrae cervicales located at the processus transversus of cervical vertebrae; and emphasize the dimensions, shape variations of foramen transversarium as well as the clinical symptoms that may be caused by these conditions. For this study, a total of 82 cervical vertebrae available at the laboratory of the Gülhane Medical Faculty Department of Anatomy were studied. Variations of foramen transversarium on all vertebrae were recorded. Foramen transversarium was present in all vertebrae. Double foramen transversarium were observed in 18 of 82 cervical vertebrae. Of them, 6 vertebrae exhibited unilateral, and 12 vertebrae exhibited bilateral double foramen transversarium. Of the unilateral transversarium, 1 was on the right side and 5 were on the left side. Foramen transversarium observed were predominantly in round form. Anterior-posterior and medial-lateral diameters of right foramen transversarium was 5.7 mm and 6.5 mm respectively while the anterior-posterior and medial-lateral diameters of left foramen transversarium were 5.5 mm and 6.6 mm respectively. In this study, incidence of double foramen transversarium was found as 23.95%. Among all double foramen transversarium, the incidence of the bilateral group was observed to be doubling the unilateral group. It's significant for clinicians to have a knowledge of this variation. Morphological variations in foramen transversarium are significant as they lead to neurological conditions due to the flow of blood passing through these openings except for C7.

Key words: *Vertebrae cervicales, double foramen transversarium, accessory foramen transversarium, morphometry.*

Introduction

There are 7 cervical vertebrae in the human. The first, second and seventh cervical vertebra are known as atypical, while other 4 are typical vertebrae. The foramen transversarium (FT) that located in the processus transversus is discriminative property of cervical vertebrae. Vertebral artery, vertebral vein and the surrounding plexus sympathicus pass through the hole. The hole called FT. Vertebral artery don't pass through C7's FT, there is only accessory vertebral vein. Therefore, FT of the 7th cervical vertebra is smaller (1). Anatomic variations of FT are significant due to vertebral vein as an extension of vertebral artery and internal vertebral venous plexus that passes through here to head for brain. The variations in number and size of FT of cervical spine may be one of the reasons for complaints like headache, migraine, and fainting assaults and are caused the compression of vertebral artery (2). Variations of the foramen which these veins pass through, may lead to critical clinical symptoms. At the same time, knowledge of these variations will provide security to the surgeon in posterior approaches to the region.

The purpose of this study is to reveal the double FT incidence as a variation condition, and emphasize FT's shape variations, as well as clinical symptoms that such conditions may lead to.

Materials and Methods

In this study, a total of 82 cervical vertebrae were studied. Bones were selected from among the bones available at the laboratory of the Gülhane Medical Faculty, Department of Anatomy. We classified the bones as C1, C2, C3, C4, C5, C6 and C7. After classifying double FTs as complete and incomplete, we then categorized them as unilateral and bilateral FTs. We classified FT shapes in five groups. Type 1 is round, Type 2 is elliptical where the main diameter is the anterior-posterior diameter that is bigger than the medial-lateral diameter, Type 3 is elliptical where the main diameter is the medial-lateral diameter that is bigger than the anterior-posterior diameter, Type 4 is elliptical that is oblique rightwards, and Type 5 is elliptical that is oblique leftwards. We further measured the anterior-posterior (A-P) and medial-lateral (M-L) diameters by means of a digital calliper (in mm) on the left and right (Figure 1).

Results

There are 18 double FTs, among total 82 vertebrae. One cervical vertebra (1.2%) exhibited asymmetry. In two vertebrae, C2 and C3 were combined. No FTs were observed in vertebra C1 and C2. No bilateral complete double FT was observed in C3. Number of complete and incomplete double FTs shown in Table I (Figure 2-5).

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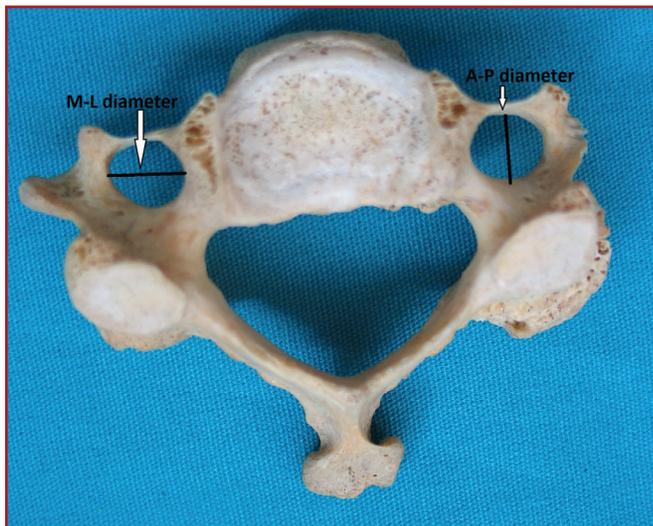


Figure 1. The anteroposterior and mediolateral diameters of foramen transversarium.



Figure 2. Bilateral complete double foramen transversarium. a: Thick septa (a thick osseous septa separates the FT) double foramen transversarium, b: Thin septa (a thin osseous septa separates the FT) double FT.

Figure 3. Complete unilateral double foramen transversarium.



Figure 4. Incomplete foramen transversarium. a: Bilateral, b: Unilateral
Figure 5. Cervical vertebrae with complete right and incomplete left foramen transversarium.

Breakdown of single- or bilateral double FTs, whether complete or incomplete, is summarized in Table II. In our study, of 82 cervical vertebrae, 12 (14.6%) were found to have bilateral double FTs, and 6 (7.3%) were found to have unilateral double FTs. In the sixth cervical vertebra, only bilateral FTs were observed. No unilateral double FT was found (Table II).

In our study, for cervical vertebrae, anterior-posterior and medial-lateral diameters of right FTs were 5.7 mm and 6.5 mm respectively. On the other hand, anterior-posterior and medial-lateral diameter of left FTs were 5.5 mm and 6.6 mm respectively (Table III). One cervical vertebra (1.2%) revealed asymmetry (right A-P diameter: 6 mm, M-L diameter: 6.5 mm; left A-P diameter: 1 mm, M-L diameter: 1.5 mm)

In our study, Type 1 FT was measured as 59.72% on the right side and 61.42% on the left side; Type 2 FT was measured as 4.11% on the right side and 1.4% on the left side; Type 3 FT was measured as 19.4% on the right side and 22.85% on the left side; Type 4 FT was measured as 9.7% on the right side and 4.28% on the left side; and Type 5 FT was measured as 6.94% on the right side and 10% on the left side (Table IV). Type 1 represents the most common phenomenon on right and left side.

Discussion

The vertebral vessels are the important in the creation of the FT, it can be obvious that variations in the existence and course of the vertebral vessels will be concluded variation in FT. A narrowing of the FTs point out narrowness of the vessels and so on. The accessory FT were most common at the lower cervical vertebrae (C5, C6 and C7), mostly in C6. The surgical anatomy of the FT and vertebral artery are prominent to the neurosurgeons and radiologists (3).

The genesis of the vertebral artery in the embryo begins at approximately 32 and is full by 40 days. This creation results from the fusion of intersegmental arterial vessels, which branch off the primitive dorsal aorta and companionship the cervical segmental nerves 2 through 8. As their link to the primitive dorsal aorta fade away, a pearl-like, longitudinal, anastomotic chain, dispatched to as the vertebral artery, is formed. At this stage in growth, the vertebral artery is tortuous and composed of a series of irregular branches (4,5). Cranially, the two vertebral arteries combine to form the basilar artery. Sometimes, two intersegmental vessels may unsuccessful to annihilate and may in fact anastomose with one another, or the segmental arteries keep very short or evanesce, while a section of the dorsal aorta remains lying against the vertebral artery, both resulting in a fenestration of the vertebral artery (6,7,8,9,10,11) In addition to, a portion of the primitive dorsal aorta may persist together with two intersegmental vessels connecting to the true vertebral artery, giving rise to vertebral vessel duplication. No embryologic clarification can be given for the differences in vessel wall composition noted in the two trunks forming a fenestration.

Several cases of duplication and of fenestration of the intra- and extracranial course of the vertebral arteries have been reported, primarily in a Japanese population (12). Vascular injury to the extracranial course of the vertebral arteries was externalized through the medium of angiography. Meanwhile, a incidental finding of fenestration of the right vertebral artery was observed; the left vertebral artery, nevertheless, showed a orderly course. Neither vertebral artery was predominant extremely the other. The fenestration was localized between the intervertebral spaces of C2–C3 and C3–C4 (13). Lasjaunias (14), announced that 'the main difference between duplications and fenestrations is that in duplication one of the vessels leaves the vertebral canal to enter the spinal canal and has a subarachnoid course which begins and finished at the level of two successive foramina transversaria and follows a cervical root, whereas fenestration remains in the vertebral canal between two successive transverse processes'. Mizukami et al. have stated that the fenestration is often related to vascular malformations (15)

Many authors have studied the FT morphology (16,17). Anatomy of FT and vertebral artery is important for neurosurgeons and radiologists. A compression in FT shows that veins passing through here may also be contracted. Since the circula-

tory system was developed earlier than the other system, sinusity of vertebral artery may be a factor in the development of FT variations. Also embryological factors may contribute to the development of these variations. These variations in FT may affect the anatomic progress of vital vascular and neurological structures and hence lead to pathological conditions.

Yadav et al. (18) report unilateral complete FT as 2.5%, bilateral complete FT as 4.16%, incomplete FT as 1.66%, and asymmetrical FT as 0.83%. In our study, unilateral complete FT was found as 7.3%, bilateral complete FT as 3.16%, incomplete FT as 16.9%, and asymmetrical FT as 1.2%. Yadav et al. (18) state that unilateral double FT is more incident than the bilateral double FT. In our study, the incidences of bilateral and unilateral FT were found as 14.6% and 7.3% respectively. Contrary to Yadav et al. (18), bilateral double FT was observed to be more incident in our study.

Aydinođlu et al. (16) report only 1 incomplete left double FT variation among 222 cervical vertebrae (0.45%). In our study, 6 incomplete left double FT variations were observed in 82 cervical vertebrae. Percentages we found reveal high variations. Traitz et al. (17) report incomplete left double FT variation as 7%. This is consistent with our findings. In their study, Aydinoglu et al. (16) report complete bilateral double FT (6.7%) as the highest incident form among the variations they have observed. Authors report left incomplete double FT (0.4%) as the least incident form. On the other hand, we observed a 3.6% complete bilateral double FT variation. Our study reveals right complete double FT (2.4%) as the least incident form.

El Shaarawy et al. (3) noted that the double FT were most common at the lower cervical vertebrae (C5, C6 and C7), mostly in C6. Jaffar et al. (19) report double FT as the most incident form (70%) in C6. In our study also double FT were seen at C6.

Sharma et al. (20) studied 200 vertebrae and found double FT in 16 of them. In their study, accessory FT incidence in C3 was 5%, accessory FT incidence in C4 was 1.5%, accessory FT incidence in C5 was 2%, and accessory FT incidence in C6 was 4%. On the other hand, in our study, we observed double FTs in 18 (21.9%) vertebrae (12 complete and 6 incomplete FTs) among 82 cervical vertebrae. Furthermore, we observed unilateral double FT in 2 vertebrae C3; bilateral double FT in 2 vertebrae C3; unilateral double FT in 2 vertebrae C4; bilateral double FT in 3 vertebrae C4; bilateral double FT in 1 vertebra C5; bilateral double FT in 2 vertebrae C5; bilateral double FT in 4 vertebrae C6; unilateral double FT in 1 vertebra C7; and bilateral double FT in 1 vertebrae C7. Variation in the ratios we found may result from both racial attributes and difference of complete-incomplete forms employed in the study. Sharma et al. (20) do not separate complete-incomplete forms in their study. In their study, Taitz et al. (17) report 7% double foramen in a total of 480 vertebrae.

Katikireddi et al. (21) reported the incidence of double FT as a total of 3% (unilateral 2%, bilateral 1%) out of 100 vertebrae. Chandravadiya et al. (22) studied on 210 cervical vertebrae. They found double FTs in only 10 of them (4.76%). Of them, 8 reveal (3.8%) unilateral double FTs, and 2 reveal bilateral double FTs (0.95%). Chandravadiya et al. (22) report double FT incidence in C5 as 6.67%; double FT incidence in C6 as 20%; and double FT incidence in C7 as 6.67%. They report a smaller size for the second foramen found. In our study, a total of 18 double FTs (6 unilateral, 12 bilateral) were observed. Number of our bilateral cases exceeds that of Chandravadiya

et al. (22). Our study reveals double FTs in 3 C5; double FT in 4 C6; and double FT in 2 C7.

Kaya et al. (23) studied 22 cervical vertebrae. They found 5 (22.7%) double FTs. Of them 3 (13.6%) are reported to be bilateral and 2 (9%) to be unilateral. In our study, double FTs were observed in 12 out of 82 cervical vertebrae (14.6%), and unilateral FTs were observed in 6 of them (7.3%).

Murlimanju et al. (24) from a study of 363 specimens and they demonstrated only 6 (1.6%) accessory foramina. Among them 5 (1.4%) vertebra had double foramina and only 1 (0.3%) vertebra demonstrated three foramina. Aggarwal and Gupta (25) reported, the incidence was present bilaterally in 9 and unilaterally in 10 vertebrae (7 right-sided and 3 left-sided) in 58 seventh cervical vertebrae. Das et al. (26) seen the double FT unilaterally and bilaterally only in two different cervical vertebrae. Chaudhari et al. (27) studied 133 cervical vertebrae, double FT was seen in 22 vertebrae (23.15%), among them unilateral double foramen was discovered in 14 vertebrae (14.73%) and the bilateral was discovered in 8 vertebrae (8.42%).

Kaya et al. (23) report right FT diameter as 6.2 mm (5.7-6.5) and left FT diameter as 6.4 mm (2.3-6.7). Karau and Odual (28) report A-P diameter as 7.05 mm and M-L diameter as 6.50 mm. Authors report no statistically significant variation between genders. In our study, right A-P and M-L diameters were calculated as 5.7 mm and 6.5 mm respectively while left A-P and M-L diameters were calculated as 5.5 mm and 6.6 mm respectively.

In their study, Kaya et al. (23) report FT asymmetry in 1 (22 bones, 4.5%) cervical vertebra. In our study, 1 cervical vertebra (82 bones, 1.2%) reveals asymmetry. Such variation in percentage results from the number of bones used.

In type classification of FTs by shape, Karau and Odual (28) report 9.8% right and 11.8% left Type 1 FT; 29.4% right and 39.2% left Type 2 FT; 4.9% right and 2% left Type 3 FT; 40.2% right and 7.8% left Type 4 FT; and 15.7% right and 39.2% left Type 5 FT. In our study, Type 1 FT was measured as 59.72% on the right side and 61.42% on the left side; Type 2 FT was measured as 4.11% on the right side and 1.4% on the left side; Type 3 FT was measured as 19.4% on the right side and 22.85% on the left side; Type 4 FT was measured as 9.7% on the right side and 4.28% on the left side; and Type 5 FT was measured as 6.94% on the right side and 10% on the left side. Traitz et al. (17) report Type 4 FT as the most incident form on the right side, and Type 2 FT and Type 5 FT as the most incident form on the left side. Our study reveals no incident Type 1 FT on the right and left side.

Anatomic pathway of vertebral artery on cervical vertebrae should be known and protected well. Even a small lesion may lead to severe bleeding culminating in death (29). In addition, compression of vertebral artery in this pathway might lead to both neurological symptoms and hearing loss due to impaired inner ear (30).

Conclusion

Surgical anatomy of FT and vertebral artery is important for neurosurgeons, radiologists and physiotherapists. Knowing the significance, incidence and variations of double FTs during cervical surgery would be critical in avoiding misdiagnosis. 2nd segment of vertebral artery is affected by osteoarthritis and atherosclerosis while 3rd segment is affected by atlas fractures, dislocations or variations in FT. Therefore, such variations in FT should be taken into consideration during a surgical in-

tervention. Also, knowledge of such variation by the surgeon would guarantee a safer intervention particularly in posterior approaches to the cervical zone. Our study is one of a detailed study of the FT in the Turkish population. Our results can be made more comprehensive studies supported by radiological data.

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