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Original article

Radiological Assessment of the Morphology and Morphometry of Cervical Vertebral Transverse Foramina in the Adult Population of Benghazi, Libya

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Abstract
The transverse foramen (TF), located within the transverse process of the cervical vertebrae, serves as a conduit for vertebral vessels and sympathetic nerves. This study aimed to investigate natural anatomical variations of the transverse foramen within a Libyan population. A retrospective analysis was conducted on 100 Libyan patients with structurally healthy cervical vertebrae (mean age: 39.3 ± 10.2 years), randomly selected from cases that underwent three-dimensional computed tomography (CT) of the cervical spine using the GE CT 1400 system. Transverse foramina were evaluated based on their shape, diameter, and number. Data were analyzed using specialized software and the Statistical Package for the Social Sciences (SPSS), applying descriptive statistics including percentages, means, and standard deviations. The findings revealed that 83.6% of transverse foramina exhibited classical morphology. The most common anatomical variation was the presence of a double foramen resembling the number 8, observed in 7.1% of cases. Bilateral double foramina were more prevalent (64%) than unilateral ones (36%), with the highest frequency at the C6 level (39%). Additionally, 28% of transverse foramina were bilateral and located at C6. Unilateral foramina were more common on the right side (32%) than the left (14%), particularly at the C5 level. Congenital absence of the transverse foramen was noted in 6.1% of cases, exclusively at the C7 level. The left-sided foramina were generally larger in diameter than those on the right. The Libyan population demonstrates a predominance of classical transverse foramen morphology, comparable to patterns observed in populations of the Mediterranean basin. These findings underscore the importance of preoperative CT imaging and precise anatomical assessment of the cervical transverse foramina prior to surgical intervention. Further large-scale studies are recommended to validate and expand upon these results
Keywords: Libya, Cervical Vertebrae, CT scan.

Introduction

Cervical vertebrae are the smallest vertebrae [1], and it's more delicate than those of the other regions of the human vertebral column [2]. It starts just below the skull and extends to the top of the thoracic spine. Approximately 8% of the overall body length is accounted for by the cervical spine [3]. The first, second, and seventh cervical vertebrae are known as atypical, while the other four are typical vertebrae [4]. The cervical spine presents biomechanical and anatomical differences in comparison with the dorsal and lumbar spines. One of the differences is the foramina transversaria (FT) in the transverse process of cervical vertebrae [5]. The cervical vertebrae are mainly recognized by the presence of the FT [6,7]. The broad kidney-shaped body is smaller than the vertebral foramen. The pedicles are short and project posterolateral. The spinous process is short and bifid [1].

The first cervical vertebra is commonly called the atlas. In Greek mythology, Atlas was the titan who held the Earth on his shoulders, just like the atlas holds the skull on top of the neck [8,9]. Atlas has no body, and the short anterior arch is projected into a tubercle in front [10]. It is named the axis because it forms the pivot upon which the first vertebra rotates. The most distinctive characteristic of this bone is the odontoid. The FT is not vertical as in the other vertebrae, but is directed upward and outward to communicate a lateral bend to the vertebral artery (VA) to enable it to ascend to the FT of the atlas. It is often called the vertebra prominence because of its prominent spine. The vertebra is not transmitting the VA in most cases. The foramen is small and may contain the vertebral vein only. The shape and size of the FT vary in different vertebrae and individuals [11]. In addition, it may present a fan array of morphological varieties [12]. The variations in FT are predicting the variation in the course and branching pattern of VA, vein, and sympathetic nerves [13], and reflect the functioning of [14,15]. The deformation and variations of FT may cause pathological conditions [11,16]. Having a good knowledge of the anatomy and variations of FT will benefit clinical diagnosis and treatment of diseases in this area [17].

Variation of FT may be associated with very unpleasant symptoms, a decrease in the quality of life [18]. The deformities and variations in FT may result in vertebral vessels being compressed by movements [19] and causing vascular insufficiency, which leads to common symptoms like migraines, shoulder pain, neck pain, or severity of cerebrovascular incidents [20]. The variation of FT in cervical vertebrae attracts attention by use of the computed tomography (CT) scan [21]. The FT variations can be easily assessed with

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Multi Detector CT scan (MDCT) examinations. Determination of foramina variations before surgical interventions on cervical vertebrae could be an important guide for surgeons [22] and guide radiologists in the interpretation of CT scan and MRI, pre-operative use of the CT scan when suspicion of a variation is present, and strongly recommends foramen variations [23].
It is noteworthy that this study is among the rare studies conducted in Arab countries with the same procedures and comprehensiveness in the research, and there is no Libyan study conducted on the same topic. This was the motivation for us to carry out this research. The study aims to figure out normal variations of the FT in Benghazi, Libya, people, which is important in cases of trauma, headache, and cerebral ischemia, in reference to its contents (vertebral vessels and nerve plexus).

Methods

This was a retrospective study that included 100 adults from Benghazi, Libya, patients (700 cervical vertebrae and 1400 foramina), aged 18-60 years, who had cervical spinal multiplanar computed tomography (CT) imaging performed for a variety of reasons. Images were randomly selected from the digital radiology archive. of the diagnostic radiology department in AL-Jalaa Hospital of Emergency in Benghazi, Libya, and the study period was from the 1st of June 2012 to December 2013. The inclusion criteria were Libyan subjects of different tribes, aged 18-60, who underwent a CT scan study with completely normal cervical vertebrae, while the exclusion criteria were non-Libyan subjects, cases with an incomplete study, cases under 18 years and above 60 years, and any vertebral image giving an impression of infection, neoplastic, traumatic, or congenital spine anomalies.
All the images studied were performed with a (General Electric) GE, 64-slice CT scan system, providing an axial field of view of 350-400mm and a trans-axial slice thickness of 0.5 mm. A low-dose CT scan from the aortic arch to the orbitomeatal baseline was obtained with the patient in the supine position (120Kvp, 300mAs, 0.5-rotation time, 16x0.5 mm collimation, pitch of 0.64). For each level of the cervical spine, axial images from C1 to C7 were selected, and all subjects were observed for a variation of the FT of both sides of each cervical vertebra. As a result, 700 cervical spines (C1 – C7) and 1400 foramina were individually evaluated for diameters, Antero-posterior Diameter (APD), and Medio-lateral Diameter (MLD), shapes, and numbers, bilaterally. Ethical approval for the study was granted by the institutional review board.

Statistical analysis

Data entry and statistical analysis were performed using Statistical Package for Social Sciences (SPSS version 18). A P-value <0.05 was considered statistically significant. Descriptive statistics, such as percentages, frequencies, means, standard deviations, and Chi-square tests, were used to compare variables statistical significance.

Results

In accordance with our inclusion and exclusion criteria,100 files of CT scan images were included in the current study, 60 for males (60%) and 40 for females (40%), as shown in (Figure 1).

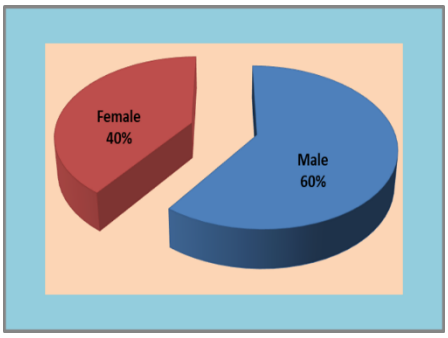

Figure 1: Distribution of cases according to sex

The mean age of our sample was 39.3 ± 10.2 years old. The subjects of this study were categorized into four groups according to their age, where each group interval is 10 years. Shows that (Table 4.1).

Table 1. Distribution of cases according to age / years.

Age group	No	%
18-28	15	15
29-39	32	32
40-50	42	42
51-60	11	11

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All the collected cases were classified into two groups: The first group is the classic group (A), all of which contain a single FT, classic size and shape, about 3/4th (76%) of cases show classic formations in FT. The second group; is the group with anatomical variations (B), all showing variable rather than classic formations, which may show one or more variation in consider to dimensions, shapes or numbers, at least one variation at one level, at one side, this group represents approximately 1 /4th (24%) of the sample, as shown in (Table 4.2). Although the variant group represents approximately a quarter of the sample, it is divided into several small subgroups, each of which does not represent a significant percentage, but it is important as a finding that will be mentioned later.

Table 2. Categorization of subjects according to FT configuration.

Configuration	No.	Percentage
Classical (A)	76	76%
Variant (B)	24	24%
Total	100	100%

The cases were (cross-tabulation) distributed according to sex and configuration of FT. Among 60 males, 47 cases (78.3%) showed the classical configuration of FT, and 13 cases (21.7 %) showed a sort of variation. Among 40 females, 29 cases (72.5%) were classical, and the rest 11 cases (27.5%) were variant, as shown in (Table 3).

Table 3: Distribution of cases according to sex and radiological finding.

Configuration of the transverse foramen	Male		Female	
	No.	%	No.	%
Classical	47	78.3	29	72.5
Variant	13	21.7	11	27.5
Total	60	100	40	100

Number of the foramina:

In both sexes, the single foramen was much more frequent (86.8%). The double foramina constituted for only (7.1%). Absent foramina constituted (6.1%). The triple foramina were not detected in this sample, as shown in (Table 4).

Table 4: Number of FT categories in cervical vertebrae.

Number of foramina	No	%
Absent	86	6.1
Single	1214	86.7
Double	100	7.1
Triple	0	0
Total	1400	100

The single foramina were the most frequent and constituted (86.8%) of all FT. The double foramina appeared less frequently and constituted (7.1%) for a particular image of the cervical spine. The double foramina are seen more frequently at the lower four vertebrae. The bilateral double foramina constituted (64%) of the total (100) double foramina, which represents a higher percentage than the unilateral form. The unilateral double foramina were seen more frequently on the RT and constituted (32%), where the LT double foramina constituted only (4 %). Specific to which level shows more frequent double foramina, C6 shows a higher percentage of double foramina (39%), and it is more frequent bilaterally, C5 shows the more frequent variation of unilateral double foramina, which constituted (14%). And C3 shows the least frequency of double foramina variation. The first (C_1) and second vertebrae (C_2) showed no double foramina, as shown in (Table 4.5).

Table 5. Distribution of cases according to the presence of double FT at special levels and sides.

Vertebral level	Unilateral RT	Unilateral LT	Bilateral
C1	0	0	0
C2	0	0	0
C3	0	0	4
C4	6	0	10
C5	14	1	22
C6	8	3	28
C7	4	0	0
100	32%	4%	64%

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In the current study, the shape is classified into four types. Type 1: (oval); Type 2: (8-shaped); Type 3: (Triangular); Type 4: (Round). The most common shape was type 1 (oval) constituted (89.1%), and considered as classical shape. The 8-shape (double foramen) constituted 7.6%, the triangular shape constituted (2.7%), and the round-constituted (0.6%) of 1314 vertebrae, as shown in (Table 6). The discrepancy in total foraminal numbers was due to 86 vertebrae having no FT (Agenesis).

Table 6: Distribution of cases according to the percentage of specific morphology of TF.

Shape	No	%
Type I {Oval (classical)}	1171	89.1
Type II (8 shape)	100	7.6
Type III (Triangular)	35	2.7
Type IV (Round)	8	0.6
Total	1314	100

In comparison between both sexes, there is no statistically significant difference in the frequency of different categories of FT shapes between males and females (P-0.69). Type 1 (oval shape) FT was seen in all cases. The most common shape variation of FT in both sexes was type 2 (8 shape). Type 4 (round shape), showed a negligible frequency and was seen only in females.

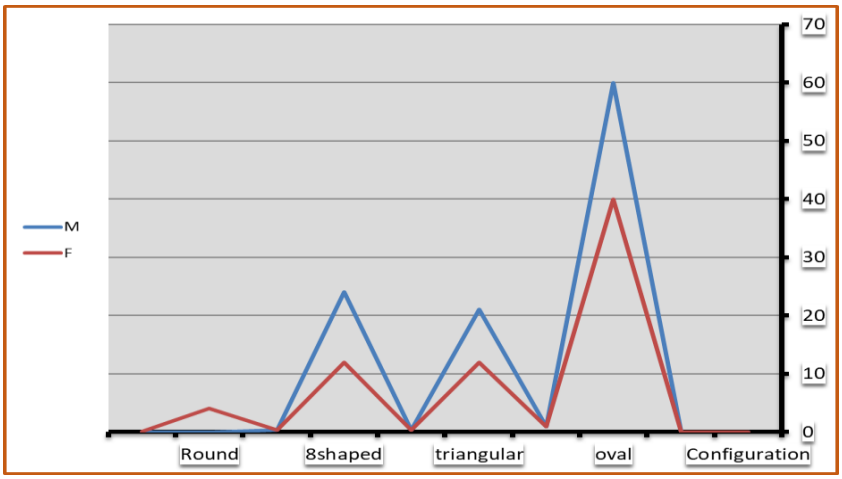

Figure 2: Line chart showing FT special configuration in both sexes.

The size of the foramina and the size of FT were estimated by measuring their APD and MLD diameters., The mean size ±standered deviation to a particular level and side was documented, as shown (Table 7). MLD range (7.50-4.65mm). And APD range (7.32-4.05mm). C1 is the larger, C7 is the smaller. Lt side FT is larger than Rt side FT with a significant statistical difference (P-0.01). In cases with double FT, the diameter of the largest was used.

Table 7: Definitive Statistics of the FT in both sides of the C1-C7 levels of the cervical spine.

Level	Right		Left	
	MLD	APD	MLD	APD
C1	7.31mm ±1.19	7.23mm±1.02	7.50mm±1.25	7.32mm±1.21
C2	7.05mm±0.98	6.72mm±1.10	7.24mm±1.21	6.52mm±1.16
C3	6.10mm±0.88	5.7mm±0.74	6.46mm±1.30	6.1mm±0.51
C4	6.03mm±0.76	5.7mm±0.79	6.60mm±1.25	5.86mm±0.79
C5	5.90mm±0.88	5.84mm±0.91	6.02mm±0.52	5.71mm±0.74
C6	5.09mm±0.75	5.6mm±0.62	6.07mm±1.06	5.37mm±0.57
C7	4.89±1.34	4.05mm±1.42	4.65mm±1.42	4.51mm±1.26

Discussion

The study of FT morphology has a long history; FT has long been the focus of research, particularly in studies conducted on dry bones. Most of the studies used a special instrument for measurement. Recently, technology has been introduced to take a more accurate measurement, like cross-sectional cuts taken by CT scan or MRI. Previous studies have reported on FT morphology, including variation in size, shape, and number. The morphological alteration of FT has been documented in many populations. The results of the

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current study are compared with published studies done on MDCT scans and another study done on dry vertebrae, according to the nationality. There is one earlier Arabic (Egyptian) study of the same subject [21] done on dry vertebrae of Caucasoid subjects, by CT scan.

It showed a common denominator to the current study results in some aspects. As well, the current study showed a common denominator with other studies in different nations, especially that living Mediterranean area in some aspects, especially as Turks [4,16,22], and Spaniards [5,23]. Oval shape FT is known as classical shape, it was the most shape types detected (84%) in Benghazi, Libya population FT, with no significant difference between both sex, this result is compatible with, the Indians [3,24], and Polish [15,25], In contrast with, Asians [26] who documented that; the round shape was the most frequently detected shape in their populations, in Asians population there was no difference between both sexes in the appearance of the round shape FT, while the triangular shape was more common in males. In the current study, the round shape of FT was detected with little frequency, only in females, while the triangular shape was detected more frequently in males.

In the current study absence of FT was detected with a low percentage (6.1%), which results slightly higher than the Turks [16], who (4%) of them had agenesis of FT, and Asians [26], who (1.3%) of them had agenesis of FT. In the current study, the absent (Agenesis) FT was seen only on C7, whereas in Ind-Europeans [24], reported that the absence of foramina was detected in C4 and C6. The duplication of TF is associated with different anatomical variations of VA, like duplication and fenestration. The duplicated VA means; there are two origins and a fusion point of duplicated VA in the neck, which lies outside the FT. but the fenestrated artery has only a single origin, which divides into two parallel trunks, which may lie outside or within the FT. In the literature, only 74 cases of fenestrated artery have been reported; most of them were left predominance. Only 5% i.e., four cases them were bilateral. While duplication of VA was reported in 22 cases, in which only 5% i.e., one case, was bilaterally symmetrical [27].

In the current study, single foramina account for 82%, and duplicated foramina were the most common normal variation. Although the double foramina variation is the most detected, it is only happening in a small percentage in Benghazi, Libya population (7.1%), and this is compatible with the Asians population [26], Indians [24], Turks [16], while another Turkish study show a slightly higher percentage 22. 4, and show (15%), (12%) respectively, of their sample have double foramina, as well as the case of Chileans [28], double FT was (17%), while the Americans, represent higher percentage of double FT. About frequency of double FT in the Indians and compare it with current study, we find many studies in literature that have many conflicting results, some of which, Mishra et al [13], are close to the results of the current study as who reported (14%) of their sample has double TF, and Zibis et al [23], who studied accessory foramen among Indo- European find that (13.7) of them had double FT. Regarding to occurrence of double foramina on a specific level, the results of the current study showed that double foramina is more common at level C6; this result is consistent with the Spaniards [5], the Asians [26], the Egyptians [21], and the Turks [4]. the Spanish study [5] also agrees with our study result, concluding that the C6 double foramen represents mainly a bilateral form. In the current study no evidence of triple foramina, while, the Indian [24], and the Indo-Europeans [23] recorded one case for each study they researched, had triple foramina. That means the triple foramina occur with rare frequency variation in most nations. Size variation in our subjects, characterized by MLD and APD measurement, ranges between (7.50-4.65mm) and (7.32-4.05mm), respectively. The (C1) is the larger and (C7) is the smaller; these results are compatible with Egyptians [21], Indo-European [23], Indians [24,3], Turks [22].

The current study results, relying on the opinion that the smallest size of FT in C7 reflects the fact that only venous blood is transported through them [21], and the VA in 88% of cases enters the FT canal at the level of C6 and only in 5% of cases at the level of C7 [21]. In current result, the size decreases caudally with non-constant values, and C7 almost smaller than C6 or absent, this compatible with Indians [24,3], and, Egyptians [21], but some of them find, that there is no difference between both sides, while in the current study the LT side TF is larger than RT with statistical significance (P-0.012).

In considering to specific side double foramen, in the current study, the bilateral form of double foramen is more common (64%) than the unilateral form (36%). This finding is consistent with that, Indians [13], Turks [4]. And against the result of some studies, which represent that the unilateral form happens with a higher percentage than the bilateral form of double foramina, including Chileans [28], Spaniards [5], where with Indo-Europeans [23], there was no difference between both forms of double foramina.

Conclusion

The Benghazi, Libya sample in the present study has a classical oval-shaped FT, the Lt side FT larger than RT, 8-shaped, and the absence of foramina was a rare variation and which is in accordance with some previous studies. Determination of foramina variations before surgical interventions on cervical vertebrae could be an important guide for surgeons, and guide radiologists in the interpretation of CT scans and MRIs.

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Conflicts of Interest

No conflicts of interest.

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