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Variations among Foramen Transversarium in Cervical Vertebrae and its Clinical Significance

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Abstract

Aim: To study the variations of Foramen Transversarium in cervical vertebrae and to analyze their morphological features with emphasize on their embryological and surgical importance. *Material and Methods:* The study included human cervical vertebrae which were procured from the dry bone collections of Department of Anatomy, Andaman & Nicobar Islands Institute of Medical Sciences, Port Blair and Sri Lakshmi Narayana Institute of Medical Sciences, Pondicherry. The age and sex were not known. The foramina transversaria of all the vertebrae were studied for shape, size and for presence of accessory foramina. *Results:* Significant number of bones with shape variations, size variations and many accessory foramen transversarium were found. The incidence of accessory foramen transversarium appears to be very high. One unilateral Arcuate canal (posterior arch canal) was identified. No incidence of three foramen and absence of foramen. *Conclusion:* Variations in number and position of foramen transversarium is important for interpreting the CT and MRI scans and essential while performing complex surgical procedures. Their morphological knowledge is clinically important since the course of the 2nd and 3rd part of vertebral artery may be distorted. These variations may be one of the causes for complaints like headache, migraine and fainting episodes due to vertebral artery compression.

Keywords: Foramen Transversarium; Cervical Vertebrae.

Introduction

Foramen transversarium is the foramen present in the lateral masses of all cervical vertebrae. It is present on both sides. It is one of the typical characteristic features of cervical vertebrae. Foramen transversarium of typical cervical vertebra transmits 2nd part of vertebral artery, plexus of sympathetic nerves and vertebral veins [1].

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Any variation in the dimensions of foramen transversarium can cause many clinical symptoms. Second part of vertebral artery passes through foramina transversaria is the most mobile part of artery during neck movements. Vertebral artery supply areas of brain stem responsible for vital functions, Cerebellum responsible for coordination, Occipital lobes responsible for sense of vision and upper 6 segments of spinal cord [2]. This implies its importance [2]. Sympathetic nerve plexus derived from cervico-thoracic sympathetic chain are passing along the foramen transversarium. In case of injury to these nerve plexus leads to Horner's syndrome with symptoms like ptosis, myosis, anhydrosis, enophthalmos etc. [2].

The vertebral veins formed from the internal venous plexus and veins of suboccipital triangle, passes along the foramen transversarium, emerges out of sixth cervical vertebra, descends anterior to the subclavian artery and terminates into the brachiocephalic vein [1].

Embryological Considerations

The foramen transversarium is formed by the fusion costal element to the body and the true transverse process of the vertebra. The vertebral vessels and nervous plexus are caught between these two bony parts. Costotransverse bar – a thin plate of bone connecting the rib element to the original transverse process; closes the foramen transversarium in the lateral aspect [3,4].

Variations of foramen transversarium in cervical vertebrae are common and various reports says that hypoplastic, duplicated, triplicated and accessory foramina transversaria are the variant varieties [5,6,7]. Such anatomical variations may lead to a different path or extra osseous path for the contained structures [5]. Accessory foramina transversaria can be due to a duplicated vertebral artery or it may be formed from a fenestration at that level in the vertebral artery [6].

Variations of the foramina transversaria can affect the course of vertebral vessels and nerves, which can attribute into various clinical pathological symptoms. A good knowledge of the anatomy and variations of these foramina will benefit clinical diagnosis and treatment of such symptoms. So we have taken this study to estimate the type and incidence of structural as well as numerical variations in foramen transversarium among typical and atypical cervical vertebrae.

Material and Methods

The study included human cervical vertebrae which were procured from the dry bone collections of Department of Anatomy, Andaman & Nicobar Islands Institute of Medical Sciences and Sri Lakshmi Narayana Institute of Medical Sciences, Pondicherry. The age and sex were not known. The foramina transversaria were examined from both sides of all the vertebrae. Difference in shape and number of all foramina transversaria were noted. Right and left foramina of same vertebrae compared for size difference.

Observations

All the foramina transversaria of 534 cervical vertebrae were examined carefully. Among them, 351 were typical cervical vertebra (C3, C4, C5 and C6) and 183 were atypical (74 atlases, 59 axes and 50 C7-vertebra prominence). The age and sex of the bones were not known. Many foramina transversaria were showed shape variations, partially formed accessory notch and fully separated accessory foramen. Accessory Foramen transversarium and one posterior arch canal were identified.

Firstly in shape, about 60% of the foramina transversaria showed circular type (Figure 1A) and 15% of the foramina transversaria showed elliptical type (Figure 1B).

FT Notch

Notch like extensions are seen in many foramina transversaria, hence we named such extensions as FT notch. This can be also referred to as partial accessory foramen.

About 7% of the total foramina transversaria showed unilateral right sided FT notch (Figure 1C 1-3).

Accessory Foramen

Accessory foramen means additional to the already existing foramen. The smaller foramen is considered as accessory to the larger foramen. About 21% of the cervical vertebrae showed accessory foramen in FT. They can be subdivided into unilateral and bilateral. Among the unilateral type many variations are identified such as unilateral right, unilateral left, posteriorly placed accessory, anteriorly placed accessory, equally divided FT etc. Only one vertebra had bilateral accessory foramina and they are placed posteriorly.

About 16 specimen showed Unilateral Left accessory foramen Figure 2A & Figure 2B.

Unilateral right Accessory and unilateral left FT notch were present in three vertebrae (Figure 2C)

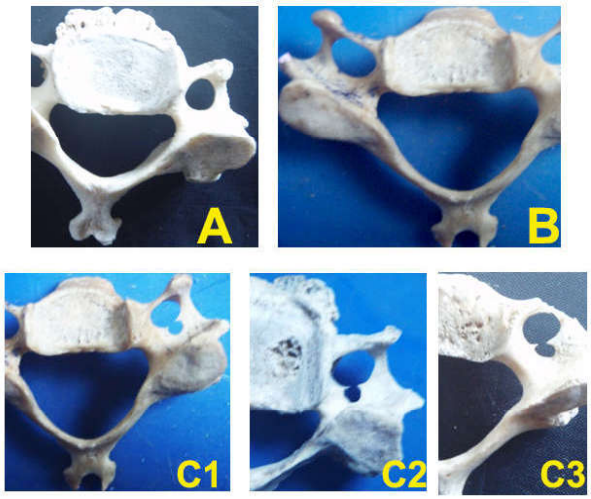

Fig. 1A: Circular type Foramen Transversarium. **1B:** Elliptical type Foramen Transversarium. **C1:** FT Notch – Unilateral Right sided. **C2:** FT Notch – Unilateral Right sided. **C3:** FT Notch – Unilateral Right sided

Variations in position of accessory foramen:

About 4 cervical vertebrae showed accessory foramen in posterior aspect of foramina transversaria. (Figure 2D)

Two cervical vertebrae showed accessory foramina in anterior aspect of Foramen transversarium. (Figure 3A)

One cervical vertebra showed equally divided Foramen transversarium (Figure 3B).

One cervical vertebra showed bilateral posteriorly placed accessory foramen (Figure 3C).

One atlas vertebra showed unilateral right sided arcuate foramen (Figure 3D).

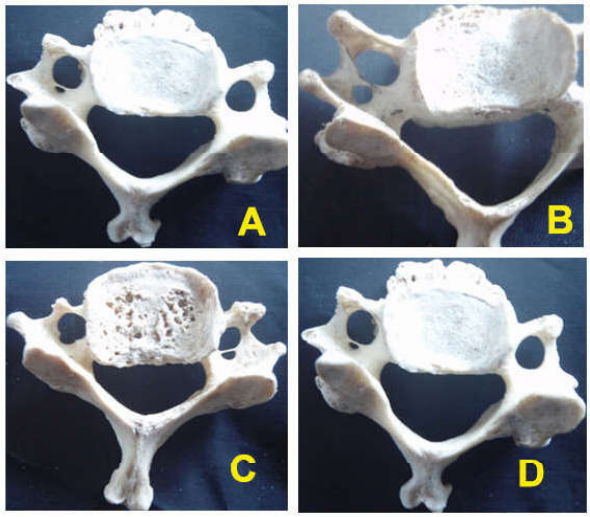

Fig. 2A: Unilateral Left Accessory. **2B:** Unilateral Left Accessory. **2C:** Unilateral Right Accessory and left FT notch. **2D:** Posteriorly placed accessory foramen

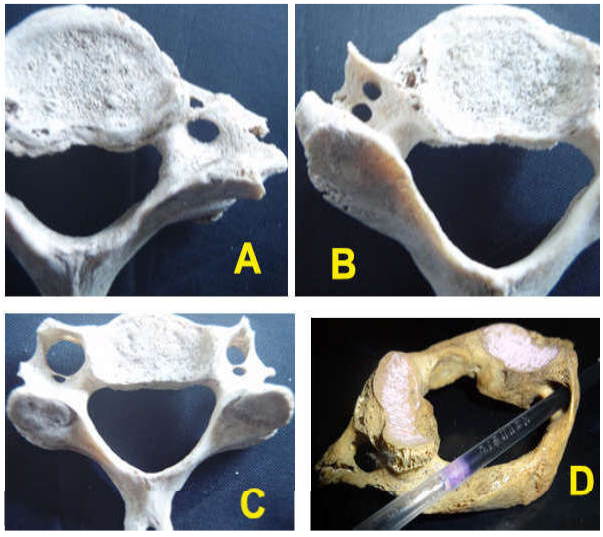

Fig. 3A: Anteriorly placed accessory foramen. **3B:** Equally divided Foramen Transversarium. **3C:** Bilateral posteriorly placed accessory foramen. **3D:** Atlas showing Unilateral Right arcuate foramen

Discussion

Das and Kapur [8] studied 132 specimens and reported unilateral as well as bilateral presence of double foramina transversaria, only in two cervical vertebrae.

In contrast, Taitz et al [4] from a study comprises 480 cervical vertebrae, observed the doubling of foramina transversaria in 34 cases. Of these, only 6 vertebrae had foramen transversarium of equal size, while the others had foramina of very small dimensions. They also observed triple foramina transversaria in one vertebrae and absence of foramen in 4 cases. The triple foramina transversaria is a very rare variation. It may be the result of double rib bone element on the same side fusing to the original transverse process, resulting in unusual number of foramina. Therefore, the vertebra with triple foramina transversaria shows two costal bars instead of one [4]. Shaarawy et al. observed that the accessory foramina transversaria were most common at the lower cervical vertebrae (C5, C6 and C7), mostly in C6 [9]. In the present study also the foramina were seen at C6 and C7.

The posterior arch of the atlas contains a groove for the third part of vertebral artery variable in size and depth [10]. In some cases this groove can be bridged by ossified part of bone called posterior ponticulus (Latin for bridge). Atlas bridges, also called ponticles, are bony outgrowths occurring on the atlas vertebra over the third segment of the vertebral artery, converting its groove into a sulcus, incomplete or complete foramen [11]. The canal thus formed over the posterior arch of the atlas is called as "arcuate foramen" and by an eponym "Kimmerle's anomaly" since Kimmerle was an early describer of this structure [12]. Other names are: "foramen sagittale", "foramen atlantoideum", "foramen retroarticulare superior", "canalis vertebralis", "retrocondylar vertebral artery" [13].

The arcuate foramen has been reported to play a role in problems like migraine and vertebrobasilar artery stroke [14,15] and the incidence of the arcuate foramen range from 1.14% to 18% depending on the study [15-19]. Seven patients out of nine were identified to have arcuate foramen and they were subjected to vertebral angiograms. Results showed that the vertebral artery passing through the arcuate foramen was constantly under stress and leads to arterial dissection and occlusion. The presence of an arcuate foramen is having strong relation to tethering of the vertebral artery and dissection from repetitive trauma with movement of the neck [14]. The complete

arcuate foramen is significantly more common in males. The partial foramen is commonest in white females. The rate of occurrence seems independent of age [17]. Bundi et al. reported the presence of retro-articular canal in 14.6% and 13.6% on the right and left sides respectively [11].

Occurrence of atlas bridges especially complete and incomplete ones predispose to vertebrobasilar insufficiency and cervicogenic syndromes especially in neck movements. The observation of atlas bridge foramina proposes that they are an important cause of vertebral artery compression [20].

The formation of vertebral artery is by the fusion of longitudinal anastomoses found in between cervical intersegmental arteries. The cervical intersegmental arteries are the branches of the primitive dorsal aorta. These intersegmental arteries eventually disappear, except the seventh artery. The seventh artery forms the proximal portion of the subclavian artery, including the beginning of the vertebral artery [21] Sim et al. [22], described that some portion of the primitive dorsal aorta may not regress along with the two intersegmental arteries which connect the vertebral artery. This arrangement may lead to double origin and duplication of the vertebral artery. The duplication is thought to represent the failure of controlled regression of two intersegmental arteries and a segment of the primitive dorsal aorta. Bilateral occurrence of these failures is the etiology behind bilateral duplication of the vertebral artery [21].

Numerous surgical procedures such as screw and plate fixation, laminar clamping and wiring in between spinous process are being done to overcome the instability of the cervical vertebral column, atlantoaxial complex or occipitocervical junction. Transpedicular and transarticular fixation of screws are also being done widely in recent year in order to stabilize the cervical column. Any mistake done during pedicle screwing will cause severe injury on adjoining important structures like the spinal cord, nerve roots and vertebral arteries [23].

Our study may provide information for the surgeons to determine the safe site of entry and trajectory for the screw implantation and also to avoid injuries to vital structures while operating around axis. Dimensions of axis vertebral foramen transversarium are important and act as an useful guide in the estimation of dilation of vertebral artery. The vertebral artery and the basilar artery contribute blood supply not only to the brain but to inner ear also and their compression may lead to irritation of sympathetic plexus, manifested not only by neurological symptoms but also by labyrinthine or hearing disturbances. To determine accurate placement of a screw in the area of any deformity resulting from fracture or partial sublaxation, ideal drill angle for transpedicular screw placement is required. Therefore careful anatomic reduction is essential.

Conclusion

Features of the atlas vertebra must be familiar before any spinal surgeries such as transpedicular screw fixation, transarticular screw fixation, interspinous wiring, and interlaminar clamp. In the present study significant number of variations among foramina transversaria were found. The incidence of accessory foramen transversarium appears to be very high. One unilateral Arcuate canal (posterior arch canal) was identified. These information will be helpful in avoiding and reducing complications such as vertebral artery injury, spinal cord injury during spine surgeries. For neurosurgeons and radiologists, the surgical anatomy of these variations is important for interpreting the CT and MRI scans and essential while performing complex surgical procedures. Their morphological knowledge is clinically important since the course of the 2nd and 3rd part of vertebral artery may be distorted. These variations may be one of the causes for complaints like headache, migraine and fainting episodes due to vertebral artery compression.

Conflicts of Interest

None

Key Messages

Variations among foramen transversarium can affect the normal course of its contentsand leads to complaints like headache, migraine and fainting episodes due to vertebral artery compression.

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