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Anatomy

# Morphological Study of Native Foramina Transversaria in the Cervical Spine

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## ABSTRACT

**Objective:** To assess number, type and diameter of accessory foramen transversarium (AFT) in the cervical spine.
**Study Design:** Descriptive observational study.
**Place and Duration of Study:** This study was conducted at Anatomy department, Sheikh Zayed Medical College, Rahim Yar Khan and Wah Medical College, Wah Cantt., district Rawalpindi. Duration of this study was two years.
**Materials and Methods:** The study included 45 sets of cervical spine (315 human cervical vertebrae). Direct measurements were taken with vernier calipers sensitive to 0.01 mm. The data were collected on a designed collection sheet. Number, type and diameter of AFT were assessed, recorded and analysed.
**Results:** Out of 315 human cervical vertebrae, the numbers of AFTs were mostly observed in the lower cervical vertebrae; C4, C5 and C6 showed AFTs present as 13.33%, 35.55% and 51.11%. AFTs were 33 on right side and 46 on left side. AFT type I was the most common present in 52 vertebrae (16.50%). The mean AFT diameter on right side was 2.13± 0.53 mm and on left side it was 2.29± 0.73 mm.
**Conclusion:** The incidence of AFT was higher in our population and AFTs were more in the lower cervical vertebrae. Studying the number, type and diameter of AFTs is of clinical significance in understanding the possible neurovascular variation and their course. Such variations should always be suspected when examining transverse processes having an unusual pattern of foramina transversaria.
**Key Words:** Accessory foramen transversarium, cervical spine, transverse process.

## INTRODUCTION

The cervical vertebrae are readily identified by the foramina transversaria present in their transverse processes. These foramina transversaria transmit the vertebral artery, the vein and sympathetic nerve fibers (vertebral nerve) from cervicothoracic ganglion in all the cervical vertebrae except the seventh.[1,2] Sometimes one or more foramina in addition to the normal or native foramen transversarium (NFT) may be present in the transverse process and are known as accessory foramina transversaria (AFT).[3] These foramina are known to exhibit morphological variations which involve many factors like mechanical stress, size and number of anatomical structures passing through them.[4] Embryological factors may also contribute to the development of these variations.[5] The deformation and variations of these foramina may affect the anatomical course of vital vascular and neural structures, and consequently may be one of the causes for complaints like headache, migraine, and fainting attacks, and are due to compression of the vertebral artery.[6] Accessory foramina (AFTs) may be unilateral or bilateral depending on the course of vertebral vessels and nerve.
The anatomical variations of the foramina transversaria are important to the endovascular interventionist and diagnostic radiologist in interpreting X-rays and CT scans.[7] Search of literature reveals that most of the anatomical and clinical studies have investigated the course (passing through foramina transversaria)[8-10] and variant origins of the vertebral artery;[11-16] only few studies are available on the morphology of AFTs and their incidence.[3,17,18] The present study was designed to find out the prevalence of AFTs in the cervical spine, to observe various types of AFTs and to estimate their size on right and left sides which have not been reported by the researchers.

## MATERIALS AND METHODS

The study included 45 sets of cervical spine (315 human cervical vertebrae) that were obtained from the Anatomy department of Sheikh Zayed Medical College, Rahim Yar Khan and Anatomy department of Wah Medical College, Wah Cantt, District Rawalpindi. Direct measurements were taken with a vernier calipers (Peacock Co., Tokyo, Japan) sensitive to 0.01 mm. The data were collected on a designed collection sheet. Some of the cervical vertebrae possessing AFTs were photographed with a digital camera. The following parameters were seen and recorded for analysis:

**1. Number of Accessory Foramina Transversaria**
The foramina transversaria were observed macroscopically in all the cervical spines on both sides (right & left). The number of AFTs (one or two) were seen and incidence of unilateral accessory and bilateral accessory foramina was noted.
**2. Types of Accessory Foramina Transversaria**
Accessory foramina transversaria were classified

according to the relative location of AFT to NFT into seven types[3] (Fig.1).

Type I - Smaller AFT (<50% NFT diameter) separated by bone and located posterior to NFT.

Type II - Smaller AFT separated by bone and located anterior to NFT.

Type III – Larger AFT (>50% of NFT diameter) separated by bone from NFT.

Type IV - Coalesced Type I.

Type V - Coalesced Type II.

Type VI - Coalesced Type III.

Type VII - Presence of more than two FTs.

**3. Diameter of Accessory Foramina Transversaria**

Diameter of AFTs was measured on right and left sides separately and the data recorded.

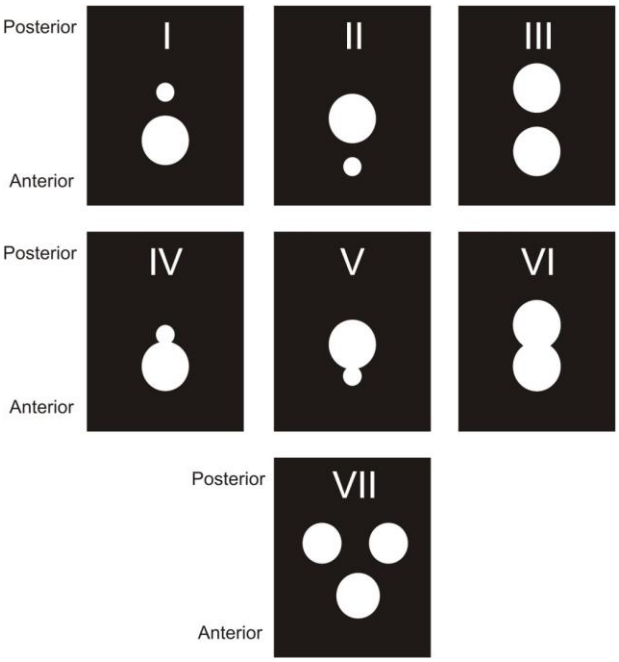


**Figure No.1: Types of AFT**

# RESULTS

**1. Number of AFTs**

In all the cervical vertebrae presence of unilateral & bilateral accessory (one or two) foramina transversaria (AFTs) were noted, their incidence in percentage was calculated, and is presented in Table-1 with the following observations:

i. In the atlas vertebrae, one atlas vertebra showed unilateral AFT (right side) and one showed bilateral AFT (4.44%).

ii. AFT was not observed in axis (C2) vertebrae.

iii. In C3 AFT was observed unilaterally on left side as 6.66%.

iv. AFTs were mostly observed in the lower cervical vertebrae (Fig. 2); C4, C5 & C6 showed AFTs present as 13.33%, 35.55% and 51.11% respectively both unilaterally as well as bilaterally (Table-1).

v. In C7, AFTs were observed unilaterally (Fig. 3) & bilaterally as 22.22%. In one C7 vertebra two AFTs (Triple FT) were found on right side and one AFT on left side (Fig. 4).

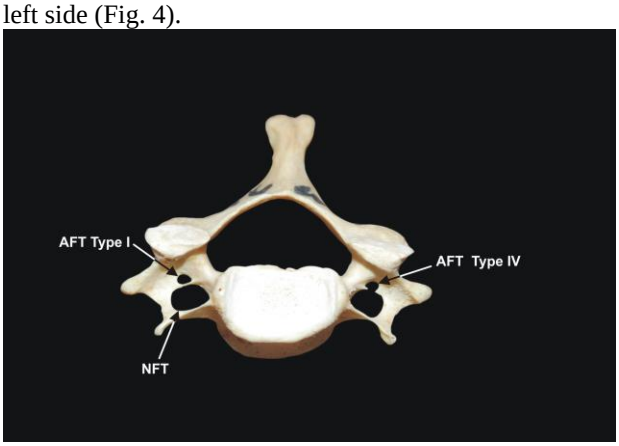


**Figure No.2: C6 vertebra showing AFT Type I and Type IV alongwith NFT**

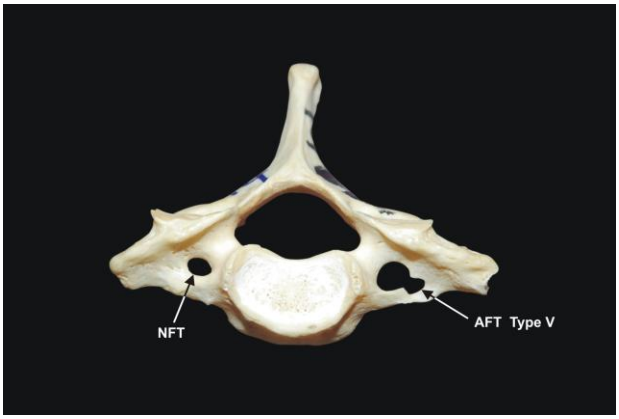


**Fig. No.3: C7 vertebra showing AFT Type V alongwith NFT**

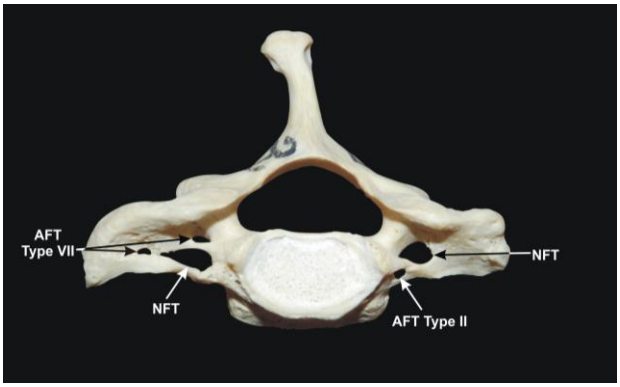


**Figure No.4: C7 vertebra showing AFT Type II and Type VII alongwith NFT**

**2. Types of AFTs**

Out of 315 vertebrae studied, 79 (25.07%) vertebrae (33 on right side and 46 on the left side) showed AFTs. Type I was the most common present in 52 (16.50%) vertebrae (Table-2).

**3. Diameter of AFTs**

Diameter of AFTs on right and left sides with their mean values, standard deviation and range was calculated (Table-3).

**Table No.1: Incidence of unilateral & bilateral AFTs and their incidence on right and left sides in the cervical spines**

| Cervical Spines | No. of vertebrae Examined | Vertebrae with unilateral AFT | Vertebrae with bilateral AFT | Total No. of vertebrae with AFT | Vertebrae with AFT on Right Side | Vertebrae with AFT on Left Side |
|---|---|---|---|---|---|---|
| **C1** | 45 | 1 | 1 | 2 (4.44%) | 2 (4.44%) | 1 (2.22%) |
| **C2** | 45 | - | - | - | - | - |
| **C3** | 45 | 3 | - | 3 (6.66%) | - | 3 (6.66%) |
| **C4** | 45 | 5 | 1 | 6 (13.33%) | 2 (4.44%) | 5 (11.11%) |
| **C5** | 45 | 11 | 5 | 16 (35.55%) | 8 (17.77%) | 13 (28.88%) |
| **C6** | 45 | 14 | 9 | 23 (51.11%) | 14 (31.11%) | 18 (40.00%) |
| **C7** | 45 | 7 | 3 | 10 (22.22%) | 7 (15.55%) | 6 (13.33%) |

**Table No.2: Types of AFTs present in the cervical spines and in each cervical level on right & left sides; right *n =33 (10.47%), left *n =46 (14.60%)**

| Cervical Spines | Type I *52 (16.50%) | | Type II *2 (0.63%) | | Type III *1(0.32%) | | Type IV *15 (4.76%) | | Type V *4 (1.26%) | | Type VI *3 (0.95%) | | Type VII *2 (0.63%) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Right *22 (6.98%) | Left *30 (9.52%) | Right *1 (0.32%) | Left *1 (0.32%) | Right - | Left *1 (0.32%) | Right *7 (2.22%) | Left *8 (2.53%) | Right - | Left *4 (1.26%) | Right *1 (0.32%) | Left *2 (0.63%) | Right *2 (0.63%) | Left - |
| C1 | 2 | 1 | - | - | - | - | - | - | - | - | - | - | - | - |
| C2 | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| C3 | - | 1 | - | - | - | - | - | 1 | - | 1 | - | - | - | - |
| C4 | 1 | 1 | - | - | - | - | 1 | 1 | - | 2 | - | 1 | - | - |
| C5 | 6 | 12 | - | - | - | - | 2 | 1 | - | - | - | - | - | - |
| C6 | 12 | 13 | - | - | - | - | 2 | 5 | - | - | - | - | - | - |
| C7 | 1 | 2 | 1 | 1 | - | 1 | 2 | - | - | 1 | 1 | 1 | 2 | - |

* = Number of cervical vertebrae showing AFTs.

**Table No.3: Diameter of AFTs on right & left sides of cervical vertebrae; Right (n =33), Left (n =46)**

| Total No. of AFTs | AFT diameter (mm) | | | |
|---|---|---|---|---|
| | Mean | S.D. | S.E. | Range |
| Right (n = 33) | 2.13 | 0.52 | 0.09 | 1.00 – 3.15 |
| Left (n = 46) | 2.29 | 0.73 | 0.11 | 0.87 – 4.00 |

# DISCUSSION

The formation of the cervical transverse process is unique that results in the establishment of foramen transversarium. The foramen transversarium is formed by the vestigial costal element fused to the body and the true transverse process of the vertebra. The vertebral vessels and nerve plexus are caught between these two bony parts. Coalescence of these bony components is correlated with developmental events of neurovascular structures running in these foramina.[20]

The vertebral arteries develop during 32nd to 40th day of gestation. In the developing embryo to vascularize the developing somites about thirty pairs of dorsolateral branches arise from the dorsal aorta and pass between successive somites from cervical to the sacral region. These dorsolateral branches are known as dorsal intersegmental arteries. In the cervical region only the dorsal branch of 7th dorsal intersegmental artery persists normally and the rest all apoptose. The proximal (first) part of vertebral artery typically originates from the 7th dorsal intersegmental artery. The dorsal branches of the dorsal intersegmental arteries in the cervical region undergo longitudinal linkage. The distal (second) part of the vertebral artery is derived from this longitudinal linkage. The anomalous blood vessels are due to unusual paths in the primitive vascular plexus (or) due to persistence of vessels normally obliterated (or) due to disappearance of vessels normally retained.[6,21]

In the cervical region vertebral arteries constitute one of the vascular components that ascend parallel to the spine through the foramina transversaria of the upper six cervical vertebrae. They supply blood to the upper (cervical) spinal cord, the brain stem and cerebellum and a significant but variable part of the posterior cerebral hemispheres.[22] The vertebral arteries are responsible for about 30% of the brain's blood supply.[23] It has been reported that this artery enters the NFT of C6 vertebra in 88% of cases, C7 (5%) and C5 (7% of cases).[15] Normally the NFT of C7 contains some branches of vessels and nerves as well as fibrous and adipose tissue.[24,25] The vertebral artery after entering the C6 NFT ascends through the remaining NFTs and

unite with the artery of other side to form the midline basilar artery at the lower border of pons. The vertebral and basilar arteries contribute to the blood supply not only to the brain, but also the inner ear. Compression or spasm of the vertebral artery is manifested not only by neurological symptoms but also by hearing disturbance.[26] A variation in origin and distribution of the vertebral artery, normally present in the NFT, can cause alterations in cerebral hemodynamics and predispose to aneurysmal formation with a great risk of cerebrovascular accidents.[6]

El Shaarawy et al[27] observed that the AFTs were most common at the lower cervical vertebrae (C5, C6, & C7), mostly in C6. Our findings also corroborate with their study being more AFTs in the lower cervical spine. Kaya et al[5] examined the ancient cervical vertebrae and found that frequency of double FT was 22.7%; unilateral double FTs were 13.7% and bilateral double FTs were 9%. In our study unilateral AFTs were 13.01% and bilateral AFTs were 12.06%.

Taitz et al[20] observed the double FTs in 34 cases while studying 480 cervical vertebrae. Among these double FTs only six vertebrae had FT of equal size, while others had foramina of very small dimensions. They also observed triple FTs in one vertebra and absent foramen in four cases. The triple FT is an unusual variation and seems to be the result of double costal element on the same side fusing to the original transverse process, resulting in unusual number of foramina. Therefore the vertebra with triple FT shows two costal bars instead of one. In the present study we detected that most of the AFTs were smaller than the NFTs. We also observed one AFT (double foramina) in 24.44% and two AFTs (triple foramina) in 0.63% of cases (Fig. 4).

Murlimanju et al[18] observed 6 (1.6%) vertebrae showing AFTs out of 363 specimens. They further stated that 5 (1.4%) vertebrae had unilateral AFTs and only 1 (0.3%) vertebra showed bilateral AFTs. Among the unilateral cases 4 were present on right side and only 1 was on the left side. In a study conducted by Sharma et al[17] 200 typical cervical vertebrae (C3-C6) showed a total incidence of AFTs 8%; out of this 0.5 % was in C3, 1.5% in C4, 2% in C5 and 4% was in C6. The incidence of AFTs was higher (25.07%) in our study (Table-1).

Roh et al[3] observed and measured not only the AFTs but also classified these AFTs into seven types during the study of 150 cervical spines. They reported 111 (74%) cases with AFTs. The majority (53%) of AFTs were of type I, 1% type II, 10% type III, 24% type IV, 1% type V, 10% type VI and 1% were of type VII. The mean AFT diameter measured was 2.6 ± 0.8 mm. His study showed higher incidence of AFTs as compared to our study. The higher incidence of type I AFT was common in both the studies. Our findings of type I was 16.50% (Table-2) and the mean AFT diameter on right side was 2.13 ± 0.52 mm and on left side it was 2.29 ± 0.73 mm.

The results of our work concluded that incidence of the AFT is higher in our population as compared to the most of the studies. These AFTs are more common in the lower cervical spine (C3-C7) mostly in C6. The multiplicity of foramina transversaria could be related to the presence of branches of vertebral vessels or nerve passing in the accessory foramina. Understanding the possible neuro-vascular variations and their course may perhaps provide the possible explanations to the variations of the NFTs and AFTs. Such variations should always be suspected when examining transverse processes having an unusual pattern of foramen transversarium. AFT narrows the size of NFT and this may result in pressure on the vertebral artery and the sympathetic plexus embedding it. Similarly the narrowing of the NFT may result in formation of atheromatose plaque in the vertebral artery which may also result in thrombosis emboli or just reflex spasm.

# CONCLUSION

The incidence of AFT was higher in our population and AFTs were more in the lower cervical vertebrae. Studying the number, type and diameter of AFTs is of clinical significance in understanding the possible neurovascular variation and their course. Such variations should always be suspected when examining transverse processes having an unusual pattern of foramina transversaria

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