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Morphometric Study of Foramen Transversarium of Cervical Vertebrae

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I. INTRODUCTION

The cervical vertebrae are seven in number, and all are recognized by the presence of foramina transversaria on the transverse process. The third to sixth cervical vertebrae are typical because they bear the common features. The first, second and seventh cervical vertebrae are atypical since each possesses specific features for identification. It is formed by the vestigial costal element fused to the body and the originally true transverse process of the vertebra. It transmits the vertebral vascular bundle that is vertebral artery, veins and the sympathetic plexus which accompanies the vessels.

The foramen transversarium is closed laterally by the costo- transverse bar, a plate of bone interconnecting the rib element to the original transverse process. This plate is grooved in its upper aspect. The cervical spinal nerves after emerging from the intervertebral foramen, cross the vertebral vessels posterior, the anterior ramus of the nerve proceeds in its course laterally and downwards in the groove of the costo-transverse bar.

The vertebral artery starts to thread the foramen transversarium only from the sixth which traverse upwards to the atlas. The seventh foramen is normally occupied only by the veins. The foramen transversarium is divided by a fibrous or bony bridge, separating the artery and the vein, the smaller posterior part (that encloses the branch of vertebral nerve and the vertebral vein) is accessory vertebral foramem. The vertebral nerve ascends from the stellate ganglion up to the level of C3, two branches from this nerve are formed running towards the seventh spinal nerve and one of these branches passes through the accessory foramen.

II. AIM AND OBJECTIVE

The foramina transversaria transmits the vertebral vascular bundle (vertebral artery and veins) and the sympathetic plexus which accompanies the vessels. Derangements of these structures in their course occur because of narrowing or deformation of the foramina, or osteophytes impinging on them. Variations of the foramen transversarium can be useful for estimating changes or variations of the vessels and accompanying nerve structures. In the absence of foramen transversarium, it is difficult and creates confusion to reach these structures, because any injury to these structures will lead to devastating complications. Hence to prevent complications while approaching vital structures, neurosurgeons, radiologists and orthopaedic surgeons should have good knowledge of such variations.

So the aim of the study is,

- To assess the presence or absence of foramen transversarium.
- To assess the number of foramen transversarium in the cervical vertebrae.
- To find out the shape – whether round or elliptical.
- To find out the diameter of the foramen transversarium : antero-posterior and transverse diameter.
- The area of the foramen transversarium.

III. MATERIALS AND METHOD

A total of 200 foramen transversarium were examined from 100 cervical vertebrae in which C1=17; C2=18; C3=13;C4=24; C5=14; C6=11; C7=03 irrespective of age and sex. The bones were obtained from the department of anatomy SRM Medical college.Chennai. The vertebrae were examined for the presence, absence, shape, size and the diameters of foramen transversarium. Presence of double foramina were noted on the right and left sides.

- The materials used for this study
  1. Digital vernier caliper
  2. Digital camera
- The shape and direction of the foramen was classified into 5 categories using the criteria by Taitz et al., (1978).The vertebra were studied as seen from above in an antero-posterior direction, the body of the vertebra facing the examiner.
- Type 1 round
- Type 2 which was elliptical with the main antero-posterior diameter
- Type 3 elliptical with main transversal diameter

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- Type 4 elliptical with main diameter oblique from right to left
- Type 5 elliptical with main diameter oblique from left to right.

All the diameters were taken on the inner aspect of the foramen.

The parameters were

a. Antero-posterior
b. Transverse
c. Area

- The cross-sectional area of the foramen transversarium were calculated using the formula for an ellipse.

  AREA =pi (D1/2 *D2/2)
  D1= horizontal length of the foramen
  D2= vertical length of the foramen
  pi= 3.14

All the measurements were taken by using a digital vernier caliper and readings were documented separately. The antero-posterior, transverse diameter and area were taken as shown in the figure.

VERNIER CALIPER

TRANSVERSE DIAMETER

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ANTERO- POSTERIOR DIAMETER

IV. OBSERVATION AND RESULTS

The examination of the presence, absence, shape, accessory foramen, their side dominance and the antero-posterior, transverse diameter and area of 200 foramen transversarium of 100 cervical vertebrae from C1 to C7 has revealed the following observations.

The foramen transversaria is present in the transverse process on both sides of all the cervical vertebrae which is a significant feature to differentiate the cervical vertebrae from other vertebrae. The foramen of C7 is small when compared with other.

The shape of the foramen is observed macroscopically and it is categorized into 5 types according to Taitz (1978). The shape and direction of the foramen is examined by this method. The number of foramina depends on the presence or absence of accessory foramen and also the absence of main foramen.

In all the 100 cervical vertebrae studied

- The foramen transversarium was present in all cervical vertebrae in both right and left sides.
- No vertebrae showed absence of foramen transversarium.

A – INCOMPLETE FORAMEN TRANSVERSARIUM

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B – UNILATERAL DOUBLE FORAMEN TRANSVERSARIUM

UNILATERAL DOUBLE FORAMEN TRANSVERSARIUM

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ASYMMETRICAL FORAMEN TRANSVERSARIUM

BILATERAL DOUBLE FORAMEN TRANSVERSARIUM

TYPE 1 (ROUND)

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A – TYPE 3(ELLIPTICAL WITH MAIN TRANSVERSAL DIAMETER)
B – TYPE 4(ELLIPTICAL WITH MAIN DIAMETER OBLIQUE FROM RIGHT TO LEFT)

– TYPE 5 (elliptical with main diameter oblique from left to right)
B – Type 2 (elliptical with the main antero-posterior diameter)

Regarding the number of foramen transversarium, the variations of the foramen includes the double foramen which is unilateral or bilateral, triple foramen, incomplete foramen and asymmetrical foramen.

Out of 100 cervical vertebrae examined , only 4 (4%) vertebrae showed the accessory foramina. Among them 2 (2%) vertebra had double foramina on both sides which is bilateral on C6 andC5. The unilateral double foramen was seen in C4 vertebra on right side and C5 on the left side

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with an incomplete foramen on the right side. Only 2 (2%) showed unilateral accessory foramen.

The accessory foramen were smaller than the regular foramen in all the vertebrae. All the accessory foramen were observed in the lower cervical vertebrae.

Only one vertebra of C7 (1%) showed asymmetrical foramen. No vertebra showed the presence of single foramen. There were no variations observed in the atlas and axis. No vertebra showed the presence of triple foramen.

The shape of the foramen was classified into 5 types. The transverse foramina on both sides were different in size and shape. In case of accessory foramen the shape of the large foramen is noted.

- The atlas shows the highest frequency of type 4 (elliptical with main diameter oblique from right to left) on the right side and type 2 (elliptical with main antero-posterior diameter) on the left side.
- The predominant type in axis is type 1 (round) and type 4 (elliptical with main diameter oblique from right to left) of the right and left side.
- Type 3 (elliptical with main transversal diameter) was observed in the right and left side of third cervical vertebra.
- The foramen transversarium of C4 showed the highest frequency of type 3 (elliptical with main transversal diameter) on both sides.
- The highest frequency of type 3 (elliptical with main transversal diameter) and type 4 (elliptical with main diameter oblique from right to left) was observed on the right and left side of the C5 vertebra.
- The C6 foramen transversarium showed type 3 (elliptical with main transversal diameter) on the right and type 1 (round) on the left side.
- C7 foramen transversarium showed the predominance of type 1 (round) on right side.

The frequency of the different types of the foramina transversaria in each side of the vertebrae and a separate graphical presentation representing each side is tabulated below,

FREQUENCY OF THE DIFFERENT TYPES OF THE FORAMINA TRANSVERSARIA IN EACH SIDE OF THE VERTEBRAE

		C_1=17(34)		C_2=18(36)		C_3=13(26)		C_4=24(46)		C_5=14(28)		C_6=11(22)		C_7=3(16)	
Type	Shape	Right	Left	Right	Left	Right	Left	Right	Left	Right	Left	Right	Left	Right	Left
1		2	0	7	4	0	2	6	7	1	0	3	7	3	1
2		5	7	2	2	1	0	3	1	3	0	0	0	0	1
3		0	1	3	5	6	7	12	9	7	1	6	0	0	0
4		9	3	5	7	4	0	0	2	2	9	2	1	0	1
5		1	6	1	0	2	4	3	5	1	4	0	3	0	0

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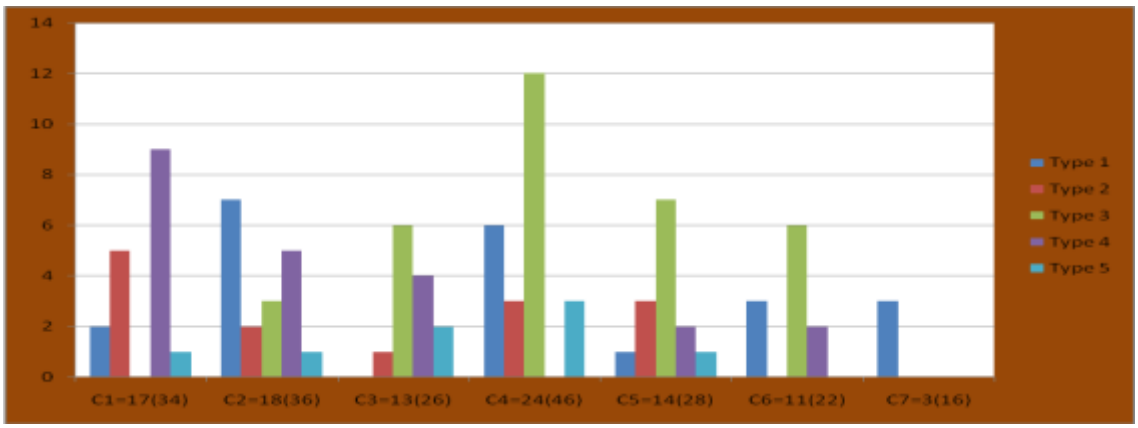
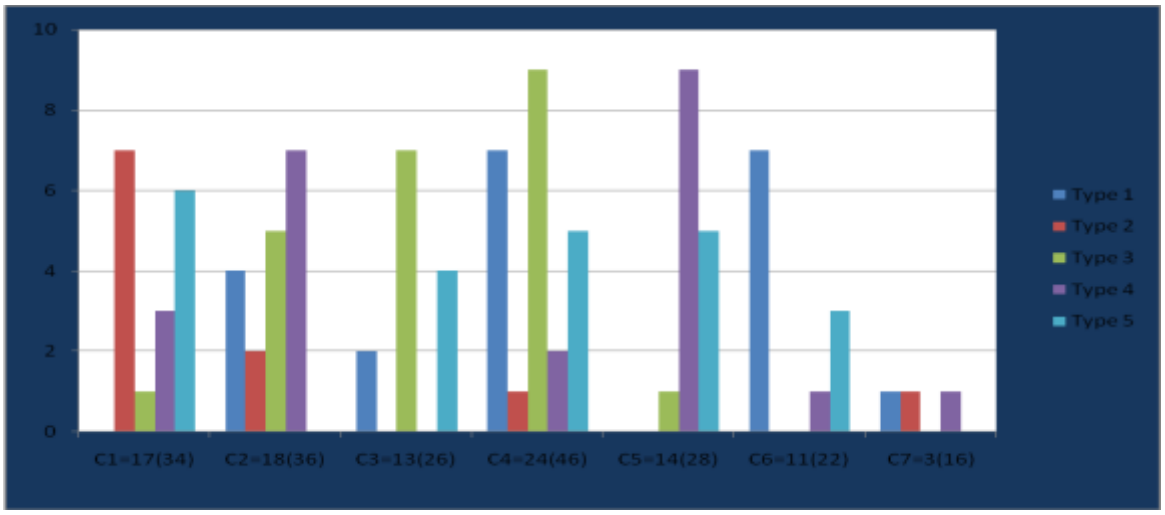


FREQUENCY OF DIFFERENT TYPES OF FORAMINA TRANSVERSARIA IN EACH SIDE OF THE VERTEBRAE RIGHT SIDE



FREQUENCY OF DIFFERENT TYPES OF FORAMINA TRANSVERSARIA IN EACH SIDE OF THE VERTEBRAE LEFT SIDE

The antero- posterior and transverse diameters were measured with the vernier caliper and the area was calculated by using the formula for ellipse.

- The mean antero-posterior diameter of C1=6.2694; C2=5.8356mm; C3=5.213mm; C4=6.0104mm;C5=5.8943mm; C6=5.2245mm; C7=4.0533mm on the right side.
- The mean antero-posterior diameter on the left sideC1=6.3056mm;C2=6.0672mm; C3=5.0731mm;C4=6.1313mm;C5=5.7721 mm;C6=5.7391mm;C7=5.4567mm.
- The mean transverse diameter on the right side wasC1=5.6729mm;C2=5.889mm; C3=5.6115mm;C4=6.3288mm;C5=6.1821 mm; C6=6.1721mm; C7=4.5233mm.
- The mean transverse diameter on the left side wasC1=5.8024mm;C2=6.0644mm; C3=5.7562mm;C4=5.9354mm; C5=5.7193mm; C6=6.1982mm; C7=5.1867.
- The mean area on the right side was C1=28.5382sq.mm;C2=27.3072sq.mm; C3=23.4269sq.mm;C4=30.2017sq.mm; C5=28.9421sq.mm;C6=25.6491sq.mm; C7=14.9167sq.mm.
- The mean area on the left side was C1=29.6418sq.mm;C2=28.9867sq.mm; C3=23.5046sq.mm; C4=28.6188sq.mm; C5=25.9929sq.mm;C6=28.0918sq.mm; C7=22.4867sq.mm.
- The transverse diameter of foramen transversarium of all cervical vertebrae showed statistical significance .
- The antero-posterior diameter and the area of foramen transversarium of all cervical vertebrae did not show any statistical significance. No statistical significance was noted in the antero-posterior,transverse diameter and area of the right and left foramen transversarium.

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MINIMAL AND MAXIMAL VALUES FOR THE LENGTH, BREADTH IN MM AND AREA IN SQ.MM OF THE FORAMINA TRANSVERSARIA IN RIGHT SIDE

		N	M	SD	SE	MIN	MAX
C_1	AP	17	6.2694	1.24473	6.30189	4.93	8.71
	T	17	5.6729	1.06937	0.25936	4.28	7.60
	A	17	28.5382	10.30410	2.49911	18.21	50.56
C_2	AP	18	5.8356	1.16109	0.27367	4.05	8.15
	T	18	5.8889	0.87529	0.20631	4.45	7.94
	A	18	27.3072	7.16338	1.68844	19.00	40.53
C_3	AP	13	5.2123	1.09516	0.30374	2.69	6.67
	T	13	5.6115	1.11210	0.30844	3.61	7.82
	A	13	23.4269	7.41914	2.05770	7.62	34.87
C_4	AP	24	6.0104	0.99380	0.20286	3.92	8.33
	T	24	6.3288	1.27341	0.25993	3.80	9.08
	A	24	30.2017	9.09121	1.85574	17.24	47.07
C_5	AP	14	5.8943	1.13057	0.30216	3.78	7.85
	T	14	6.1821	1.36201	0.36401	3.42	8.77
	A	14	28.9421	9.55358	2.55330	12.05	45.4
C_6	AP	11	5.2245	1.06215	0.32025	3.97	6.79
	T	11	6.1727	0.79214	0.23884	4.78	7.09
	A	11	25.6491	7.45907	2.24899	14.90	37.52
C_7	AP	3	4.0533	1.29218	0.74604	3.20	5.54
	T	3	4.5233	0.86002	0.49653	3.66	5.38
	A	3	14.9167	7.49536	4.32745	9.19	23.40

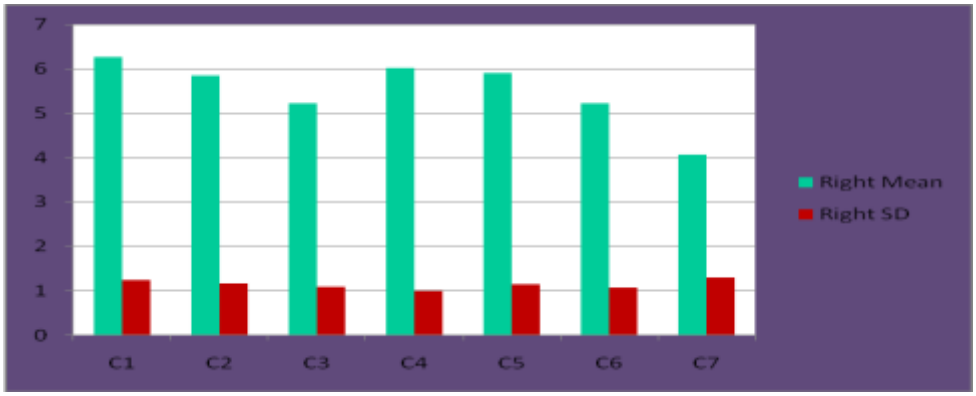
MINIMAL AND MAXIMAL VALUES FOR THE LENGTH, BREADTH IN MM AND AREA IN SQ.MM OF THE FORAMINA TRANSVERSARIA IN LEFT SIDE

		N	M	SD	SE	MIN	MAX
C_1	AP	17	6.3506	1.55574	0.37732	4.23	9.91
	T	17	5.8024	1.15093	0.27914	3.28	8.23
	A	17	29.6418	11.1818238	2.71217	12.70	50.69
C_2	AP	18	6.0672	1.00568	0.23704	4.46	7.67
	T	18	6.0644	0.80995	0.19091	4.87	7.81
	A	18	28.9867	6.68649	1.57602	20.17	42.49
C_3	AP	13	5.0631	1.18081	0.32750	2.20	7.27
	T	13	5.7562	1.21424	0.33677	3.12	7.74
	A	13	23.5046	7.99577	2.21763	5.39	36.24
C_4	AP	24	6.1313	0.83793	0.17104	4.83	8.03
	T	24	5.9354	0.77014	0.15720	4.54	7.90
	A	24	28.6188	5.65594	1.15451	19.39	42.23
C_5	AP	14	5.7721	1.01481	0.27122	3.41	7.31
	T	14	5.7193	0.97026	0.2593	4.22	7.43
	A	14	25.9929	6.14324	1.64185	11.48	33.73
C_6	AP	11	5.7391	1.14619	0.34559	4.02	7.56
	T	11	6.1982	0.71421	0.21534	5.09	7.30
	A	11	28.0918	7.21366	2.17500	16.06	42.81
C_7	AP	3	5.4567	1.41143	0.81489	4.01	6.83
	T	3	5.1867	0.75659	0.43682	4.46	5.97
	A	3	22.4867	7.35756	4.24789	14.04	27.50

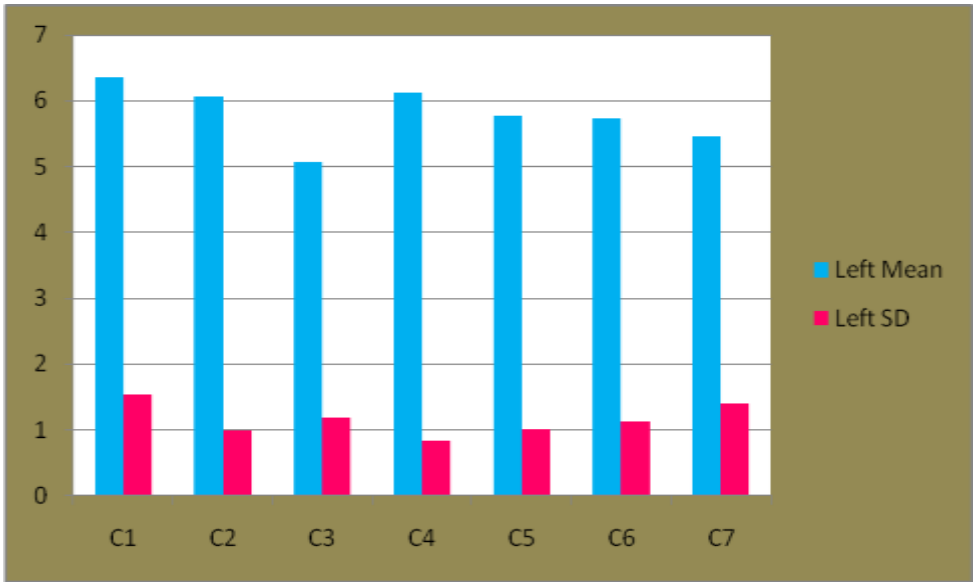
THE MEAN AND STANDARD DEVIATION OF ANTERO-POSTERIOR DIAMETER OF FORAMEN TRANSVERSARIUM

S.NO	VERTEBRA	RIGHT MEAN &SD	LEFT MEAN & SD
1.	C1	6.2694+/-1.24	6.3506+/-1.55
2.	C2	5.8356+/-1.16	6.0672+/-1.00
3.	C3	5.213+/-1.09	5.0731+/-1.18

4.	C4	6.0104+/-0.99	6.1313+/-0.83
5.	C5	5.8943+/1.13	5.7721+/-1.01
6.	C6	5.2245+/-1.06	5.7391+/-1.14
7.	C7	4.0533+1.29	5.4567+1.411



THE MEAN AND STANDARD DEVIATION OF ANTERO-POSTERIOR DIAMETER OF FORAMEN TRANSVERSARIUM RIGHT SIDE



THE MEAN AND STANDARD DEVIATION OF ANTERO-POSTERIOR DIAMETER OF FORAMEN TRANSVERSARIUM LEFT SIDE

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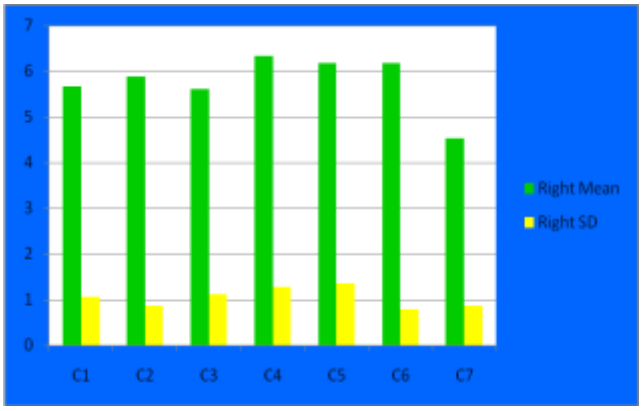
THE MEAN AND STANDARD DEVIATION OF THE TRANSVERSE DIAMETER OF FORAMEN TRANSVERSARIUM

S.NO	VERTEBRA	RIGHT MEAN&SD	LEFT MEAN&SD
1.	C1	5.672+/-1.06	5.8024+/-1.15
2.	C2	5.8889+/-0.87	6.0644+/-0.80
3.	C3	5.6115+/-1.11	5.7562+/-1.21
4.	C4	6.3288+/-1.27	5.9354+/-0.77
5.	C5	6.1821+/-1.36	5.7193+/-0.97
6.	C6	6.1727+/-0.79	6.1982+/-0.71
7.	C7	4.5233+/-0.86	5.1867+/-0.75



THE MEAN AND STANDARD DEVIATION OF THE TRANSVERSE DIAMETER OF FORAMEN TRANSVERSARIUM RIGHT SIDES

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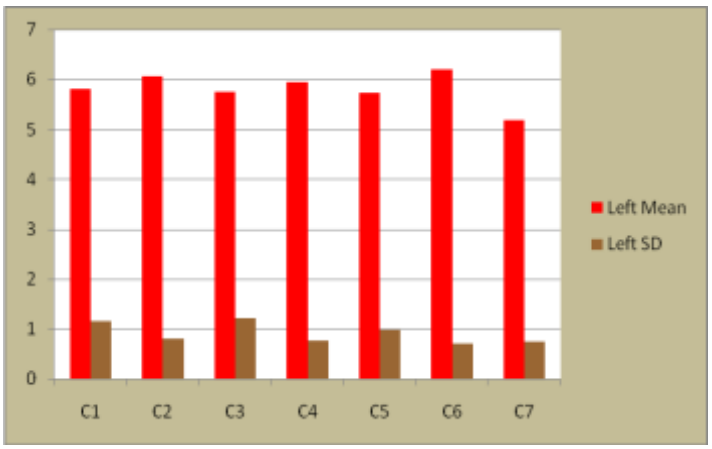

THE MEAN AND STANDARD DEVIATION OF THE TRANSVERSE DIAMETER OF THE FORAMEN TRANSVERSARIUM LEFT SIDE

THE MEAN AND STANDARD DEVIATION OF THE AREA OF FORAMEN TRANSVERSARIUM

S.NO	VERTEBRA	RIGHT MEAN&SD	LEFT MEAN&SD
1.	C1	28.5382+/-10.30	29.6418+/-11.18
2.	C2	27.3072+/-7.16	28.9867+/-6.68
3.	C3	23.4269+/-7.41	23.5046+/-7.99
4.	C4	30.2017+/-9.09	28.6188+/-5.65
5.	C5	28.9421+/-9.55	25.9929+/-6.143
6.	C6	25.6491+/-7.45	28.0918+/-7.21
7.	C7	14.9167+/-7.49	22.4867+/-7.35

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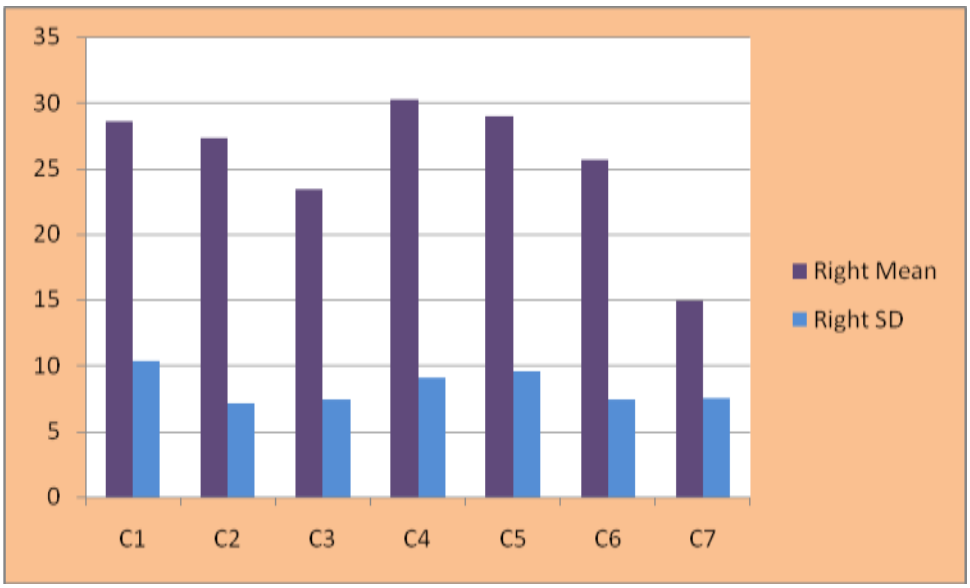
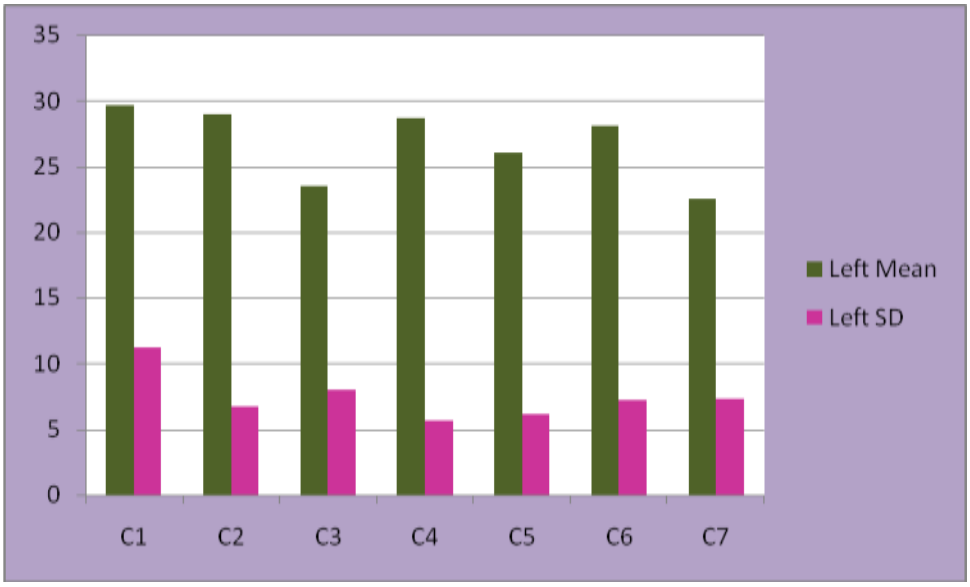


THE MEAN AND STANDARD DEVIATION OF THE AREA OF FORAMEN TRANSVERSARIUM RIGHT SIDE



THE MEAN AND STANDARD DEVIATION OF THE AREA OF FORAMEN TRANSVERSARIUM LEFT SIDE

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
RAP	Between Groups	22.063	6	3.677	2.947	.011
	Within Groups	116.054	93	1.248		
	Total	138.117	99			
RTRANS	Between Groups	13.710	6	2.285	1.843	.099
	Within Groups	115.328	93	1.240		
	Total	129.038	99			
RAREA	Between	950.257	6	158.376	2.108	.060

	Groups					
	Within Groups	6987.864	93	75.138		
	Total	7938.122	99			
LAP	Between Groups	15.228	6	2.538	1.978	.077
	Within Groups	119.309	93	1.283		
	Total	134.537	99			
LTRANS	Between Groups	3.897	6	.650	.735	.623
	Within Groups	82.165	93	.883		
	Total	86.063	99			
LAREA	Between Groups	465.664	6	77.611	1.341	.247
	Within Groups	5382.982	93	57.882		
	Total	5848.646	99			

V. DISCUSSION

Presence of foramen transversarium:

Paul Bundi Karau et.al (2013) 204 foramina transversaria of 102 atlas vertebrae were studied and they stated that all the cervical vertebrae had foramina transversaria.

In Renu Chauhan study of 100 atlas vertebrae ,the foramen transversarium was found in all the vertebrae.

In the present study of 100 cervical vertebrae ,all the transverse process showed the presence of foramen transversarium.

Absence of foramen transversarium :

C.Taitz et al (1978) observed 8 vertebrae with single foramen transversarium

Vasudeva (2009) in his study reported the absence of foramen transversarium on the left side of atlas vertebrae.Absence of foramen transversarium was not noticed in Muralimanju et al(2011) study.

C.Taitz et al (1978) In their study they observed absence of foramen transversarium at C4 (3), C6 (1). They did not mention the side of absence.

Others like Desai S.D et al (2010) noticed absence of foramen transversarium on the left side in atlas vertebra during routine osteology class.And Satheesha Nayak (2007) reported that in osteology demonstration classes they noticed bilateral absence of foramen transversarium in atlas vertebra.

In the present study none of the foramen transversarium in cervical vertebra was absent.

COMPARISION OF ABSENCE OF FORAMEN TRANSVERSARIUM WITH OTHER'S STUDY

Author	Prevalence
Vasudeva (2009)	1
Muralimanju et al (2011)	0
C.Taitz et al (1978)	4
Satheesha Nayak (2007)	1
Desai S.D et al (2010)	1
Present Study	0

NUMBER

Unilateral Double Foramen Transversarium:

4 (3.9%) unilateral double transverse foramen were noticed in which 1 on the left side and 3 on the right side of 102 atlas vertebrae in Paul Bundi Karau (2013) study.

Serdar Kaya et al(2011) examined 15 skeletons, among that 22 cervical vertebrae, double foramen transversarium was found in 5 (22.7%) vertebrae with 3 unilateral in right side of C4 vertebrae.

In Divya Agrawal et al(2012) study they observed 8 accessory foramen transversarium in 160 cervical vertebrae in which 4 of them had double foramen transversarium unilaterally 3 on right side 2.5%.

Archana Sharma e t al (2010) 50 sets of typical cervical vertebrae were examined, in that 16 foramen transversarium showed unilateral and bilateral double foramen details regarding the number were not mentioned.In Rekha et al (2013)

double foramen was observed in 10 cervical vertebrae.

Only 6 (1.6%) showed accessory foramen transversarium, among them 5 (1.4%) had double foramen,unilateral double foramen 4 on right side and 1 on left side. They also stated that unilateral foramen was more common than the bilateral Muralimanju et al(2011) .

Athar Maqbool et al (2014) They noticed C4 (13.33%),C5 (35.55%),C6 (51.11%) showed accessory foramen transversarium 33 on right side and 46 on the left side.

In Das srijit et al (2005) they observed presence of double foramen transversarium unilaterally and bilaterally in 132 cervical vertebrae. In the present study only 2 vertebrae showed unilateral double foramen. Pretty Rathnakar et al (2013) they reported 8 (5.7%) vertebrae with accessory foramen transversarium, 5 (3.6%) unilateral.

Chaudhari et al (2013) Double foramen transversarium was noticed in 22 vertebrae (23.15%), 14 (14.73%) with unilateral double foramen transversarium. Among unilateral 7 was found in typical cervical vertebrae and 7 in C7. They also stated that unilateral double foramen was more common than bilateral and the accessory foramen were smaller than the regular foramina.

Laxmi Chandravadiya et al (2013) reported double foramen was observed in 10 vertebrae (4.76%) among them unilateral in 8 vertebrae (3.80%).

C.Taitz et al (1978) 34 vertebrae showed double foramen transversarium with the highest frequency at (C6,C7).

In the present study only two vertebrae showed unilateral double foramen transversarium was seen in C4 vertebrae on the right side and C5 on the left side.(2%) which is closer to the study of Divya Agrawal et al (2012),Muralimanju et al (2011) -(1.6%),Das et al (2005) – (1.5%)

SHOWING PREVALENCE OF DOUBLE FORAMEN TRANSVERSARIUM IN DIFFERENT STUDY POPULATIONS

Author	Prevalence	Study Sample	Population
Taitz.C et al (1978)	7%	480	Indian
Nagar et al (1999)	8.6%	1388	Roman-Byzantine Jewish
Das et al (2005)	1.5%	132	Indian
Kaya et al (2011)	22.7%	262	Jewish
Paul Bundi Karau et al (2012)	3.9%	102	Kenyans
Rekha et al (2013)	6.54%	153	Indian
Archana Sharma et al (2010)	8%	200	Indian
Akram Abood et al (2004)	7%	33	Indian
Laxmi Chandravadiya et al (2013)	4.76%	210	Indian
Chaudhari M.L et al (2013)	23.15%	133	Indian
Divya Agrawal et al (2012)	2.5%	160	Indian
Pretty Rathnakar et al (2013)	5.7%	140	Indian
Muralimanju et al (201)	1.6%	363	Indian
Present Study	4%	100	Indian

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Bilateral Double Foramen Transversarium:

Serdar Kaya et al (2011) , among 200 cervical vertebrae, double foramen was found in 5 (22.7%) and bilateral in 2 (C5).

In Divya Agarwal et al (2012) they reported 8 accessory foramen transversarium in 160 cervical vertebrae in which 2 (2.5%) showed bilateral double foramen transversarium.Murali manju et al(2011) among 6 accessory foramen only 1 (0.3%) showed bilateral accessory foramen transversarium.

In Pretty Rathnakar et al(2013) they mentioned 2 (1.42%) bilateral foramen transversarium among 8 (5.7%) accessory foramen transversarium.

Chaudhari et al (2013) in their study they reported bilateral double foramen was found in 5 typical cervical vertebrae and 3 in C7 cervical vertebrae of 133 vertebrae.2 vertebrae (0.95%) bilateral double foramen was observed among 10 cervical vertebrae in Laxmi Chandravadiya et al (2013).

Some authors like Bai Huiying et al (2011) noticed that in 19.3% of double foramen were found mostly in C6,C4 vertebrae.Jaroslaw et al (2013) stated 3 (2.7%) accessory foramen was found in atlas vertebrae at C6 (45.6%) rarest at C3 (2.8%) .Kunihiko Kimura et al (1984) double foramen was found in 11% in C6 vertebrae.Y.I Anas et al (2009) noticed presence of accessory foramen in atlas vertebrae and also in C5,C6 but the side was not mentioned.

In the present study only 2 showed bilateral accessory foramen (2%) which is closer to the study of Divya Agrawal et al (2012),(2.5%).

Triple Foramen Transversarium:

Pretty Rathnakar et al (2013) found out in 8 (5.7%) accessory foramen only one showed triple foramen on the right side. In C.Taitz et al(1978) study triple foramen was noticed in a single vertebrae.

In the present study no vertebrae showed the presence of triple foramen transversarium.

COMPARISION OF TRIPLE FORAMEN TRANSVERSARIUM WITH OTHER'S STUDY

Author	Prevalence
Pretty Rathnakar et al (2013)	1
C.Taitz et al (1978)	1
Present study	0

Incomplete ForamenTransversarium:

In Paul Bundi Karau et al (2013) study of 102 atlas vertebrae , incomplete foramen transversarium was observed in 8 vertebrae were 6 on the right side and 2 bilateral.

Divya Agrawal et al (2012) they noticed 0.625% one case of incomplete foramen transversarium in 160 cervical vertebrae.

Rekha et al (2014) study of 153 atlas vertebrae ,double foramen was noticed in 10 and incomplete foramen was noticed in 6 .

Gupta.C et al (2013) they studied 35 dried atlas vertebra in that 8.57% with incomplete foramen transversarium.

Pretty Rathnakar et al (2014) noticed incomplete foramen transversarium on the left and Serdar Kaya et al (2011) noticed 2 vertebrae with incomplete foramen transversarium.

In the present study, only 1(typical) vertebrae showed unilateral incomplete foramen transversarium on the right side .

COMPARISION OF INCOMPLETE FORAMEN TRANSVERSARIUM WITH OTHER'S STUDY

Author	Prevalence	Study Sample
Paul Bundi Karau et al (2013)	8	102
Divya Agrawal et al (2012)	1	160
Rekha et al (2014)	6	153
Gupta .C et al (2013)	2	35
Pretty Rathnakar et al (2013)	1	140
Serdar Kaya et al (2011)	2	22
Present Study	1	100

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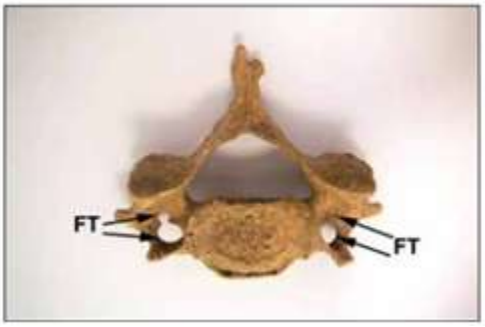
Pretty Rathnakar Study



Serdar Kaya Study

Present Study

COMPARISION OF INCOMPLETE FORAMEN TRANSVERSARIUM WITH OTHER'S STUDY.

Asymmetrical Foramen Transversarium:

Serdar Kaya et al (2011) out of 22 cervical vertebrae,asymmetrical foramen transversarium was noticed in 1 vertebrae (4.5%) and another study of Divya Agrawal et al (2012) only one asymmetrical foramen transversarium (0.625%) was observed. In the present study of 100 cervical vertebrae only C7 (1%) showed asymmetrical foramen transversarium.

COMPARISION OF ASYMMETRICAL FORAMEN TRANSVERSARIUM PRESENT STUDY WITH SERDAR KAYA STUDY

Serdar Kaya Study

Present Study

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COMPARISION OF ASYMMETRICAL FORAMEN TRANSVERSARIUM WITH OTHER'S STUDY

Author	Study Sample	Prevalence
Serdar Kaya et al (2011)	22	1
Divya Agrawal et al (2012)	160	1
Present study	100	1

Variations:

Muralimanju et al (2011) stated that no variations was observed in atlas and axis vertebrae, all the accessory foramen were observed in the lower cervical vertebrae (C6,C7).

Chaudhri M.L et al (2013) reported that the unilateral accessory foramen transversarium was more common than bilateral accessory foramina .The accessory foramina were smaller than the regular foramina, the double foramen transversarium was observed only in the lower cervical vertebrae (C5,C6,C7), each vertebrae was having atleast one foramen transversarium on either side.

Laxmi Chandravadiya et al (2013) also stated that the unilateral double foramen were more common than the bilateral, all the double foramina were observed in lower cervical vertebrae of C5,C6,C7 and also stated that the accessory foramen were smaller than the regular.

Akram Abood et al (2004) observed accessory foramen transversarium were mostly noted in the lower cervical vertebrae (C5, C6, C7) mostly in C6 (70%).The axis did not show accessory foramen.

In the present study no variations was noticed in the atlas and axis vertebrae, all the accessory foramen were noticed in the lower cervical vertebrae and also as stated by previous authors the size of the accessory foramen was smaller than the regular foramina.

Shape:

Paul Bundi Karau et al (2013) they categorized the shape of the foramina transversaria into type 1 to type 5 by using a recognized criteria. On the right side type 2 (29.4%),type 4 (40.2%) predominates and on the left side types 2 and 5 (37.2%) predominates on each side. Bilaterally type 2 foramina were commonest, comprising 68.6% of all shapes.

Rekha et al (2014) In 153 atlas vertebrae, 5 shapes were noted by using a recognized criteria, type 4 was predominant on right side and type 2 and 5 on the left side.

Athar Maqbool et al (2014) type 1 were common in 52 cervical vertebrae (16.80%).

Bai Huiying et al (2011) 710 transverse foramina were observed most of them are elliptical with type 3.

Kunihiko Kimura et al (1984) observed elliptical shape (54%) with the highest frequency and round (14%) of 50 cervical vertebrae

Among the five types of shapes of foramen transversarium in the present study theType one (round) was common in C2,C4,C7.

- Type two (elliptical with the main antero-posterior diameter)was seen in equal amount of all vertebra.
- Type three (elliptical with main transversal diameter) was noted in C3,C4,C5,C6.
- Type four(elliptical with main diameter oblique from right to left) was observed in C1,C2 and C6.
- Type five (elliptical with main diameter oblique from left to right) was noticed in equal amount in all the vertebrae except C7.

COMPARISION OF THE SHAPE OF THE FORAMEN TRANSVERSARIUM WITH OTHER'S STUDY

Author	Sample Size	Right Side	Left Side
Paul Bundi Karau et al(2013)	102	Type 2 and Type 4	Type 2 and Type 5
Rekha et al (2014)	153	Type 4	Type 2 and Type 5
Present Study	100	Type 1 and Type 3	Type 3 and Type 4

Akram Abood et al (2004) reported that C1 foramen transversarium was the largest while C7 was the smallest.

In the present study the foramen transversarium of C7 was smallest when compared to the other cervical vertebrae.

C.Taitz et al (1978) studied the types in all cervical vertebrae and found the atlas showed the highest frequency of types 4 and 5 on the right and left foramen transversarium. The lateral aperture of the axis was predominant on type 1, in contrast to the interior aperture where types 4 and

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5 predominated.The foramen transversarium of vertebrae C3,C4 and C5 showed a high frequency of type 3 (the left foramen transversarium of C5 vertebra showed an equal prevalence of type 1).C6 foramen transversarium are mainly of type 1 but the right foramen transversarium showed an equal prevalence of type. C7 foramen transversarium showed a preponderance of types 4 and 5.

COMPARISION OF TAITZ ET AL STUDY WITH THE PRESENT STUDY

	Taitz et al study		**Present study**	
Cervical Vertebrae	**Right side**	**Left side**	**Right side**	**Left side**
C1	Type 4 and Type 5	Type 5	Type 4	Type 2
C2	Type 1	Type 1	Type 1	Type 4
C3	Type 3	Type 3	Type 3	Type 3
C4	Type 3	Type 3	Type 3	Type 3
C5	Type 3	Type1 and Type 3	Type 3	Type 4
C6	Type 1 and Type 3	Type 1	Type 3	Type 1
C7	Type 5	Type 4	Type 1	Type 1,2,4

Diameters:

Paul Bundi Karau et al (2013) measured the right and left side of the transverse foramina the cross-sectional area of 36.30sq.mm and 37.20sq.mm. The mean antero-posterior diameter was 7.05mm and the mean transverse diameter was 6.50mm, the mean antero-posterior amd transverse diameter did not so much difference on the right and left side.

Akram Abood et al (2004) stated that there was no significant statistical variations in the area of foramen transversarium between the right and left side.Tabulation representing the comparision of Akram Abood's study with the present study.

Serdar Kaya et al (2011) stated that the mean diameter of foramen transversarium was 6.2mm in right side and 6.4mm in left side.

Qu Dongbin et al (1999) studied the clinical significance of axis vertebrae by measuring its diameter and stated that the diameter of both sides were similar in size with the mean diameter 6.1+/- 0.7mm.

Cagnie B.Barbara et al (2005) reported that the diameter of the transverse foramen was increased from C3 to C6, while the transverse foramina of C7 had the smallest diameter. The mean diameter of the left foramina were greater than those of the right side.

Bai Huiying et al (2001) measured the sagittal and transverse diameter of 1,456 transverse foramen in 728 cervical vertebrae with 6.0+/-1.0, 5.9+/-1.1, 5.4+/-1.2, 5.3+/1.

Rekha et al (2014) the area between the right and left transverse foramen did not show much significance. In the present study no statistical significance was noted in the area between the right and left side.

In the present study the mean antero-posterior diameter ranging from 4.053mm to 6.269mm in the right side. The mean antero-posterior diameter ranging from 5.0731mm to 6.3056mm in the left side. The mean transverse diameter ranging from 4.523mm to 6.328mm in the right side. The mean transverse diameter ranging from 5.1867mm to 6.1982mm in the left side. The mean area ranging from 14.916sq.mm to 3.020sq.mm in the right side. The mean area ranging from 22.48sq.mm to 29.64sq.mm in the left side.

COMPARISION OF AKRAM ABOOD'S STUDY WITH THE PRESENT STUDY

		Akram Abood Study		**Present Study**	
	Vertebra	**Mean left area**	**Mean right area**	**Mean right area**	**Mean left area**
1.	C1	31.8(n=29)+/-8.27	32.7(n=29)+/-9.47	28.53(n=17)+/-10.30	29.64(n=17)+/-11.18
2.	C2	24.0(n=29)+/-4.94	24.1(n=29)+/-6.69	27.30(n=18)+/-7.16	28.98(n=18)+/-6.68

3.	C3	26.70(n=29)+/-5.72	26.8(n=29)+/-4.89	23.42(n=13)+/-7.41	23.50(n=13)+/-7.99
4.	C4	25.6(n=30)+/-5.77	26.1(n=30)+/-5.11	30.20(n=24)+/9.09	28.61(n=24)+/5.65
5.	C5	26.3(n=29)+/-7.04	26.7(n=29)+/-6.46	28.94(n=14)+/-9.55	25.99(n=14)+/6.14
6.	C6	29.4(n=30)+/-10.7	29.1(n=30)+/-6.74	25.66(n=11)+/-7.45	28.09(n=11)+/7.21
7.	C7	22.3(n=27)+/-8.08	23.9(n=29)+/-9.72	14.91(n=03)+/-7.49	22.4(n=03)+/-7.35

VI. SUMMARY

- 100 cervical vertebrae of which C1=17; C2=18; C3=13; C4=24; C5=14; C6=11; C7=3 were examined in order to investigate the morphometric changes in the foramen transversarium.
- The foramen transversarium is present in the transverse process of all cervical vertebrae on both sides.
- No absence of foramen transversarium was observed.
- Two foramen transversarium one of C6 and C4 showed bilateral double foramen.
- Unilateral double foramen transversarium was seen in C4 vertebra on right side and left side was noted in C5.
- The elliptical shaped foramen was observed in most of the vertebrae.
- The foramen transversarium of C7 was small when compared to other vertebrae.

Among the five types of shapes of foramen transversarium

- Type one (round) was common in C2,C4,C7.
- Type two (elliptical with the main antero-posterior diameter)was seen in equal amount of all vertebra.
- Type three (elliptical with main transversal diameter) was noted in C3,C4,C5,C6.
- Type four(elliptical with main diameter oblique from right to left) was observed in C1,C2 and C6.
- Type five (elliptical with main diameter oblique from left to right) was noticed in equal amount in all the vertebrae except C7.
- All the accessory foramen was noted in the lower cervical vertebrae of C5 and C6.
- There was no case of triple foramen transversarium .
- Incomplete foramen was also noticed in typical verterbra
- No case of absence of foramen transversarium.
- The mean antero-posterior diameter of C1=6.2694; C2=5.8356mm; C3=5.213mm; C4=6.0104mm; C5=5.8943mm; C6=5.2245mm; C7=4.0533mm on right side.
- The mean antero-posterior diameter of left side C1=6.3056mm;C2=6.0672mm; C3=5.0731mm;C4=6.1313mm; C5=5.7721mm;C6=5.7391mm; C7=5.4567mm.
- The mean transverse diameter on the right side wasC1=5.6729mm;C2=5.889mm; C3=5.6115mm;C4=6.3288mm; C5=6.1821mm;C6=6.1721mm; C7=4.5233mm.
- The mean transverse diameter on the left side was C1=5.8024mm;C2=6.0644mm; C3=5.7562mm;C4=5.9354mm; C5=5.7193mm; C6=6.1982mm; C7=5.1867.
- The mean area on the right side was C1=28.5382sq.mm;C2=27.3072sq.mm; C3=23.4269sq.mm;C4=30.2017sq.mm; C5=28.9421sq.mm;C6=25.6491sq.mm; C7=14.9167sq.mm.
- The mean area on the left side was C1=29.6418sq.mm;C2=28.9867sq.mm; C3=23.5046sq.mm;C4=28.6188sq.mm; C5=25.9929sq.mm;C6=28.0918sq.mm; C7=22.4867sq.mm.
- The transverse diameter of foramen transversarium of all cervical vertebrae showed statistical significance.
- The antero-posterior diameter and the area of foramen transversarium of all cervical vertebrae did not show any statistical significance. No statistical significance was noted in the antero-posterior,transverse diameter and area of the right and left foramen transversarium

VII. CONCLUSION

The incidence of accessory foramen transversarium was higher in the lower cervical vertebrae. Studying the number, type and diameter of accessory foramen transversarium is of clinical significance where else the accessory foramen transversarium narrows the size of the real transverse foramen and this may be result in pressure on the vertebral artery and the sympathetic plexus surrounding it.

Similarly the narrowing of the transverse foramen may result in the formation of atheromatose plaque which may result to thrombosis emboli or just reflex spasm.

The prevalence of accessory transverse foramen provides the occurrence of duplications or fenestrations in the vertebral artery. The deformation and variation of this foramen might affect the anatomical course of vital vascular and neural structures and consequently cause some pathological conditions.

The tortuosity of the vertebral artery may be a factor on the development of variations of foramen transversarium. Variations in the number, size results in headache, migraine and fainting attacks due to compression of vertebral artery.

An absence of foramen transversarium could mean absence of vertebral artery or an anatomical variations where the artery runs along the transverse process without entering the foramen.

The multiplicity of the foramen transversarium could be related to presence of branches of vertebral artery passing in accessory foramen .It may clarify hidden pathway of branches of the vertebral artery.

In early fetal life most of the human bones including vertebrae, is formed by cartilaginous model. During bone growth new layers are added to the pre-existing surfaces. Reduced foramen area of some cervical vertebrae are mentioned in the study. This may be attributed to such periosteal growth at the foramen margins to fit around their neuro-vascular and other contents.

The anatomical knowledge of variations of foramen transversarium may be important for clinicians and radiologists for proper interpretation of X-ray and CT scans.

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