Received: 01.04.2011 / **Accepted:** 07.04.2011
DOI: 10.5137/1019-5149.JTN.4456-11.1

Double Foramen Transversarium Variation in Ancient Byzantine Cervical Vertebrae: Preliminary Report of an Anthropological Study

Eski Bizans Servikal Vertebralarında Çift Foramen Transversarium Varyasyonu: Antropolojik Bir Çalışmanın Ön Sonucu

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ABSTRACT

AIM: Foramina transversaria (FT) are located on the transverse processes of cervical vertebrae. These foramina are known to exhibit variations with regard to size, shape and may even be absent or duplicated. The aims of this study are to investigate the shape, size and variations of FT in an ancient population and to point out the importance of double FT in the human anatomy.

MATERIAL and METHODS: 262 ancient skeletons, dated 6th c AD, were unearthed from the Iasos Archaeological site between 1979 and 1987. Of these skeletons, 22 cervical vertebrae belonging to 21 individual skeletons were examined for the variations of FT.

RESULTS: Fifteen (68.2%) of the skeletons were male and 6 were female. All of the FT were round in shape. Among the 22 cervical vertebrae, double FT was found in 5 (22.7%) vertebrae, while unilateral in 3 and bilateral in 2. Asymmetrical FT was observed only in one (4.5%) vertebra. The mean diameter of FT was 6.2 mm in the right side and 6.4 mm in the left.

CONCLUSION: Double FT exists since the antiquity. The recognition of this variation provides safety and effectiveness for the posterior approaches of the cervical spine.

KEYWORDS: Iasos, Cervical vertebra, Double foramen transversarium

ÖZ

AMAÇ: Foramen transversarium (FT) servikal vertebraların transvers çıkıntıları üzerine yerleşmiştir. Bu delikler şekil ve boyutlarına göre farklılıklar gösterir, hiç olmayabilirler veya çift olabilirler. Bu çalışmanın amaçları; FT'un boyut ve şekline göre varyasyonlarını antik çağdaki iskeletlerde araştırmak ve insan anatomisinde çift FT olmasının önemini vurgulamaktır.

YÖNTEM ve GEREÇLER: Iasos arkeolojik bölgesinden 1979-1987 yılları arasında MS 6.yüzyıla tarihlenen 262 iskelet çıkartılmıştır. Bu iskeletlerden, 21 ayrı iskelete ait 22 servikal vertebra FT'un varyasyonları yönünden incelenmiştir.

BULGULAR: İskeletlerden 15 (%68,2) tanesi erkek, 6 tanesi dişi bireye aitti. Tümünde yuvarlak yapıda FT vardı. 22 servikal vertebradan 5 (%22,7) tanesinde çift FT vardı ki bunlardan 3 tanesinde çift FT bilateral yerleşimli, 2 tanesinde ise unilateral yerleşimli idi. Asimetrik FT ise sadece bir (%4,5) servikal vertebrada izlendi. FT'un ortalama çapı sağ taraf için 6,2 mm, sol taraf için ise 6,4 mm olarak bulundu.

SONUÇ: Çift FT antik çağlardan beri mevcuttur. Bu varyasyonun bilinmesi servikal omurgaya posterior yaklaşımlarda güvenlik ve etkinlik sağlar.

ANAHTAR SÖZCÜKLER: İasos, Servikal omurga, Çift foramen transversarium

INTRODUCTION

Historical Overview:

The site of Iasos has been continuously settled since the Early Bronze Age (1). Levi (16) and Laviosa (15) suggested that the Iasos inhabitants were in close contacts with the Aegean islands, and especially with Minoan Crete. They also suggested that Iasos has been a Minoan colony going back to 1900 BC. Iasos became of a member of Attica-Delos sea league at 5th c. BC (12). Persian Empire ruled Iasos between the 5th and 4th c. BC (12) and governed by Amorges, a Persian noble (11). During the Peloponnesian war, Iasos was attacked and sacked by the Spartians and all the inhabitants were slaughtered or sold into slavery (26). After Spartian power in the Aegean was destroyed by Conon in 394 BC (23), Iasos was rebuilt, possibly with the aid of Knidos, and it joined a league of Aegean states that included Ephesos, Rhodes, and Samos. Following the Peace of Antalcidas in 386 BC (27), Iasos was dominated by Hekatomnos, later by Mausolos and the satrapy of Caria (21). Iasos was later liberated by Alexander the Great (21),

but in 125 BC, it, along with all of Caria, became part of the Roman province of Asia. City of Iasos survived throughout the Roman and Byzantine periods (20). In Late Roman times, Iasos flourished into a center of the Christian faith and a bishopric under the metropolis of Aphrodisias (15). In the 6th c. AD, Iasos has an important and strategic position related to the fleet that was stationed in the region as part of the defensive-administrative system of Quaestura exercitus established by Byzantine Emperor Justinian (17). Iasos gradually declined in the Ottoman period.

Anatomical aspects:

The cervical vertebrae are readily identified by the foramen transversarium (FT) perforating the transverse processes. This foramen transmits the vertebral artery, the vein, and sympathetic nerve fibres. The vertebral artery enters its vertebral course nearly always at the FT of C6; it is not surprising, therefore, that the foramen of C7, which transmits only the vein, is small or even sometimes absent (8).

The deformation and variations of this foramen may affect the anatomical course of vital vascular and neural structures, and consequently cause pathological conditions. Double FT or "FT bipartita" is a rare condition and seldom reported in the literature (2). It may be unilateral or bilateral depending on the course of vertebral artery. The tortuosity of the vertebral artery may be a factor on the development of the variations of the FT. Embryological factors may also contribute to the development of these variations (18). In addition, the presence of the variation of FT may cause vertebrobasilar insufficiency as a result of neck movements. Variations in the number and size of the FT of cervical vertebrae may result in headache, migraine and fainting attacks due to compression of vertebral artery (5). The association of double FT and duplication of vertebral artery is also possible but it is not a rule.

The aim of this study is to investigate the frequency of duplication of the FT in ancient cervical vertebrae and to discuss the clinical importance of this foramen.

MATERIAL and METHODS

Twenty-two dry cervical vertebrae belonging to 21 of 262 ancient skeletons excavated in Iasos (Figure 1A,B) between 1979 and 1987 were studied for exhibiting FT variations, with regards to duplication. All of the skeletons were unearthed from the necropolis of Iasos by Italian archaeological team and all of them belonged to the 6th century AD, Byzantine period. The cervical bones were stored in dry boxes at the Department of Anthropology.

Before the study, all the dust and dried soil were cleared away off the vertebrae. The determination of age was made by Brothwell technique (4), while biological sex was determined using dimorphic aspects of the pelvis and skull (6). This information allowed the skeletons to be classified into three age groups such as: young adult (17-25 years), middle adult (26-35 years) and late adult (36-45 years).

The shape, size and duplication of the FT were recorded and photographed. Doubling site, symmetry and shape were investigated. The diameter of each FT was measured by a micrometer.

RESULTS

A total of 262 skeletons were excavated and 22 cervical vertebrae belonging to 21 (8%) individuals were suitable for morphological examinations. Fifteen (71.4%) of them were male, 6 were female. Five skeletons were young adults, 14 (66.7%) skeletons were middle adults and 2 were late adults.

Double FT (Figure 2) was observed in 5 (22.7%) cervical vertebrae. The duplication was bilateral in 2 vertebrae and unilateral in 3 vertebrae. Asymmetrical FT was found only in one (4.5%) vertebra (Figure 3). In one individual skeleton, unilateral double FT was observed in C4 vertebra while bilateral in C5 level vertebra (Figure 4A,B). The diameter of the FT was 6.2 mm (5.7-6.5) in the right side and 6.4 mm (2.3-6.7) in the left side.

DISCUSSION

FT was investigated in ancient cervical vertebrae and the frequency of double FT was found 22.7% of the 22 cervical vertebrae. Double FT was bilateral in 9% and unilateral in 13.6% of all cervical vertebrae. Asymmetrical FT was observed in only one vertebra. The overall frequency of double FT was high regarding to the current literature. But the size of FT for both side was similar with the literature. The sample size is low and represent only 8% of all skeletons which were found in the necropolis. This is the limitation of this study.

Iasos is located on a peninsula, surrounded by sea on three sides, within the Kiyikislacik village, 28 km. from Milas. This city had been inhabited since the early bronze age. After some preliminary research by Charles Texier in 1835 (25), the site of Iasos has been excavated regularly by the Italian School of Archaeology at Athens under the directorate of Doro Levi (1960-1972), Clelia Laviosa (1972-1984) and Fede Berti (1984). The city is mainly situated on the rocky peninsula. The necropolis was unearthed by Laviosa and Berti and a total of 262 skeletons belonging to 6th century AD (Byzantine period) were found (1). These skeletons are preserved and still under investigation in the Department of Anthropology at Ankara University.

FT is a bony canal seen in the transverse process of all the cervical vertebra between C1 and C7 levels. This foramen usually contains vertebral artery (except C7), veins, and sympathetic nerves. The size and shape of the foramen varies for each vertebra and individual. Absence, duplication or asymmetry of the FT may be observed in some people (7,18). A single cadaveric study by Das et al. (7) reported duplicated FT in 2 out of 132 specimens (1.5%). Taitz et al. (24) checked 480 vertebrae from various populations for the presence of multiple FT. They reported double FT in 7% of the vertebrae, and only one vertebra manifesting three transverse foramina unilaterally. Higher frequency of this trait was reported

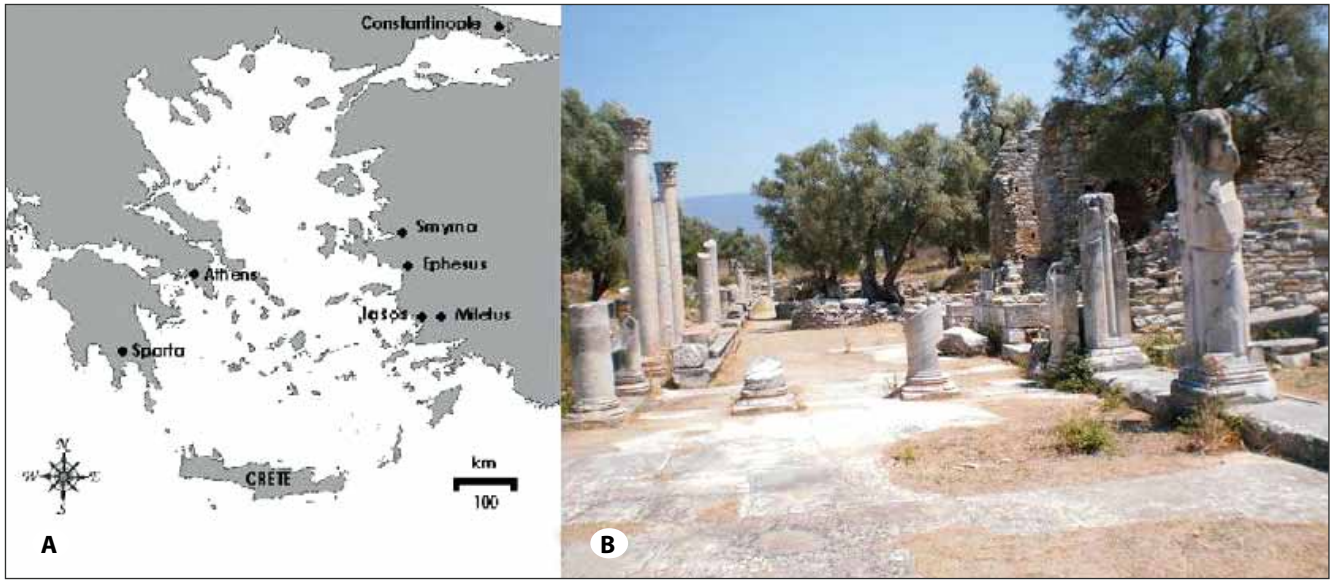

Figure 1: A) The location of Iasos and important cities around the Aegean Sea at the 6th century AD. **B)** The agora (market place) of the Iasos Archaeological site.

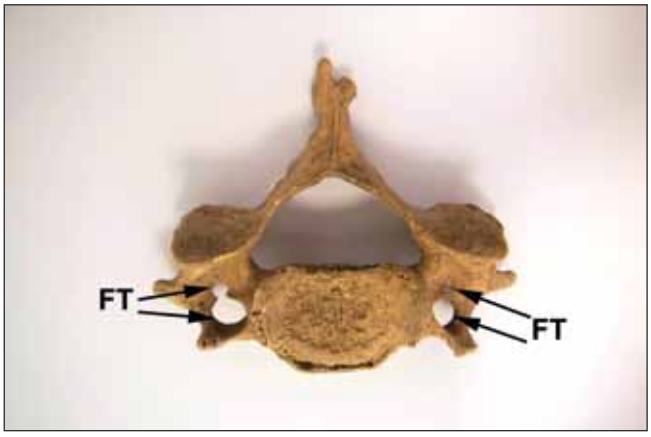

Figure 2: Bilateral duplication of foramen transversarium (FT).

Figure 3: Asymmetrical foramen transversarium (FT).

for the Roman-Byzantine Jewish population: 8.6% of the vertebrae showed unilateral or bilateral occurrence of double foramina transversaria (19). Large FT (12x7 mm) was also noted in several vertebrae of this study (19). Aydınoğlu et al. (2) investigated 222 cervical vertebrae and found that the frequency of bilateral duplication of FT was 6.7%. In our study, the frequency of the double FT was 22.7% and bilateral double FT was observed in 9% of the samples. But the samle size is low to achieve precise statistical information on FT.

The cause of variations on the size and shape of the FT is not well known. It may be developmental or related to the variations of the course of vertebral artery. The direct correlation between the size of the FT and the artery is under debate. Hadley (10) and Hyyppa et al. (13) found that tortuosity of the vertebral artery may cause bone destruction. Thus, it may be a factor in the size of the foramina. Kovacs (14) also described bony excavation on the anterior surface of the superior articular process by pressure of the vertebral artery. Since the vertebral vessels are a factor in the formation of the FT, it can be assumed that variations in the presence and course of the vessels will be manifested in changes of the FT. Conversely, variations of the FT can be useful for estimating changes or variations of the vessels and accompanying nerve structures (24). Similar correlation may be suggested for double FT. One of the foramina may be occupied by the vertebral artery and the other by vertebral vein. But the course of vertebral artery may be distorted due the variations of FT. Epstein (9) found the arteries of the left side are bigger than those of the right. Traitz et al. (24) also found that the left FT is larger than the right FT. This results is similar to our observations that the left FT are generally larger than the right FT.

Although exact numbers have not been reported, duplicated FT is likely to be associated with anatomical variants of vertebral artery, such as duplication and fenestration.

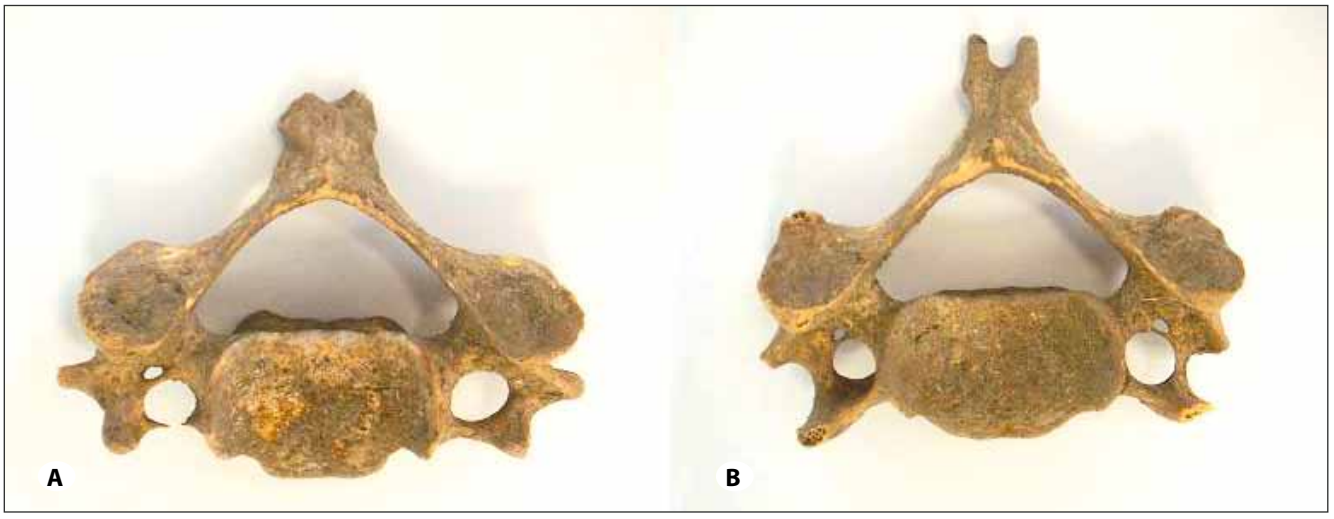

Figure 4: A) Unilateral double FT at the 4th cervical vertebra. **B)** Bilateral double FT at the 5th cervical vertebra of the same skeleton.

Duplicated vertebral arteries have two origins and fusion points in the neck outside of spinal canal. Fenestrated vessels have single origins and divide into two parallel trunks within or outside of the vertebral canal. Only 74 cases of fenestration have been reported in the literature, most of them demonstrate left predominance. Four (5%) of them are bilateral. In contrast, there are 22 cases of vertebral artery duplication. Only one (5%) of them is bilaterally symmetric (18,22). In our study, we could not evaluate the vertebral arteries, but we only examined FT. Duplication of FT may be associated with those of vertebral artery.

The embryogenesis of the vertebral arteries occurs between day 32 and 40 of gestation. They are formed from fusion of the longitudinal anastomoses which connect the cervical intersegmental arteries following the course of the 2 through 8 cervical segmental nerves. The intersegmental arteries regress during the embryonal development. Only the 7th intersegmental artery do not regress and becomes the proximal portion of the subclavian artery which give rise to the vertebral artery (18). It has been speculated that persistence of a portion of the primitive dorsal aorta with 2 intersegmental arteries may give rise to vertebral artery duplication. Failure on the regression of the intersegmental arteries can result in vertebral artery fenestration (22). This fenestration may contribute to the development of the double FT, but it is not proven yet.

In conclusion; the variations and duplication of FT exist since the antiquity. The recognition of variations of the FT is important particularly during posterior cervical surgery.

ACKNOWLEDGMENT

The access to the Iasos skeletal material was given by the kind permission of Prof. Berna Alpagut from the Department of Anthropology, Ankara University.

REFERENCES

1. Alpagut B: The pre-study on the cranial remains of Iasos people (VIth century AD). Results of the 4th Archaeometry Meeting, TC Kültür Bakanlığı, Ankara, 1988
2. Aydınoğlu A, Kavaklı A, Yeşilyurt H, Erdem S, Eroğlu C: Foramen transversarium bipartita. Van Tıp Dergisi 8:110-112, 2001
3. Berti F. "Les Travaux de la Mission Archaeologique Italienne à Iassos en 1987", The meeting of the 10th excavation results II, Ankara, 1988
4. Brothwell DR: Digging up bones. London: Natural History Museum, 1981
5. Caovilla HH, Ganança MM, Munhoz MS, Silva ML: Síndrome cervical. Quadros Clínicos Otoneurológicos Mais Comuns. Atheneu, São Paulo, Vol. 3, Cap 11, 95-100, 2000
6. Cox M, Mays S: Human osteology in archaeology and forensic science. Cambridge University Press, pp. 118-121, 2006
7. Das Srijit, Suri R, Kapur V: Double Foramen Transversaria: An Osteological Study with Clinical Implications. Int Med J 12:311-313, 2005
8. Ellis H: Clinical Anatomy. Miami: MA: Blackwell publishing, 2006:325-328
9. Epstein BS: The Spine. A Radiological Text and Atlas. 3 rd ed. Philadelphia: Lea and Febiger, 1969:24,25,65
10. Hadley LA: Tortuosity and deflection of the vertebral artery. Am J Roentgenology 80:306-312, 1958
11. Herodotos: The histories with an English translation by AD Godley. Cambridge: Harvard University Press, 1920: 5.121
12. Hornblower S: Mausolos. Oxford, 1982:14
13. Hyyppa SE, Laasonen EM, Halonen V: Erosion of cervical vertebrae caused by elongated and tortuous vertebral arteries. Neuroradiology 7:49-51, 1974
14. Kovacs A: Subluxation and deformation of the cervical apophyseal joints; a contribution to the aetiology of headache. Acta Radiol 43:1-16, 1955

15. Laviosa, C: "Iasos", Princeton Encyclopaedia of Classical Sites, Princeton, 1977: 402
16. Levi D: The excavations of Iasos (Çev. Necdet Adabağ), (İtalyan Kültür Heyeti Arkeolojik Araştırmalar Bölümü), Ankara: 1986
17. Maas M: The Cambridge companion to the age of Justinian. Cambridge: Cambridge University Press, 2005: 120
18. Mikityansky I: Neuroradiology Case of the Week. Case 334. University of Rochester Medical Center. www.urmc.rochester.edu/smd/rad/neurocases/Neurocase334.htm (Accessed on March 30, 2011)
19. Nagar Y, Taitz C, Reich R: What can we make of these fragments? Excavation at "Mamilla" Cave, Byzantine period, Jerusalem. Int J Osteoarchaeol 9:29-38, 1999
20. Özer Y: The geography and history of Caria. (Unpublished Ms.c thesis), Muğla University 22-25, 2007 (In Turkish)
21. Rhodes PJ: A history of the classical Greek world. 2nd ed. Singapore: Wiley&Blackwell, 2010: 324
22. Sim E, Vaccaro AR, Berzlanovich A, Thaler H, Ullrich CG: Fenestration of the extracranial vertebral artery: Review of the literature. Spine 26: E139-142, 2001
23. Strauss BS: "Thrasybulus and Conon: A Rivalry in Athens in the 390s B.C." Am J Philology 105: 37–48, 1984
24. Taitz C, Nathan H, Arensburg B: Anatomical observations of the foramina transversaria. J Neurol Neurosurg Psychiatr 41: 170-176, 1978
25. Texier C: The history, geography and archaeology of Asia Minor. Ankara: Enformasyon ve Dokümantasyon Hizmetleri Vakfı, 2002:236
26. Thucydides: The peloponnesian war. London. Ed. and trans. Dent J M, New York: EP Dutton, 1910: 8.28.2
27. Underhill GE: Athens and the Peace of Antalcidas. The Classical Review 10:19-21, 1896