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Original Research Article

PARTIAL LATERAL BRIDGES AND SUPRATRANSVERSE FORAMEN IN HUMAN ATLAS VERTEBRAE: AN OSTEOLOGICAL STUDY IN PUNJAB

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ABSTRACT

Background: The lateral outgrowth from the superior articular facet(SAF) to the posterior root of the transverse process of the atlas forms the partial lateral bridge(PLB) and when complete forms the supratransverse foramen (STF). Presence of such bridges may predispose to vertebrobasilar insufficiency. Since there are fewer studies on the lateral bridge therefore the present study was aimed to know the incidence of lateral bridges and STF and also to know the dimensions of STF as the knowledge about such dimensions helps in interpretation of radiological findings, provide guidance for neurosurgical intervention.

Materials and methods: A total of 80 undamaged, dry human atlas vertebrae were obtained from the Department of Anatomy, Government Medical College and SGRDIMSAR, Amritsar, Punjab, India. The Partial lateral bridge(PLB) and Supratransverse Foramen(STF) were identified following the criteria used by Mitchell (1998a, 1998b). Measurements were taken of the maximum dimensions of the STF in (Supero-inferior and Medio-lateral planes) and ipsilateral Foramen Transversarium (FT) in (Ventro-dorsal and Medio-lateral planes). The cross-sectional area of STF and ipsilateral FT was calculated.

Results: Total 7 (8.75%) lateral bridges in atlas vertebrae occurred. 6 (7.5%) lateral bridges occurred in association with the posterior bridges and 1(1.25%) isolated partial lateral bridge occurred on the left side. Partial lateral bridges were found in 2 bones(2.5%) on right side and 4(2.5%)bones on left side. 1 (0.625%) Complete lateral bridges forming STF was observed on right side. Rt. Supra-Transverse Foramen Height (STFH) and Width (STFW) was found to be 5.4mm and 6.2mm. Ipsilateral Foramen Transversarium Length (FTL) and Width (FTW) was found to be 6.4mm and 5.9mm. The cross-sectional area of Rt. STF was 26.28mm^2 and the cross-sectional area of ipsilateral FT was 29.64mm^2 and ipsilateral FT area was smaller than STF.

Conclusion: The findings in the present study indicate a higher prevalence of lateral bridges on the left side. Difference in the cross sectional area of STF and ipsilateral FT may lead to compression of V.A and this compression becomes evidently symptomatic in extreme manipulations of the neck. Patients presenting with vertebrobasilar insufûciency or cervicogenic syndromes should be evaluated to explore the possibility of the presence of lateral atlas bridges as etiological factor

KEY WORDS: Lateral Bridge, Supratransverse Foramen, Foramen Transversarium, Vertebral Artery, Cross-Sectional Area

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INTRODUCTION

In the atlas vertebra, the bony outgrowths in the form of posterior bridges, arcuate foramina or the lateral bridges may cause external pressure on the vertebral artery, when it passes from the foramen transversarium(FT) of the atlas vertebra to the foramen magnum of the skull [1]. The incidence of lateral bridge is less common as compared to Posterior bridge thus having limited research in the available literature [2-6]. The lateral bridge was first described by MacAlister (1869) as a variety of the 'posterior glenoid process' termed as the 'gleno-transverse bony arch'. It is a lateral outgrowth of bone from the superior articular facet or lateral mass to the posterior root of the transverse process of the atlas [2,3]. When complete, the foramen thus formed is termed as supratransverse foramen (STF) [7,8]. The lateral bridge of the atlas rarely occurs in isolation but is thought to be secondary to or associated with the more commonly found posterior bridge [2] which is formed by an exostosis passing from the posterior surface of the lateral mass to the posterior margin of the vertebral artery groove of the atlas and when complete it is variously described as: Kimmerle variant, Arcuate Foramen, Retrocondylar vertebral artery ring, Retroarticular canal, Ponticuli [9-12].

Under normal circumstances, Vertebrobasilar ischaemia from compression of the vertebral arteries by osteophytes is uncommon[13] but presence of such bridges may predispose to vertebrobasilar insufficiency when the vertebral artery(V.A) passes from the foramen transversarium of the atlas. Physicians, neurologists and surgeons operating in this area of atlas vertebra should be aware of this variation as a cause of vertebro-basilar insufficiency [14].

During the extreme rotatory movements of head and neck or during therapeutic manipulation of the cervical spine, this pressure is severe enough leading to compression of the V.A [4]. Reducing its cross-sectional area and compromising its blood flow [6]. Since there are fewer studies of the lateral bridge of the atlas, therefore the present study was aimed to know the incidence of the lateral bridge and STF and also to know the dimensions of STF as the knowledge about such dimensions helps in interpreting compression syndromes in the neck region, interpretation of radiological findings and provide guidance for neurosurgical intervention in relation to atlas vertebrae and aid in diagnosis of craniovertebral manifestations.

MATERIALS AND METHODS

A total of 80 undamaged, dry human atlas vertebrae were obtained from the Department of Anatomy, Government Medical College and SGRDIMSAR, Amritsar, Punjab, India. All the atlas vertebrae were thoroughly cleaned and numbered from 1-80.

The Partial lateral bridge and Supratransverse Foramen (STF) were identified following the criteria used by Mitchell (1998a, 1998b) [7,8].

The atlas vertebrae were examined for the evidence of further exostosis from the lateral border of the superior articular facet(SAF) and from the posterior root of the transverse process in the region of the posterolateral border of the FT. (Figure1.) The specimens exhibiting such bony outgrowth were classified as having partial lateral bridge and complete lateral bridge or supratransverse foramen(STF) of the atlas.

Linear dimensions of complete STF and ipsilateral FT (Figure 2,3) observed during the study of 80 atlas vertebrae were measured with the help of a vernier caliper with a least count of 0.02 mm. Measurements were taken of the maximum dimensions of the (STF)Supra-Transverse Foramen (in Supero-inferior and Medio-lateral planes) and ipsilateral (FT)Foramen Transversarium (in the Ventro-dorsal and Medio-lateral planes). All the measurements were taken directly from the bones and then the data was stored on the computer sheet. Osteophytic encroachments were also observed on both the sides of the vertebrae.

Supra-Transverse Foramen Height (STFH): It is the maximum dimension of STF in supero-inferior plane, taken from floor of the lateral mass to the bony strut from superior articular Facet(SAF) & marked as SI. (Figure 2)

Supra-Transverse Foramen Width (STFW): It is the maximum dimension of ASTF in medio-lateral plane, taken from root of superior

articular Facet (SAF) to lateral part of transverse process & marked as M'L'. (Figure 3)

Foramen Transversarium Length (FTL): It is the maximum dimension in ventro-dorsal plane & marked as VD. (Figure 2)

Foramen Transversarium Width (FTW): It is the maximum dimension in medio-lateral plane & marked as ML. (Figure 3)

The cross-sectional area of the STF and ipsilateral FT was calculated using the formula for the area of an ellipse.[7] (Mitchell, 1988a). Area (A) = π x (D1 x D2 x 1/4)

Where D1= horizontal length of the foramen, D2 =vertical length of the foramen and π = 3.14

Fig. 1: Superior View of Atlas Vertebra Showing Lt. Partial LB (With Black Arrows) And Associated Lt. Complete AF And Rt. STF.

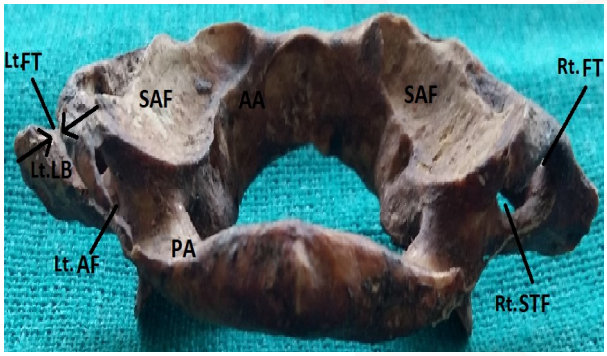


Fig. 2: Superolateral View of Atlas Vertebra Showing Super Inferior And Ventrodorsal Dimension of Rt. STF (STFH) & Rt. FT(FTL).

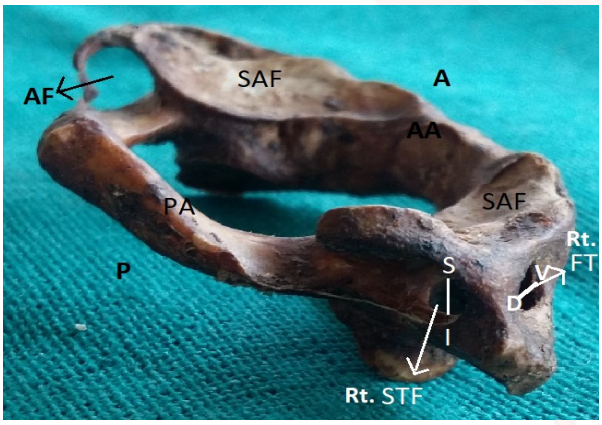
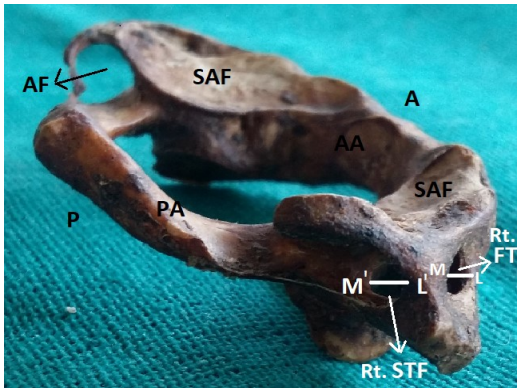


Fig. 3: Superolateral View of Atlas Vertebra Showing Mediolateral Dimensions of Rt. STF (STFW) & Rt. FT(FTW).



The Student's t-test was applied to evaluate the existence of possible difference between the mean of right and left sides of the vertebrae. Results have been considered significant when p<0.05".

RESULTS

Total 7(8.75%) lateral bridges in atlas vertebrae occurred. 6(7.5%) lateral bridges occurred in association with the posterior bridges and 1(1.25%) isolated partial lateral bridge occurred on the left side. (Table 1)

Incomplete or partial lateral bridges were found in 2 bones(2.5%) on right side and 4(2.5%)bones on left side. 1(0.625%) Complete lateral bridges forming STF was observed on right side. In terms of sides, 7(4.37%) lateral bridges out of 160 sides were observed, 2(1.25%) on right side and 4(2.5%) on left side and 1 STF(0.625%) on left side. (Table 1)

Rt. Supra-Transverse Foramen Height (STFH) and Width (STFW) was found to be 5.4mm and 6.2mm. Ipsilateral Foramen Transversarium Length (FTL) and Width (FTW) was found to be 6.4mm and 5.9mm (Table 3)

The cross-sectional area of Rt. STF was 26.28mm^2 and the cross-sectional area of ipsilateral FT was 29.64mm^2 and the area of ipsilateral FT was smaller than STF. (Table 4)

Table 1: Showing Incidence of Lateral Bridge (Partial & STF) In Present Study.

Author/Year Population	Total Sample	Type of Atlas Bridge	N	Partial Lateral Bridge(PLB) (Incomplete)			Supra-Transverse Foramen (Complete)			Total (PLB & STF)
				Right	Left	Bilateral	Right	Left	Bilateral	
Present Study 2019 Punjab, India	80	Lateral bridge (LB) Associated with Posterior Bridge(PB)	6	2(2.5%)/80 bones 2(1.25%)160 sides	3(3.75%)80 bones 3(1.87%)160 sides	-	1(1.25%)80 bones 1(0.625%)160 sides	-	-	6(7.5%)
		Isolated Lateral bridge	1	-	1(1.25%)80 bones 1(0.625%)160 sides	-	-	-	-	1(1.25%)
		Total	7	2(2.5%)/	4(5%)		1(1.25%)			7(8.75%)
				6(7.5%)						

Table 2: Comparison of Reported Incidence of Lateral Bridge With The Present findings.

	Author	Year	Population	N	Prevalence (%) Lateral Bridges
1	Le Double A F [24]	1912	-		1.80%
2	Barge JAJ [25]	1918	-		2.30%
3	Hayek H [26]	1927	-		2.90%
4	Toro I & Szepe L [27]	1942	-		3.50%
5	Radojevic & Negtovanic [28]	1963	-	280	2.50%
6	Malhotra VK et al [29]	1979	Kanpur, UP	350	0.80%
7	Taitz & Nathan [6]	1986	American white and black	672	3.80% 31% -complete (69% 9) incomplete
8	Dhall et al [20]	1993	Rohtak, Haryana	148	13.50%
9	Mitchell J [8]	1998b	South African population	1354	9.70% 12.24% (18)-complete 87.76% (129) incomplete
10	Hasan M et al [21]	2001	North Indian(UP)	350	7 (2%): 1(0.29%)Bl 2(0.57%)Rt. 4(1.14%) Lt.
11	Le Minor et al [23]	2004	French	500	1.8
12	Paraskevas & Papaziogas [22]	2005	-	176	11.36%
13	Karau Bundi et al [30]	2010	Kenyan	102	4 (3.9%) on Rt side only
14	Present Study	2019	Punjab, India	80 (160)	7(8.75%)LB-Rt.3 (3.75%) -Lt.4 (5%) 1(1.25%)-STF 6(7.5%)PLB

Table 3: Comparison of Dimensions of Supratransverse Foramen (STF) & Ipsilateral foramen Transversarium (FT) In Different Populations.

Author	Year / Population	N	Incidence or percentage	STFH (S-I) mm		STFW (M-L) mm		FTL (A-P)		FTW (S-I) mm	
				R	L	R	L	R	L	R	L
Hasan M et al [21]	2001 North Indian(UP)	350	7 (2%)	7	7	7.25	7.5	8.13	8.67	7	6.83
Karau Bundi et al [31]	2010 Kenya	102 vertebrae	4 (3.9%) on Rt side	5.05	-	5.45	-	-	-	-	-
Present Study	2019 Punjab, India	80	1(1.25%) –Rt. side	5.4	-	6.2	-	6.4	-	5.9	-

Table 4: Comparison Of Cross Sectional Area Of Supratransverse Foramen (STF) & Ipsilateral Foramen Transversarium (FT) In Different Populations.

Author	Year	Population	N	Rt. STFA (Area) mm 2	Lt. STFA (Area) mm 2	Rt. FTA (Area) mm^2	Lt. FTA (Area) mm^2
Hasan M et al [21]	2001	North Indian (UP)	350	42.85	39.88	46.68	51.14
Karau Bundi et al [31]	2010	Kenya	102	27.3	-	36.3	37.2
Present Study	2019	Punjab, India	80	26.28	-	29.64	-

DISCUSSION

An individual with a lateral bridge associated with posterior bridge of atlas may further results in increased compression of the vertebral artery [15] and compromised blood flow during extreme rotation of head and neck movements [16-18]. In the present study, Incidence of lateral bridge (8.75%) is lower than posterior bridge(16.66%) [19].

These findings support those of previous researchers that lateral bridges are less common as compared to the posterior bridges. This can be explained by loss of lateral ponticle early in development resulting in higher incidence of posterior ponticles than lateral [6-8].

As depicted from Table 1, 6(7.5%) out of 7(8.75%) lateral bridges in atlas vertebrae occurred in association with the posterior bridges and 1(1.25%) isolated partial lateral bridge occurred on the left side. None of the authors have commented upon the isolated lateral bridge in the available literature. Out of total 7(8.75%) lateral bridges, partial lateral bridges were found in 2 bones(2.5%) on right side and 4(5%) bones on left side though complete lateral bridge, forming supratransverse foramen was found in one bone(1.25%) on the right side. In terms of sides, out of 160 sides, 2(1.25%) partial lateral bridges were observed on right side, 4(2.5%) on left side and 1 STF(0.625%) on right side. It is evident that incomplete or partial lateral bridges were more commonly observed on the left side in the present study. These findings support the findings of Dhall et al (1993) [20] who also observed an increased incidence of lateral bridges on the left side and correlated with the larger superior articular facets on that side [21]. Our findings support those of Paraskevas et al (2005) that the lateral bridges are unilateral in occurrence [22] as in the present study also there was no bilateral occurrence of lateral bridge. The complete lateral bridge(STF) in this study was found on the right side, which is at variance with Le Minor et al (2004) who observed complete lateral bridges on the left side in 55.6% and right side in 33.3% [23].

In the population studied, incomplete lateral bridges were observed in 7.5% of cases. Taitz et al (1986) [6] observed a prevalence of 69%, whereas Mitchell (1998b) [8] observed a prevalence of 87.7%. The higher prevalence observed by them may be attributed to sample selection of only atlas vertebrae with complete posterior bridges.

It is revealed from comparative analysis of Table 2 that the incidence of lateral bridge in the present study was found to be more than the incidence reported by many researchers in the past. [24,25,26,27,28,29,6,21,23,30] and was found to be less than reported by Dhall et al (1993), Mitchell (1998b) and Paraskevas & Papaziogas (2005) [20] [8] [22].

The lateral bridge may form an additional foramen (STF) for the vertebral artery [7,8]. Relatively little attention has previously been paid on dimensions of the complete lateral bridges, as evidenced by paucity of data in available literature. Complete lateral bridge, forming supratransverse foramien(STF) for the vertebral artery was found in one bone(1.25%) on the right side in the present study. A glance at Table 3 reveals that in the present study the mean superoinferior diameter (STFH) of the right STF was 5.4mm and the mean mediolateral (STFW) diameter of Rt. STF was 6.2mm. For the ipsilateral foramen transversarium of the atlas vertebra the ventrodorsal diameter(FTL) and the mediolateral diameter(FTW) was found to be 6.4mm and 5.9mm respectively on the right side of atlas vertebra.

These findings of STF in the present study showed no major difference when compared with work done by Karau Bundi et al (2010) [31] in Kenyan population however there is paucity of information on the dimension of FT. It is also revealed from the comparative data of Table 3 that the findings of STF and ipsilateral FT of atlas had slightly lesser value in the present study when compared with Hasan et al (2001) [21] in UP most probably due to racial factors. However length of 7mm of lateral bridge of left side of atlas vertebra has been reported in anatomical laboratory at the University of Alabama at Birmingham [32]. These dimensions of STF and ipsilateral FT are however important, in calculating the cross-sectional area of the foramen and knowing the direction of compression of the artery. It is therefore possible that the most likely direction of compression of the vertebral artery is superoinferior, like in the retroarticular canal [31].

It can be deduced from Table 4 that the cross-sectional area of Rt. STF was 26.28mm^2 and Rt. FT was 29.64mm^2 in the present study. There was no major difference between the Rt. STFA in the present study as compared to the study done in Kenyan population by Karau Bundi et al (2010) [31] but Rt. STFA was found to be less in

the present study than work done by Hasan et al (2001) [21] in UP population. Where as ipsilateral Rt. FTA in the Kenyan population and in UP population was found to be more than in the present study.

More notable is the fact that area of the STF was smaller than the area of the ipsilateral FT on the right side of atlas vertebra. This concurs with the findings of the previous researchers [21,31]. Who also found smaller area of STF than the ipsilateral FT. The difference in the dimensions and cross sectional area of STF and ipsilateral foramina transversaria (FT) of the atlas means that the space for vertebral artery to pass through is reduced and this may compromise blood flow in the vessel [7,8]. This compression becomes evidently symptomatic in extreme rotation and manipulations of the neck [33,34].

CONCLUSION

The findings in the present study support the previous assertions that lateral bridges are less common than the posterior bridges and indicate a higher prevalence on the left side. Presence of STF means the vertebral artery and its accompanying structures must pass through an additional foramen after exiting the FT of the atlas. The observation in the present study that STF smaller than ipsilateral FT suggests that they are an important cause of VA compression. In such patients extreme rotations or manipulation of the neck may further alter the blood flow in the vertebral artery and clinically the patient may present with headache, vertigo, migraine and fainting attack. Present study also strengthens the assertion that vertebral artery compression due to lateral bridges should always be ruledout in patients presenting with cervicogenic pains.

ABBREVIATIONS

SAF- Superior Articular Facet
PLB- Partial Lateral Bridge
STF- Supra-Transverse Foramen
FT- Foramen Transversarium
STFH - Supra-Transverse Foramen Height
STFW - Supra-Transverse Foramen Width ()
FTL - Foramen Transversarium Length ()
FTW - Foramen Transversarium Width ()
Bl- Bilateral, **VA-** Vertebral artery

Conflicts of Interests: None

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