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Morphological features and anatomical variations of the Foramen Transversarium in Cervical vertebrae: A study in Eastern Indian population

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Abstract

Introduction: The foramina transversaria (FT) is a cardinal feature of the Cervical Vertebra. It transmits the vertebral vascular bundle (vertebral artery, and veins) and the sympathetic plexus which accompanies the vessels. Variations in number, size, shape & other morphological details of foramen transversarium give rise to neurological as well as hearing impairment. We in the index study, deliberated over the variations of FT as well as accessory FT. This in turn will help neurology surgeons as well as orthopedic surgeons while performing surgeries on the cervical spine.

Objectives: Study of variations in number, size, shape & other morphological details of foramen transversarium in order to facilitate spinal surgery of cervical vertebra. Materials and Methods: A cross sectional, single center, observational study was conducted in a tertiary care hospital with 160 sets, exactly 1099 human cervical vertebrae. All cervical vertebrae were observed macroscopically, on both the sides for presence of:

- Variations in number, size, shape & other morphological details of foramen transversarium.
- Variations in number, size, shape & other morphological details of accessory foramen transversarium.

Results: According to our observation type 4 is the most prevalent category in the right side (39.67%); whereas type 5 (30.12%) is the commonest category in the left side, being closely seconded by type 1(28.57%). The incidence of AFT (Accessory Foramina Transversarium) varied from 2.5% to 17.61 %. There is progressive increase in incidence from C1 to C7 except C2 where the incidence was zero.

Conclusion: The data provided by the present study on the morphology of foramen transversarium can be helpful in the interpretation of radiographic pictures and in computerized tomography for the diagnostic purposes. They may also be of assistance in determining a more accurate surgical approach to the removal of osteophytes or spurs compressing the vertebral arteries, or for other interventions in that area.

Keywords: Cervical vertebrae; Foramina Transversarium; Morphological and anatomical variations; Eastern India

1 Introduction

Imagine for a moment, a person is walking in a busy market place. He suddenly hears his name. While trying to look back at the source of the sound, his head starts reeling. He feels nausea, weakness of one half of the body and ultimately becomes unconscious. In this study we will get to know the cause of this malady, which will help us in timely management of this condition.

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Above mentioned condition is known as BOW HUNTER'S STROKE. This is caused due to compression of vertebral artery associated with head movement [1,2]. Stenosis of the vertebral artery can result from narrowing of the lumen of Foramen Transversarium.

The present study is an observational study and is undertaken on dried bones of unknown sex and age. The study has been conducted in a prestigious Institute of Eastern India, in the Department of Anatomy. The foramina transversaria (FT) is a cardinal feature of the Cervical Vertebra. It transmits the vertebral vascular bundle (vertebral artery, and veins) and the sympathetic plexus which accompanies the vessels [3].

Derangements of these structures in their course because of narrowing or deformation of the foramina, or osteophytes impinging on them, have been investigated morphologically and the obtained data is compared and examined in the light of previous works in this field.

The objective of the present study is to find the variations in number, size, shape & other morphological details of foramen transversarium.

Morphological analysis of our finding will further enrich our knowledge, which is particularly important for the neurology and orthopedic surgeons during various cervical spine surgeries.

For the clinicians; variations in number and size of FT may be one of the causes for complaints like headache, migraine and fainting attacks. These symptoms may be due to the compression of vertebral artery [4].

This study will also be useful to the radiologists in interpreting X- ray and CT scans.

2 Material and methods

2.1 Study Area

Department of Anatomy, Medical College and Hospital, Kolkata, West Bengal, India.

2.2 Study Subjects

160 sets , exactly 1099 (as some sets were incomplete) dried human cervical vertebrae were obtained from the donated cadavers in the Department of Anatomy , Medical College, Kolkata , West Bengal for our study.

2.3 Study Sample Selection

The cervical vertebrae, both typical and atypical were randomly selected irrespective of age and sex.

2.4 Inclusion criteria

All cervical vertebrae were observed macroscopically, on both the sides for presence of:

- Variations in size, shape, direction of main diameter of FT and accordingly its classification.
- Unilateral or bilateral accessory foramen transversarium (FT).
- Complete or incomplete AFT.
- Asymmetry in size of main foramen transversarium.
- Incomplete main foramen transversarium
- Presence of osteophytic encroachment.

The vertebrae were studied as seen from above in an antero-posterior direction.

Vertebrae with the above mentioned features were photographed and the data was compiled and analyzed using Microsoft excel software.

2.5 Exclusion criteria

Fused, fractured and broken vertebrae were excluded from our study.

2.6 Study Period

January 2016 to January 2017 (1 year)

2.7 Sample size

1099 dry human cervical vertebrae.

2.8 Study Design

A cross-sectional, single-centre, observational study.

2.9 Parameters & Procedures

Vertebrae were photographed and findings were recorded.

The data were compiled and analyzed using Microsoft Excel software.

3 Results

According to our observation *type 4* is the most prevalent category in the right side (39.67%); whereas type 5 (30.12%) is the commonest category in the left side, being closely seconded by type 1(28.57%). We found that majority of the foramina on the right side had type 4 shape, while the left side had types 1 and 5. This is not in full correlation with the work done by Taitz et al [5] and Karau PB (where on the right side had type 4 shape, while the left side had types 2 and 5).

Unilateral double FT (Figure 4) was observed in 80 (7.28%) cervical vertebrae. The incidence of AFT (Accessory Foramina Transversarium) varied from 2.5% to 17.61 %. There is progressive increase in incidence from C1 to C7 except C2 where the incidence was zero (Table 2). The duplication was bilateral in 85 vertebrae (7.73%). The incidence was maximum in C6 (28.75%) and least in C1& C2 (0%), (Figure5, Table3).

Incomplete Bilateral (B/L) AFT was found in (34.38%) of the sixth cervical vertebrae (C6), (Figure 6, Table 4). Maximum incidence of complete AFT were observed in C_6 vertebrae, 50 among 1099 vertebrae (31.25%), (Figure 7, Table 5).

Asymmetry in the relative size of the two main foramina transversaria in an individual vertebrae was noted in our study. It is observed that incidence of larger FTs in right side was 45.32% , that in left side was 22.66% & FTs of both sides in a vertebra are of same size i.e. symmetrical in 32.02%, (Figure 9).

Osteophyte-narrowing of FT was noted in - 26 cervical vertebrae in this study population (2.4%), (Figure 10,11).In 4 atlas & 5 axis vertebrae out of the total 1099 cervical vertebrae we found the main transverse foramina were incomplete, (Figure 12,13).

Table 1 Different categories of shape of transverse foramina and their incidence

Shape and direction of axes	Pictorial presentation	Right Side	Left Side
Type 1		244 (22.20%)	314 (28.57%)
Type 2		70 (6.37%)	18 (1.63%)
Type 3		140 (12.74%)	157 (14.29%)
Type 4		436 (39.67%)	279 (25.39%)
Type 5		209 (19.02%)	331 (30.12%)

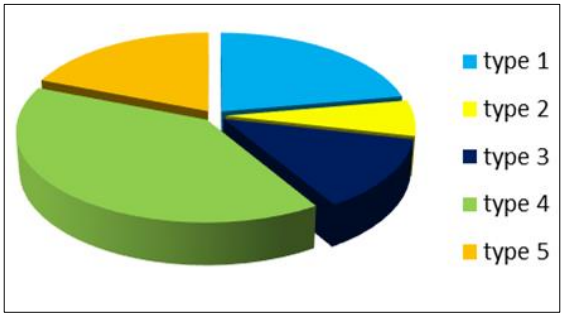

Figure 1 For right side

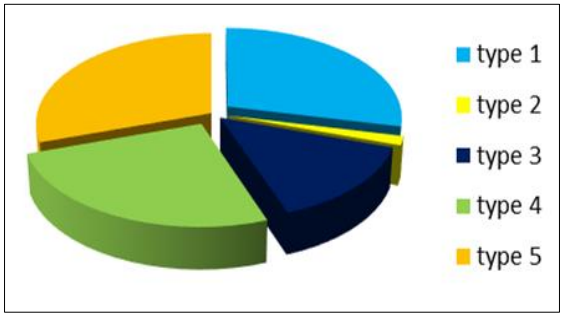

Figure 2 For left side

Pie charts showing comparative view of different categories of FT of both sides

Figure 3 Different vertebrae showing five different categories of foramen transversarium

Unilateral double FT (Figure 2) was observed in 80 (7.28%) cervical vertebrae.

Figure 4 C_6 vertebra showing unilateral AFT

Table 2 Incidence of U/L AFT in different cervical vertebrae

Type of vertebrae	No.of vertebrae examined	Vertebrae with unilateral AFT	Incidence in %
C_1	160	4	2.5
C_2	159	0	0
C_3	154	6	3.9
C_4	154	5	3.25
C_5	153	14	9.15
C_6	160	23	14.38
C_7	159	28	17.61

So, U/L AFT were observed in 80 vertebrae among 1099 vertebrae (7.28%).

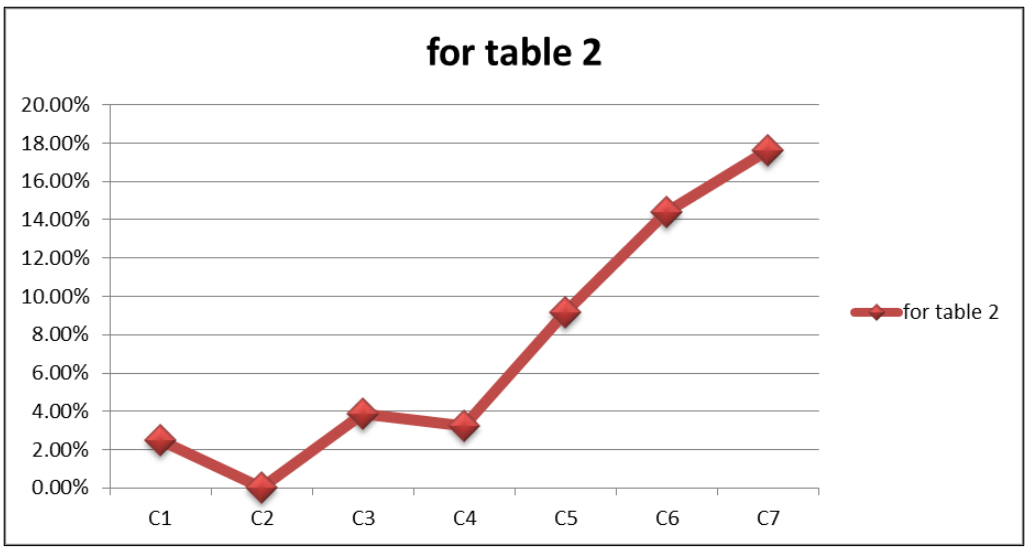

Figure Graphical representation of the incidence of U/L AFT in different cervical vertebrae

The duplication was bilateral in 85 vertebrae (7.73%).

Figure 5 A typical vertebra with B/L AFT

Table 3 Incidence of B/L AFT in different cervical vertebrae

Type of vertebrae	No. of vertebrae examined	Vertebrae with bilateral AFT	Incidence in %
C1	160	0	0
C2	159	0	0
C3	154	5	3.25
C4	154	5	3.25
C5	153	23	15.03
C6	160	46	28.75
C7	159	6	3.77

So, B/L AFT were observed in 85 vertebrae among 1099 vertebrae (7.73%).

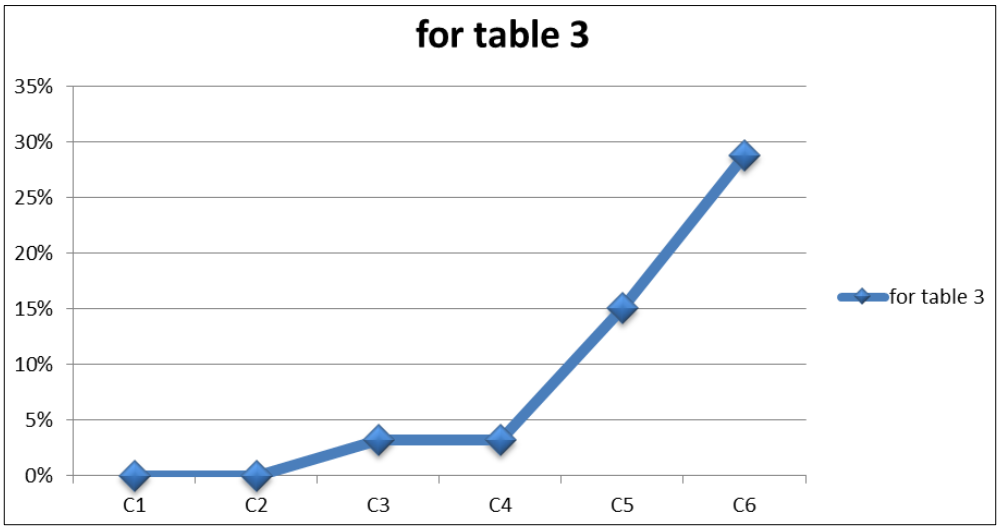

Figure Graphical representation of the incidence of B/L AFT in different cervical vertebrae

We examined each vertebra for the presence incomplete AFT.

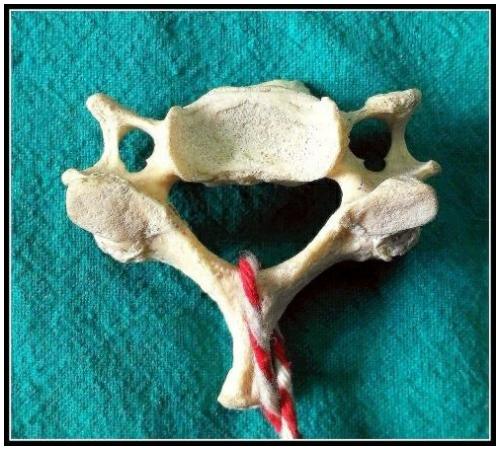

Figure 6 Vertebra showing B/L incomplete AFT

Table 4 Incidence of incomplete AFT in different cervical vertebrae

Type of vertebrae	No. of vertebrae examined	Vertebrae with Incomplete AFT	Incidence in %
C1	160	0	0
C2	159	0	0
C3	154	0	0
C4	154	0	0
C5	153	28	18.3
C6	160	55	34.38
C7	159	9	5.66

So , maximum incidence of incomplete AFT were observed in C_6 vertebrae, 55 among 1099 vertebrae (34.38%) .

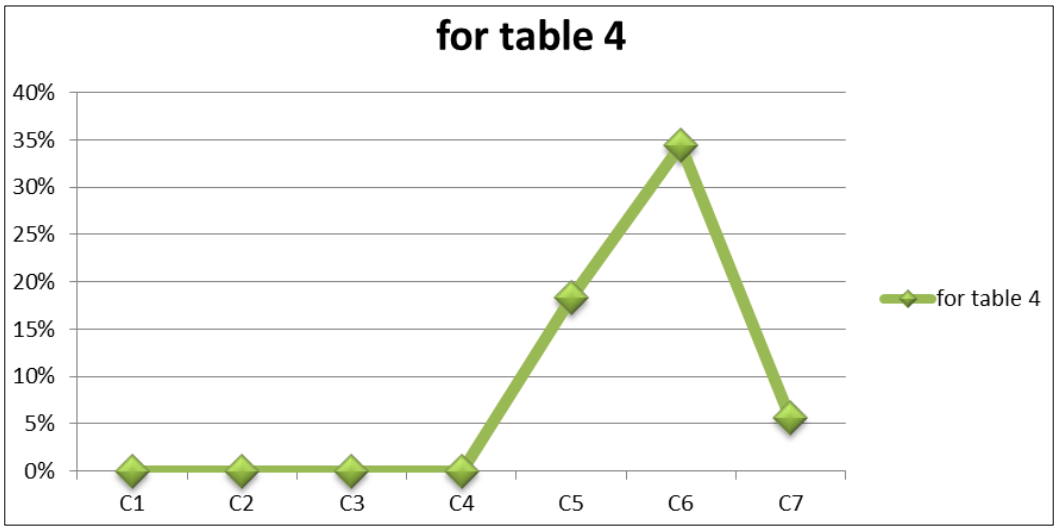

Figure Graphical representation of the incidence of incomplete AFT in different cervical vertebrae

Maximum incidence of complete AFT were observed in C_6 vertebrae, 50 among 1099 vertebrae (31.25%).

Figure 7 A C5 vertebra showing bilateral complete AFT

Table 5 Incidence of complete AFT in different cervical vertebrae

Type of vertebrae	No.of vertebrae examined	Vertebrae with complete AFT	Incidence in %
C1	160	5	3.13
C2	159	0	0
C3	154	10	6.49
C4	154	15	9.74
C5	153	32	20.92
C6	160	50	31.25
C7	159	28	17.61

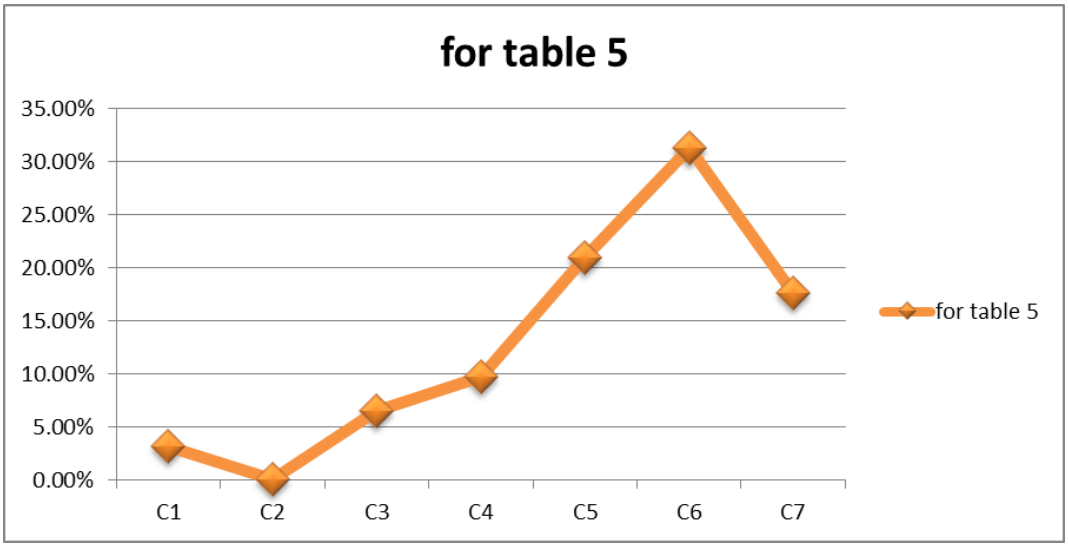

Figure Graphical representation of the incidence of complete AFT in different cervical vertebrae

Asymmetry in the relative size of the two main foramina transversaria in an individual vertebrae was noted in our study. It is observed that incidence of larger FTs in right side was 45.32% , that in left side was 22.66% & FTs of both sides in a vertebra are of same size i.e. symmetrical in 32.02% .

Figure 8 Bilaterally asymmetrical FT in a typical cervical vertebra

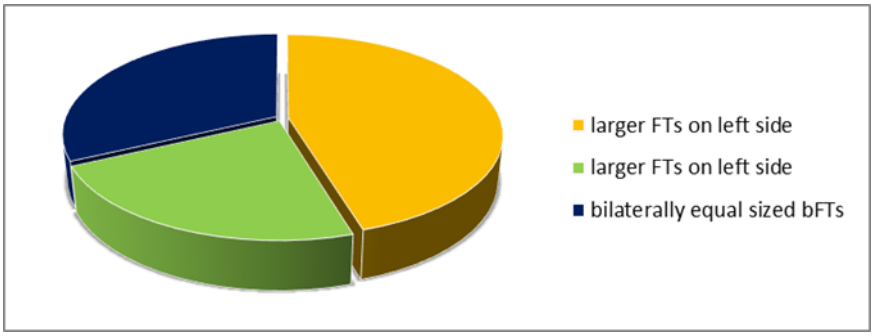

Figure 9 Bilateral symmetry of FTs

Pie chart showing comparative representation of asymmetry of FT on both sides of a vertebra

Osteophyte-narrowing of FT was noted in - 26 cervical vertebrae in this study population (2.4%)

Figure 10, 11 Photographs osteophytes narrowing the transverse foramina in two different C_5 vertebrae in our study sample can be appreciated

In 4 atlas & 5 axis vertebrae out of the total 1099 cervical vertebrae we found the main transverse foramina were incomplete

Figure 12 The atlas vertebra in the photograph shows incomplete anterior arch of right foramen transversarium

Figure 13 The axis vertebra in the photograph shows incomplete foramen transversarium on right side

Table 6 Incidence of double transverse foramina in different study populations

Author	Year	Prevalence of accessory foramina	Study sample	Population
Taitz et al	1978	7%	480	Indian
Nagar et al	1999	8.6%	1388	Roman-Bynzatine-Jews
Das et al	2005	1.5%	132	Indian
Kaya et al	2011	22.7%	262	Jewish
Karau PB,Oduia P.	2012	3.9%	102	Kenyans
Esakkiammal N. et al	2016	15.3%	241	Indian
Present study	2017	15.01%	1099	Indian

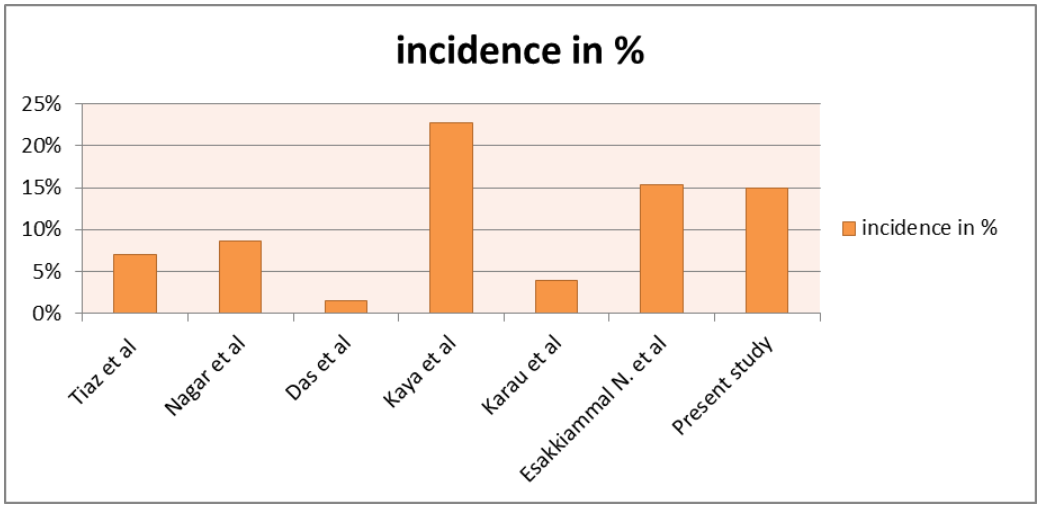

Figure 14 Bar diagram depicting comparison between incidence of accessory FT as seen by various authors and the present study. Esakkiammal N. et al shows 15.3% incidence of AFT which is so very close to our finding (15.01%)

4 Discussions

The FT of 6th to 1st cervical vertebrae transmits the 2nd part of the vertebral artery, vertebral veins, and sympathetic nerves from inferior cervical ganglion [10, 14]. Presence of another foramen apart from FT in the transverse process of cervical vertebrae is called accessory FT which is smaller in size than the primary foramen. Generally, it is found in the sixth cervical vertebra and less frequently in other typical cervical and 7 th cervical vertebrae.[22]

The cervical vertebrae are identified by the presence of foramen transversarium in the transverse processes. These foramina are known to exhibit variations with respect to the shape and size and numbers. Under such circumstances the course of vertebral artery may be distorted. The variations in number and size of foramina transversaria of cervical spine may be one of the causes for complaints like headaches, migraine and fainting attacks, usually due to compression of the vertebral artery[28]. Their etiology may be related to the variations of the course of vertebral artery and to developmental causes [12]. Since the vertebral vessels are a factor in the formation of the FT, it can be assumed that variations in the presence and course of the vessels will be manifested in changes of the FT. Conversely, variations of the FT can be useful for estimating changes or variations of the vessels and accompanying nerve structures.[10]

In our study, we categorized the shape of the transverse foramina according to criteria by Taitz et al. [10, 11]

From table 1, we can see, the main transverse foramen can be categorized into five types depending on the shape and main diameter of the foramen;

- type 1 - round,
- type 2 - elliptical with main diameter (length) anteroposterior,
- type 3 - elliptical with main diameter transverse (breadth) ,
- type 4 - elliptical with main diameter oblique, from right to left,
- type 5 - elliptical with main diameter oblique from left to right.

We found that majority of the foramina on the right side had type 4 shape i.e. 436 foramina on the right side among 1099 right transverse foramina (39.67%) . This finding is similar to Rekha et al [31], where type 4 is commonest on right side but doesn't match with the results of Taitz et al[10] and Karau PB.[20]. So as a whole type 4 is the commonest type according to our study.

While on the left side type 5 is the most prevalent type (30.12%), being closely seconded by type 1 (28.57%). This agrees with the results of Taitz et al [10], Rekha et al [31].

N.S.Sunitha[27] observed that Type 1 shape of foramen transversarium was 32% in the study contributing to commonest shape in their study followed by type 3 and 5 in 21%;

The least common shape was found to be type 2 which contributed to only 6% of the total cervical vertebrae[27] which exactly corresponds with our findings.

This difference in shape may be related to the mechanical stresses due to neck movements. Pathological changes of the movements could therefore be expressed in changes of the foramina.[10]

Caovilla et al [6] (2000) showed variations in the number and size of the foramen transversarium may be one of the causes of headache, migraine and fainting attacks due to compression of the vertebral artery. Small foramen was found in C5, C6 and C7 cervical vertebra (Fig 6). Thus frequent small foramina were found in the lower group of cervical vertebrae.

The direct correlation between the size of the FT and the artery should be questioned in certain cases. Many big FT may be due to the presence of big veins or simple connective tissue. This is normally the case of the FT in the seventh cervical vertebra, where the foramen is normally occupied only by the vertebral vein or veins.

Regarding observation done over incidence of U/L AFT in different cervical vertebrae , we found that 80 out of 1099 vertebrae i.e. 7.28% bearing unilateral AFT. C_7 showed 17.61% incidence , C_6 showed 14.38% and C_5 9.15% incidence, which shows AFTs are more prevalent in the lower cervical vertebrae.

Chandravadiya et al [7] also concluded that all the double foramina were observed in the lower cervical vertebrae (C5, C6, and C7).

According to Kaya S et al[21] double FT was unilateral in 13.6% of all cervical vertebrae.

The duplication was bilateral in 85 vertebrae (7.73%). 46 C_6 vertebrae among 160 samples (28.75%)presented AFT, which makes C_6 the commonest to bear B/L AFT, seconded by the C_5 vertebrae , the percentage being 15.03.

In the Study of Kaya S et al[21] double FT was bilateral in 9% all cervical vertebrae, though their study sample was small, only 22 vertebrae.

We can appreciate tabular representation of the same in tables numbering 2 and 3.

We also documented our study sample for the presence of complete and incomplete AFT. C_6 showed maximum frequency of both of the above mentioned types of AFT (31.25% and 34.38% respectively).

We also observed that these AFTs are more frequent in the lower cervical vertebrae, C5, C6 or in C7.

Graphical representation of the same is shown in table 4 and 5.

Akhtar et al [2] conducted study on 174 cervical vertebrae and found 25 (14.4%) cervical vertebrae had accessory FT. amongst these, accessory FT was present unilaterally in 20 (11.5%) and bilaterally in 5 (2.9%) cervical vertebrae. In our study bilateral and unilateral AFT have almost similar incidence 7.3% and 7.28% respectively.

Chandravadiya et al [7] observed the double foramen transversarium in 4.76% of the cases.

Chaudhuri ML et al ,[8] observed the double foramen transversarium in 23.15% of the cases.

Das Srijit (2005)[12] reported two cases of double foramen transversarium in 132 human cervical vertebra.

C Taitz et. Al (1978)[10] studied 36 spines and reported 34 vertebrae which were having double FT.

In thet study by Esakkiammal N et al [14] , 134 typical cervical vertebrae were examined and accessory FT was found only in 37 (27.6%) vertebrae.

Jarostaw Wysocki et al [19] studied 100 vertebral columns and reported divided foramen most frequent at the level of C_6 (45.6%) and rarest at the level ofC_3 (2.8%).

Jaffar et al [18] reported accessory FT in lower cervical vertebra mostly in C6 (70%).

Kaya S et al[21], investigated in ancient cervical vertebrae and the frequency of double FT was found in 22.7% of cases.

The study of Nagar Y. et al, [25] 8.6% of the vertebrae showed unilateral or bilateral occurrence of double foramina transversaria.

Out of 175 cervical vertebrae the double foramen transversarium was found in only 10 vertebrae in the study conducted by Patil Nilima et al[29] . The incidence was calculated as 5.71%.

Rathnakar.P [30] reported 8 out of 140(5.7%) vertebrae with accessory foramen transversaria.

Sharma et al [34] reported, out of 200 typical vertebrae 16 vertebrae were showing accessory foramen.

Out of 210 cervical vertebrae the double foramen transversarium was found in only 10 vertebrae in the study of Chandravadiya et al [7]. The incidence of which is calculated as 4.76%.

A study conducted by Murlimanju et al [23] (2011), Wysocki et al (2003)[37] on 363 typical & atypical cervical vertebrae presented an accessory F.T in 1.6% vertebrae.

A case of triplicate accessory F.T has been reported by Wysocki et al., (2003), Nayak (2007)[36] while no such vertebra was found in the present study.

Double FT may be correlated by the presence of duplicate vertebral arteries.[10,17,32,33,34,35] Absence of FT could mean absence of the vertebral artery [10]. A duplicate vertebral artery may potentially serve to protect patients against ischemic attacks to the brain and provide collateral blood flow to the basilar artery.

Compression of vertebral artery will not only lead to neurological symptoms but also to hearing disturbances.[32]

Our study also includes asymmetry in the relative size of the two main foramina transversarium in an individual vertebrae .Right sided FTs are larger in maximum cases ,in 45.32%, which can explain the migraine attack in one half of head resulting from narrower vertebral artery in the affected side.

Hadley (1958)[16] and Hyyppa et al. (1974)[15] found that tortuosity of the vertebral artery may cause bone destruction. Thus, it may be a factor in the size of the foramina.

Epstein (1969)[13] and Tiaz et al[11] found the arteries of the left side bigger than those of the right. This is in contrast to our observation where we found the right FT are generally larger than the left FT.

Regarding osteophytic encroachment of foramen transversarium, we found the most frequently affected FT were those of cervical vertebrae 5 and 6. This corresponds to the area of the cervical spine where the osteophytes develop more frequently and reach the largest dimensions, which corresponds with the work done by Nathan, 1962.

In the study by N.S.Sunitha,[27]osteophytes were found partially covering the foramen transversarium in 3% cases just alike our finding with a percentage of 2.4.

Kovacs[22], Tatlow and Bammer et al [36], have shown from their studies that impingement of osteophytes can cause compression of the vertebral artery.

Citlow JS [9] (1999) showed that compression of vertebral artery at C5 by osteophyte caused vertigo triggered by neck extension.

It should be remembered that both the vertebral and basilar arteries correspond to the blood supply not only of the brain but also of the inner ear. Therefore compression of the vertebral arteries or spasms of the same arteries could be manifested not only by neurological symptoms, but also by labyrinthine or hearing disturbances, Romanov et al [32].

In 4 atlas & 5 axis vertebrae out of the total 1099 cervical vertebrae of our study sample, we found the main transverse foramina were incomplete.

According to the study of Sethi et a, l24 2% of atlas had absent costal element.

5 Conclusion

The data provided by the present study on the morphology of foramen transversarium can be helpful in the interpretation of radiographic pictures and in computerized tomography for the diagnostic purposes. They may also be of assistance in determining a more accurate surgical approach to the removal of osteophytes or spurs compressing the vertebral arteries, or for other interventions in that area.

Keeping the vertebral artery intact, constitutes an important concern to neurology surgeons while performing surgeries on the cervical spine since minor accidental damage to vertebral artery can lead to grave consequences and even death. Hence, the knowledge of all kind of variations in the anatomy and morphology of accessory FT in cervical vertebrae will be helpful to both radiologists and neurosurgeons in preventing vascular catastrophic due to accidental damage of vertebral artery

Compliance with ethical standards

Disclosure of conflict of interest

The authors have no conflict of interest.

Statement of informed consent

Not applicable as the study has been conducted on dry bones.

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