



Anatomical variations in foramen transversarium

KEYWORDS

Foramen transversarium, cervical vertebrae, atlas, retroarticular foramen

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ABSTRACT

Foramen transversarium (FT) is the foramen present in the transverse process of cervical vertebra. Vertebral artery, vertebral vein and sympathetic nerve pass through the FT of C1-C6 vertebrae. Variations in the FT in the form of shape, number, complete or incomplete, unilateral or bilateral and accessory foramen are widely documented. Incomplete unilateral FT in atlas and accessory unilateral, accessory bilateral, incomplete unilateral FT in other cervical vertebrae were noticed in cervical vertebrae.

The vertebral artery which passes from FT of atlas enters in the cranial cavity to form circle of Willis. Any variation in FT can create impact on vertebral artery to give rise to vascular insufficiency. So such variations are clinically significant radiology, neurosurgery and spine surgery point of view.

Introduction

Presence of FT, small vertebral body with beveled edges and bifid spine are the characteristic features of typical cervical vertebra while absence of body and spine is the peculiarity of atlas. In all cervical vertebrae FT is present through which important structure like vertebral artery passes along with vertebral vein and sympathetic nerve except FT of C7 through which vertebral vein passes. Vertebral artery gains attention of spine surgeon and radiologist as it becomes part of circle of Willis later on. Vertebral arteries are very well protected by FT on all sides so variations in number, shape and side are bound to create effect on vertebral artery. Wide documentation on variations in FT is available. These variations can be double FT on one or both sides, complete or incomplete on one or both sides, presence of accessory foramen on one or both the sides. Vertebral vessels are responsible for formation of foramen transversarium¹. It can be assumed that variations in the course of vertebral vessels may cause variations in FT¹

24 atlas, 50 typical cervical vertebrae and 40 seventh cervical vertebrae were studied in terms of foramina transversarium in department of anatomy in MGM medical college. Variations in the FT of atlas, C-7 and typical cervical were noticed. It created interest to think over possible reasons about their presence. The variations which were found were studied and compared with the data of other authors.

Materials and methods

24 Atlas vertebrae
50 typical cervical vertebrae
40 seventh cervical vertebrae

Variations in FT were noticed. These variations were classified. Photographs were taken and labeled.

Results

It was found that

Unilateral incomplete FT in 3 atlas (Fig 1)
Unequal size of FT on both sides in a) 1 atlas and b) in 1 typical cervical vertebra (Fig 2)

Difference in size of FT in different vertebrae A) C7 and B) Typical cervical vertebra (Fig 3)

Incomplete unilateral accessory FT on right side in 3 cervical vertebrae (Fig 4)

5. Complete unilateral accessory FT on right side and incomplete unilateral accessory FT on left side. (Fig 5-a), bilateral accessory FT in 2 cervical vertebra (Fig 5-b,c), bilateral incomplete accessory FT in 1 vertebra (Fig 5-d)

Fig 1 shows incomplete unilateral FT on right side (a,c) and left side (b)



Fig 2 shows difference in the size of FT on both sides a) atlas b) typical cervical vertebra



Fig 3 shows difference in the size of FT in different vertebrae

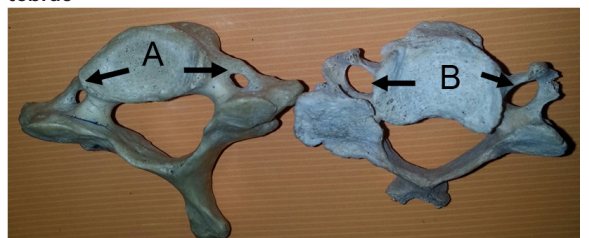
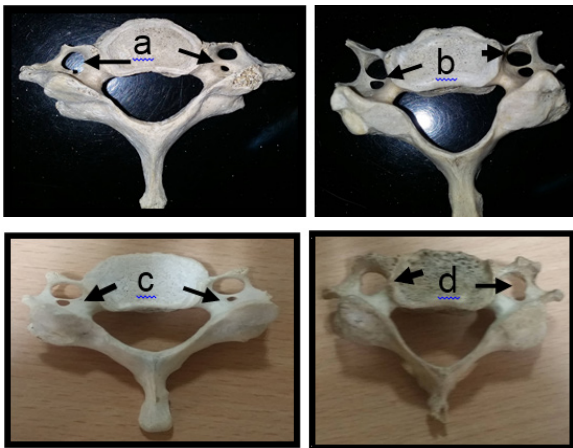


Fig 4 shows incomplete unilateral accessory FT on right side



Fig 5 shows complete unilateral accessory FT on right side and incomplete unilateral accessory FT on left side in 1 vertebra (a), shows bilateral complete accessory FT (b,c), bilateral incomplete accessory FT in 1 vertebra (d)



Discussion

The term FT is Latin word for transverse foramen. It refers to bilateral foramina found lateral to vertebral body in the cervical vertebra. There is a controversy about the development of tip of transverse process of atlas vertebra. It develops from true transverse element². It develops from costal element³. Vertebrae develop from sclerotome portion of somites derived from paraxial mesoderm which is regulated by HOX gene. Sclerotome undergoes resegmentation and caudal half of sclerotome grows and fuses with cephalic half of subsequent sclerotome. The caudal part of cervical sclerotome forms lateral masses and anterior and posterior arches of atlas. FT develops by vestigial costal element anteriorly and true transverse process posteriorly. In atlas vertebra true transverse process is represented by a thick posterior bar in intrauterine life which fuses eventually with thin anterior bar developed in 3-4th year of life from ventrolateral aspect of articular pillar and thus completes the formation of FT. Hence in atlas the FT is formed by fusion of anterior and posterior bars as they pass around the position of vertebral artery at the age of 3-4 years⁴. FT is the result of special formation of cervical transverse process. It is formed by a vestigial costal element fused to the body and true transverse process of vertebra. Vertebral artery, vein and nerve plexus are caught between the bony parts⁵. Incomplete FT was formed due to partially developed anterior bar of FT and never of posterior bar^{6,7}.

Along with embryological factors other factors like anatomical variations in vertebral artery and functional conditions may play important role in the formation of incomplete FT. It was noted that that tortuosity of vertebral artery may cause bone erosion or obstruct the complete formation of FT⁸

Many authors have studied transverse process of atlas and found incomplete unilateral FT in 8 atlas (55)⁶, 5 atlas (50)

7, 6 atlas (153)⁹, 8 atlas¹⁰, 12 atlas (300)¹¹, 1 atlas (200)¹. In all the cases anterior bar of FT was absent. We also found unilateral incomplete FT on anterior side in 3 cases (Fig 1).

Anterior and posterior bar of FT provides support and protection to the vertebral vessels. In case of incomplete FT there could be displacement of vascular structures from their position and can lead to symptoms. During the movements like rotation and extension of neck there is stretch on vertebral vessels causing displacement in case of incomplete FT. Awareness of such variations is important radiology point of view as these variations can be misread as fractures. This knowledge of variations is also important for spine surgeons as chances of injury to vertebral vessels can be minimized.

These variations may be responsible for vertigo and many neurological disturbances and hence it is of clinical significance¹.

Size of FT is directly proportional to caliber of vertebral artery. Size of FT carries clinical significance as vertebral artery insufficiency may be seen in case of narrowing of FT. We have observed unequal size of FT on both sides in one atlas (Fig 2) almost the double size of the other (right side transverse diameter 8 mm and on left side it is 4 mm). Unequal size of FT on both sides created interest to find out different possibilities for its occurrence. In 1 out of 153⁹ difference in size of FT was noticed. Size of FT was bigger on left side¹² but we have observed that the right side FT is bigger than left side (Fig 2).

Small FT means small caliber of vertebral artery or narrowing of vertebral artery. Narrowing of FT may place patients at risk for vertebral artery insufficiency or thrombus formation. Also the compression of vertebral artery as a result of stenosis of FT may also lead to clinically important consequences for patients at risk¹³. During the development of bone, new layers are added to preexisting surfaces. Reduced foramen area of some cervical vertebrae may be attributed to periosteal growth at foramen margins to fit around their neurovascular and other contents¹⁴.

Difference in the size of FT was seen in C7 and typical cervical vertebra (Fig 3). The transverse diameter in A is 3 mm and in B is 7mm. Possible reason for this change could be caliber of vertebral artery. Usually vertebral artery enters FT of C6, sometimes FT of C7. During its course vertebral artery does not have constant caliber within FT. The FT of C7 can be smaller or absent. When FT of C7 is not found to contain vertebral artery then branches of vessels or nerves, fibrous and adipose tissue is present¹⁵. This may be the reason for having small FT.

Sometimes FT can be wider as compared to other side. In such cases possible predisposing factor may be the tortuosity of vertebral artery. Tortuosity reported to cause erosion and enlargement of FT and so widening of FT¹⁶.

Accessory FT or duplication of FT is one more variation seen in cervical vertebrae. These foramen may be complete or incomplete, unilateral or bilateral. We have observed three variations in the cervical vertebrae. Incomplete unilateral accessory FT on right side (Fig 4) in one vertebra. Complete unilateral accessory FT on right side and incomplete unilateral accessory FT on left side (Fig 5-a) in one vertebra and bilateral complete accessory FT (Fig 5-b,c) in one vertebra and bilateral incomplete accessory FT was seen in one cervical vertebra (Fig 5-d).

Many authors have observed similar variations, incomplete accessory FT was seen in 8 and complete in 12 out of 102 cervical vertebrae¹⁰. Unilateral duplication was seen in 6 and bilateral duplication was seen in 4 out of 175 cervical vertebrae¹⁷. Unilateral double FT was seen in 14 and bilateral double FT was seen in 8 out of 133 cervical vertebrae¹⁸. Complete unilateral FT was seen in 12, incomplete unilateral was seen in 8 and bilateral accessory FT was seen in 14 out of 210 cervical vertebrae¹⁹. Complete unilateral FT was seen in 6 and incomplete in 4 and bilateral complete and incomplete FT was seen in 18 and 3 respectively in 220 cervical vertebrae²⁰. Unilateral FT was seen in 3 and bilateral in 2 cervical vertebrae out of 262 21, Unilateral FT was seen in 10 and bilateral in 9 cervical vertebrae out of 120²². Incomplete double FT was seen in 6 and complete in 4 cervical vertebrae out of 153⁹

Vertebral artery develops from longitudinal anastomosis that links 2nd to 6th cervical intersegmental arteries. Most intersegmental arteries regress except the 7th which forms the origin of vertebral artery. Failure of occlusion of intersegmental arteries may be responsible for duplication or fenestrations of vertebral artery¹³. Duplication of vertebral artery offers collateral blood flow so becomes protective but such arteries may carry more risk of thrombus formation and embolization leading to severe ischemic attacks¹³.

Anatomically FT is described to be divided by fibrous or bony bridge, separating artery and vein²³, the smaller posterior part that encloses a branch of vertebral nerve and vertebral vein is called accessory FT²⁴. If the bony bridge develops incompletely then incomplete accessory FT can form. Branches of vertebral nerve pass through accessory FT²³. Separate area in the form of complete accessory FT for vertebral vein and nerve offers limited space. Any irritation or inflammation of nerve causes pressure effect on nerve and vein as well.

Such duplication of FT or accessory FT may be suggestive of duplication of vertebral artery or separate area for vertebral nerve and vein. Awareness of such variation and its incidence is clinically important for spine surgeons to prevent intraoperative complications by damaging vertebral artery and vein.

Conclusions

Incomplete FT in atlas, unequal size of FT on both sides may be related to vertebral artery insults.

Risk of thrombus formation and embolization may increase with presence of accessory FT

Variations in FT carry lot of clinical significance so such variations should not be ignored.

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