



Research Article

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# Morphological Study of the Foramen Transversarium of the Atlas Vertebra among Egyptian Population and Its Clinical Significance



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## Abstract

**Background:** Foramina transversaria are characteristic bony features of the cervical vertebra, they are located on the transverse process of cervical vertebrae. These foramina are of anatomical importance as they provide bony passages for several anatomical structures namely vertebral artery, vertebral vein and sympathetic nerves. They have known to exhibit variations with regard to size, shape and may even absent, incomplete or duplicated.

**Objective:** This study aim to investigate the morphology and variations of foramina transversaria of the human atlas vertebrae and to point out the clinical importance of these variations.

**Material and methods:** 135 atlas vertebrae of Egyptian origin were studied. They were available in the dissecting room of the anatomy department, Faculty of Medicine, Cairo University. Each vertebra was studied morphologically for the presence of various shapes of foramen transversarium, presence or absences of any morphological anomaly like accessory foramen or incomplete foramen.

**Results:** Four shapes were noted. Type 1 (rounded) was predominant 54.1%, type 2 (oval) less prominent 29.6%, type 3 (irregular) 10.4% and type 4 (quadrangular) 5.8%. Double foramina were founded in 23 vertebrae, incomplete foramina in 9 vertebrae and accessory incomplete foramina were seen in 12 vertebrae.

**Conclusion:** The morphological knowledge of this type of variation is clinically important because the course of the vertebral artery may be distorted in such condition. It may be compressed leading to some neurological symptoms or even hearing disturbances. Also, the knowledge of this type of variation is important for the neurosurgeon during posterior surgical approaches of cervical spine. It is also useful for radiologist during CT and MRI scan.

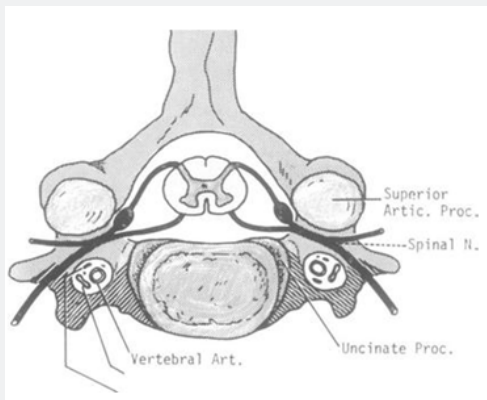
**Keywords:** Atlas vertebra; Cervical vertebra; Morphometry; Transverse process; Transverse foramina

## Introduction

The atlas is a ring of bone and consists of a pair of lateral masses connected by a short anterior arch and a long posterior arch. The transverse processes projects laterally from the lateral masses and longer than that of other cervical vertebrae except the seventh [1]. Marking the transverse processes, the foramen transversaria (FT) which are located on the transverse process and are cardinal features of cervical vertebrae [2]. FT transmits the vertebral vascular bundle (vertebral artery, and veins) and the sympathetic plexus which accompanies the vessels. Derangements of these structures in their course because of narrowing or deformation of the foramina, or osteophytes impinging on them, have been extensively investigated by many authors. The importance of such disturbances to these vital vessels and nerves is obvious. Embryologically, FT is the result of the special formation of the cervical transverse processes.

It is formed by a vestigial costal element fused to the body and the originally true transverse process of the vertebra; the vertebral vessels and nervous plexus are caught between the bony parts. The FT is closed laterally by the “costotransverse bar”, a plate of bone interconnecting the rib element to the original transverse process (Figure 1). Generally, any variations in the FT may affect the vital structure i.e. vertebral artery entrapment that may cause vertebrobasilar insufficiency. The knowledge of these variations is important for surgeons and radiologist for interpreting CT and MRI scans [3]. From the surgical point of view, study of the FT is of great value to the neurosurgeons for posterior approaches of cervical spines [4]. These foramina exhibit variations in their shape, size, number and even presence or absence. Morphometry and anomalous variations are important to the neurosurgeons in determining

the etiology, side predilection and vascular variations in the atlanto-occipital region [5].



**Figure 1:** Schematic cervical vertebra: shows the foramen transversaria with the various structures passing through it. Shaded portion of transverse process represents rib component.

There is correlation between the atlas morphology with head and neck posture [6]. Thus, the presence of other bony variations, as well as the prevalence of neck syndromes and injuries necessitates the study of the atlas transverse foramina. The recognition of this variation provides safety and efficiency for the posterior approaches of cervical spine [7]. From the clinical point of view, occipital neuralgia is usually unilateral and has a characteristic shock like pain lasting for a short duration indicative of neural origin [8]. The pain is confined to the dermatome of the nerve root at the lower occipital region of scalp and upper neck. Compression of the nerve root by an abnormal course of vertebral artery has been reported in the literature. Bony abnormalities at the craniovertebral junction can cause occipital headache due to abnormal course of vertebral artery and joint instability [8,9].

**Aim of the Study**

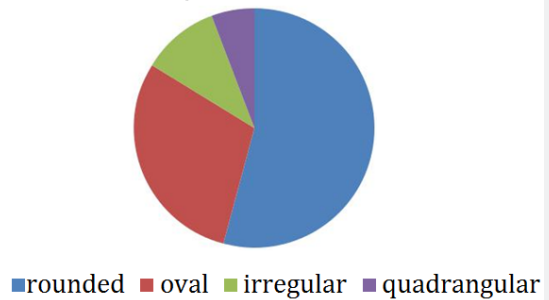
This study aims to investigate the morphology and variations of foramina transversaria of the human atlas vertebrae and to point out the clinical importance of these variations.

**Materials and Methods**

Dried 135 atlas vertebrae of Egyptian origin and of adult size and unknown sex were obtained from the Dissecting room of dental students, department of Anatomy, Cairo University, Faculty of Medicine, for the present study. Broken or incomplete atlases were excluded from the study. The vertebrae were examined for the presence or absence of foramina, double foramina and incomplete foramina. The side and shapes of the foramina also noted. The shapes of the foramina were classified into four categories using the criteria by Taitz et al. [10]. According to the shape and direction of the main diameter, the transverse foramina were classified into four types; (they were studied as seen in an A-P direction where the anterior arch facing the examiner).

**Results**

Shape of the FT



**Figure 2:** Pie chart showing predominance of rounded FT compared with other shape.



**Figure 3:** Superior view of Atlas vertebrae showing unilateral double FT (arrow) on the root of the transverse process



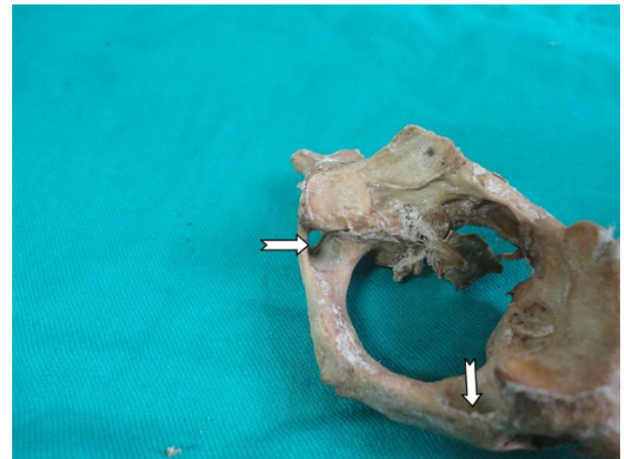
**Figure 4:** Superior view of Atlas vertebrae showing bilateral double FT (arrows) located on the posterior arch.

The whole 135 dried vertebrae, used for this study, were examined for the presence or absence of foremen transversaria and the presence of accessory or incomplete foramen. The following results were recorded: Double foramina were observed in 23 vertebrae (17.7%) 7 on the left and 13 on the right and 3 on

both sides. The accessory foramina were present on the posterior root of the transverse process in 10 cases while in 13 cases the foramina were observed at the posterior arch (Figure 3-5). Some accessory foramina were too small. Incomplete foramina were observed in 9 vertebrae (6.9%), 4 on right 3 on left 2 bilateral (Figure 6). Also, in 6 vertebrae (4.6%) incomplete accessory foramina were observed with different shape semicircular, hemi circular and U shape in Figure 7 with 2 on the left 3 on right 1 bilateral (Table 1). Study of the shape of the foramina transversaria based on the anteroposterior and mediolateral measurements showed four different shapes; type 1 (rounded) was predominant 54.1%, type 2 (oval) less prominent 29.6%, type 3 (irregular) 10.4% and type 4 (quadrangular) 5.8%.



**Figure 5:** superior view of Atlas vertebrae showing bilateral incomplete FT (arrows) indicating absence of costal element of both transverse process of atlas vertebra..



**Figure 6:** Superior view of Atlas vertebrae showing bilateral double FT (arrows) located on the posterior arch.

**Table 1:** Percentage of occurrence of complete, incomplete, doubled and absent foramen transversaria of atlas vertebrae.

Foramen Transversarium	Number	Total Number Studied bilaterally	Percentage
Complete	126	252	93%
Incomplete	9	11	7%
Double foramina	23	26	17.70%
Incomplete accessory	6	7	4.60%
Absent	0	260	0%



**Figure 7:** Superior view of Atlas vertebrae showing incomplete accessory FT (arrows) with different shape (7A) semicircular (7B) hemi circular (7C) U shape.

**Discussion**

As one of the three bony components of the cranio-vertebral junctions the atlas constitutes a clinically significant entity mainly because of importance of its grooves and foramina in the region of posterior and lateral margin [5]. Transverse foramen of atlas has been studied in terms of shape, morphometry and presence or absence in Kenyans [6]. In the current study,

the shapes of the foramen transversarium were categorized into four different categories, rounded 54.1%, oval 29.6%, irregular 10.4% and quadrangular 5.8%. In atlas vertebrae, true transverse process is represented by a thick posterior bar in intrauterine life, which fuses eventually with thin anterior bar developed in third – fourth year of life from ventrolateral aspect of articular pillar and thus completes the formation of FT. Hence in atlas, the foramen transversarium is formed by fusion of

anterior and posterior bars as they pass around the position of vertebral artery at the age of 3-4 years [7]. The variable shape of foramen transversarium as observed in the current study were categorized on the basis of their plane and maximal medio lateral dimension in coronal plane [8]. The variable shapes of foramina have been known to have a correlation with the tortuosity and size of vertebral artery, which is in turn dependent subsequent on loading forces and stresses in the neck [9].

It has been observed that in some cases the accessory FT was too small compared with the original FT. Thus smaller foramen was explained by absence of vertebral artery or a variation where the artery runs along the transverse process without entering the foramen [6]. The current study found double foramina in 23 vertebrae (17.6%). Several authors have reported double or triple foramina in cervical vertebrae without specific reference to the atlas. These variations are possibly linked with duplication of the vertebral artery. However, occurrence of multiple transverse foramina may not necessarily reflect vertebral artery variations, as one foramina may be occupied by veins and nerves. The cause for this variation in cervical vertebrae without specification to atlas was attributed to fusion of two costal elements with the transverse process [11]. Moreover, these variations may be attributable to possible genetic differences and also carrying

**Table 2:** Showing prevalence of double transverse foramina in different study populations.

Author	Year	Prevalence of double foramina	Study sample	Population
Taitz et al. [10]	1978	7%	480	Indian
Nagar et al. [5]	1999	8.60%	1388	Roman
Das et al [11]	2005	1.50%	132	Indian
Kaya et al [12]	2011	22.70%	262	Jewish
Karau PB, Oduia P [8]	2012	3.90%	102	Kenyans
Rekha BS [13]	2013	6.54%	153	Indian
Present study	2017	17.70%	135	Egyptian

From the current study, it could be suggested that variations of the foramina can be useful for estimating changes or variations of vessels this runs concurrently with previous literature [13]. The occurrence of incomplete transverse foramina in atlas should be noted by radiologist, as these can be confused with other anomalies [6]. On the other hand, some authors have noticed that the vertebral artery covers about two thirds of the minimal diameter and more than half of maximal diameter of the transverse foramen [11]. Moreover, it has been suggested that the preponderance of osteophytes on lateral margins of FT could lead to narrowing of mediolateral diameter leading to compression of vertebral artery and its dissection [13]. Hence it can be assumed that oval shape FT oval 29.6% with anteroposterior diameter greater than mediolateral diameter had minimal risk of vertebral artery compression syndrome. Also, it is well known that any narrowing of FT may result in formation of atheromatous plaques in vertebral artery which may result in thrombosis/emboli /reflex spasm predisposing to vertebrobasilar insufficiency [14].

heavy loads on the head, which has been associated with various bony bridges on the atlas vertebrae [8].

In this study, incomplete transverse foramina were also found in 9 vertebrae (11%), it could be explained on the base of erosion of bones as the age advances. However, the age of the bones was difficult to assess because of lack of information about age related changes in most of these studies. Also, incomplete accessory transverse foramina were also found in 6 vertebrae (4.6%), most of them mainly located at the posterior root. However, the age of the bones was difficult to assess because of lack of information about age related changes in most of these studies. It is reported that tortuosity of the vertebral artery may cause bony erosion, or impede complete formation of the transverse foramen [12,13]. Developmental changes could account for the anomaly observed. Other explanations of incomplete foramina are tensions and stress applied to bones by the running vessels through foramina with relatively free movements of the cervical spine [14]. Furthermore, the natural tortuosity of vertebral artery may cause bony destruction which could be minimal leading to bony bridge or sever [15]. Accordingly, the shape of incomplete foramina in the current study is semicircular, hemi circular and U shape (Table 2).

### Conclusion

The study has revealed existence of many variations in the transverse foramina of atlas among Egyptian. The data provided in the present study is helpful in interpretation of radiographic features of atlanto-occipital region, as well as surgical access. Also, this suggests that defects in the FT of the atlas vertebrae may be included in the cervicovertebral junction anomaly, when anomalous can cause occipital headache. So that, neurosurgeons should be aware of such variations while operating at the level of first cervical vertebra so as to prevent accidental injury of the vertebral artery and thereby preventing any neurological deficit. On the other hand, radiologists must also be aware of this fact in order to correctly interpret the radiograph or CT scan or MRI image of the cranio-vertebral region.

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