Original article

A quantitative analysis of atlas vertebrae and its abnormalities

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Abstract

Introduction: The anatomy of the atlas vertebra reveals complex, three-dimensional structures, showing extensive variability in morphology. Features of the atlas vertebra must be familiar before any spinal surgeries such as transpedicular screw fixation, transarticular screw fixation, interspinous wiring, and interlaminar clamp. So, this study was undertaken to assess the various dimensions of the first cervical vertebra and evaluate their relationship with the vertebral artery foramen, and also to decide the safe locations for different surgical methods. **Materials and Methods**: In this study, thirty five dried specimens of atlas vertebrae were examined. Various dimensions of the vertebrae were measured, using vernier calliper and any abnormalities present in it were noted down and photographed. Statistical analyses of the measurements were done. **Results**: Abnormal foramina and retroarticular canal were seen in 5.7% of specimens. Incomplete foramen transversarium were seen in 8.57% of specimens. Mean of all parameters of atlas were tabulated. Commonest shape of superior articular facet was oval in 42.8% of specimens. **Conclusion**: The knowledge of these measurements and the variations present may be of importance to orthopaedic surgeons, neurosurgeons. This information may also be helpful in avoiding and reducing complications such as vertebral artery injury, spinal cord injury during spine surgeries.

Keywords: atlas, anatomy, vertebral artery, retroarticular canal, measurements.

1 Introduction

The first cervical vertebra, namely the atlas (C1) has different anatomical features from other cervical vertebrae.

The atlas holds the globe of the skull and is devoid of body and spine. It has two lateral masses linked by an anterior and posterior arch. The posterior arch of the atlas forms about 3/5 of the atlantal ring. The superior surface of the posterior arch bears a wide groove immediately behind the lateral mass for vertebral artery, dorsal rami of first cervical nerve and venous plexus. The flange like superior border of posterior arch of the atlas gives attachment to posterior atlanto-occipital membrane. This membrane is incomplete at each lateral border to permit way for the vertebral artery and first cervical nerve. The lateral edge of the membrane sometimes ossifies, converting the groove into canal. Thus the neurovascular groove is converted into a bony ring or a bony canal, which is called as "retroarticular canal" or "retro-articular vertebral artery ring" (SYLVIA, KULKARNI and HATTI, 2007).

The third part of vertebral artery appears from foramen transversarium of the atlas, turns backwards and medially behind the lateral mass of the atlas, and lies in the neurovascular groove on posterior arch of the atlas. It then passes through the opening in anterior part of posterior atlanto-occipital membrane and enters the foramen magnum. The vertebral artery in its way from foramen transversarium to the formation of basilar artery in the cranial cavity is vulnerable to damage or distortion from external factors like bony or ligamentous structures. The retro-articular canal of the atlas vertebra (formed by posterior bridging) is one such example which may cause external pressure on vertebral artery (SYLVIA , KULKARNI and HATTI, 2007).

Superior articular facets which are present on the atlas vertebrae face superomedially and are well known for nodding movements and furthermore for the weight bearing of the head. These are also known for the reception of the condyles of the occipital bone to form an atlantooccipital joint (LALIT, PIPLANI, KULLAR et al., 2011).

Existence of atlas bridges chiefly complete and incomplete ones predisposes to vertebrobasilar inefficiency (KARAU, OGENG'O, HASSANALI et al., 2010).

Numerous surgical procedures such as interlaminar clamp, interspinous wiring, and plate and screw fixation have been currently employed to correct the instability of the atlantoaxial complex or occipitocervical junction produced by numerous traumatic and non-traumatic conditions.

Recently, transarticular and transpedicular screws fixation has been widely used in stabilizing the cervical column. Inappropriate insertion of pedicle screws can cause damages to adjoining vital structures such as the spinal cord, nerve roots, cranial nerves, and vertebral arteries (SENGÜL and KADIOGLU 2006).

So, this study was undertaken to look for the variations that can occur in the atlas vertebra and to assess the various measurements of the first cervical vertebra quantitatively and analyse their relationship with the vertebral artery foramen and to determine the safe sites for different surgical methods.

2 Materials and Methods

In this study thirty five human C1 vertebrae of unknown age and sex were examined. All samples were inspected to ensure that the vertebrae were intact and free from osteophytes or metastatic tumors before measurements were made. All parameters were measured using a vernier caliper.

Any variations present in the vertebra was also noted and photographed.

Different parameters for C1 as described in (Figures 1 and 2) were defined and measured.

Statistical Analysis was done for all the parameters.

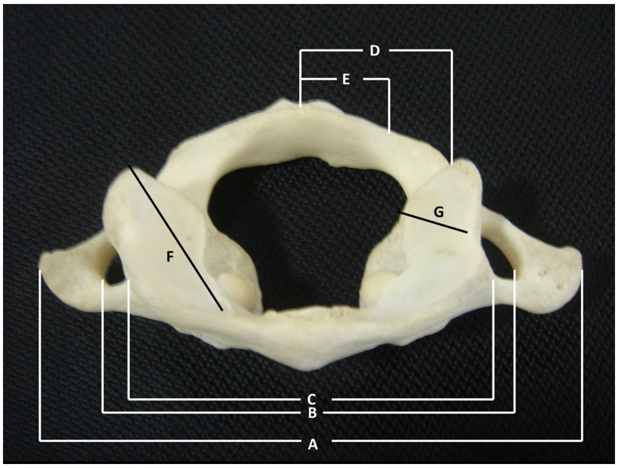

Figure 1. Description of atlas measurements taken from the superior aspect. The width of atlas was measured as the distance between both tip of transverse process (A). Outer distance of vertebral artery foramen was measured as the distance between both lateral-most edges of the transverse foramen (B).Inner distance of vertebral artery foramen was measured as the distance between both medial-most edges of the transverse foramen (C). Outer distance of vertebral artery groove was measured as the distance from midline to the lateral-most edge of the vertebral artery groove on outer cortex (D). Inner distance of vertebral artery groove was measured as the distance from midline to the medial-most edge of the vertebral artery groove on inner cortex (E). The length of superior articular facets was measured as the A-P dimension of articular surface (F). The width of superior articular facets was measured as the transverse dimension of articular surface (G).

This study has been approved by the ethical committee.

3 Result

The mean and range of all measurements done on atlas are shown in Table 1.

Abnormal foramina and retroarticular canal were seen in 5.7% of specimens each (Figure 3). Incomplete foramen transversarium were seen in 8.57% of specimens (Figure 4). Abnormal foramina on posterior arch, Incomplete posterior arch, spur on anterior arch, thick body, thin vertebral artery groove and abnormal inferior articular facet were seen in 2.85% each (Figures 3-5).

Commonest shape of superior articular facet was oval in 42.8% of specimens then it was figure of 8 shape in 31.4% of cases, kidney shape in 7.1%, bilobed in 5.2%, trilobed and irregular in 4.3% each, triangular, V- shape and leaf shape in 1.4% each (Figures 3, 4 and 6).

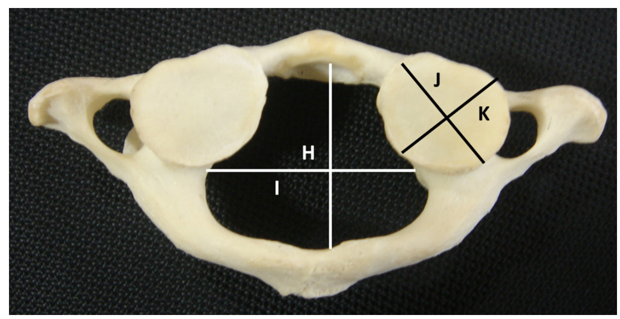

Figure 2. Description of atlas measurements taken from the inferior aspect. The maximum A-P diameter of the vertebral canal was measured along the midsagittal plane passing through the canal's widest point (H). The maximum transverse diameter of the vertebral canal was measured along the frontal plane passing through the canal's midpoint (I). The length of inferior articular facets was measured as the A-P dimension of articular surface (J). The width of inferior articular facets was measured as the transverse dimension of articular surface (K).

Table 1. Anatomic parameters of the atlas.

Letters on the illustrations	Description of parameter		Mean (cm)	Range (cm)
A	Width of Atlas Vertebra		7.25	5.7-8.7
B	Outer distance of vertebral artery foramen		5.76	5.2-6.7
C	Inner distance of vertebral artery foramen		4.52	3.8-5.6
D	Outer distance of vertebral artery groove	RIGHT	2.30	1.8-2.6
		LEFT	2.20	1.7-2.8
E	Inner distance of vertebral artery groove	RIGHT	1.28	1.1-1.6
		LEFT	1.38	1.2-1.6
F	Length of the superior articular facet	RIGHT	2.15	1.8-2.7
		LEFT	2.18	1.7-2.6
G	Width of Superior Articular Facet	RIGHT	1.18	0.7-2
		LEFT	1.15	0.8-1.7
H	The maximum A-P dimension of the vertebral canal		3.04	2.7-3.9
I	The maximum transverse dimension of the vertebral canal		2.77	2.4-3.1
J	Length of the inferior articular facet	RIGHT	1.80	1.4-2.2
		LEFT	1.79	1.3-2.9
K	Width of the inferior articular facet	RIGHT	1.46	1.1-1.7
		LEFT	1.52	1.2-2.9

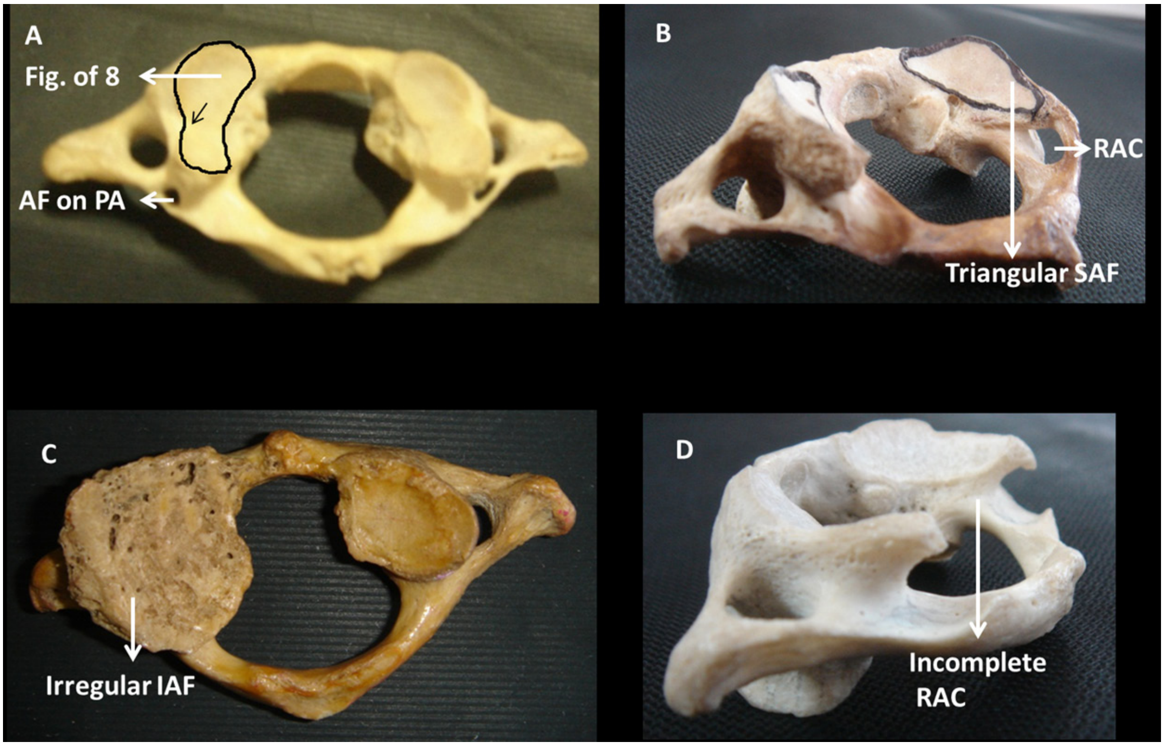

Figure 3. Photograph A) Showing abnormal foramina (AF) on posterior arch (PA) of atlas and figure of 8 shape superior articular facet (SAF). B) Showing retro articular canal (RAC) in atlas and triangular superior articular facet (SAF). C) Showing irregular inferior articular facet (IAF). D) Showing incomplete retroarticular canal (RAC).

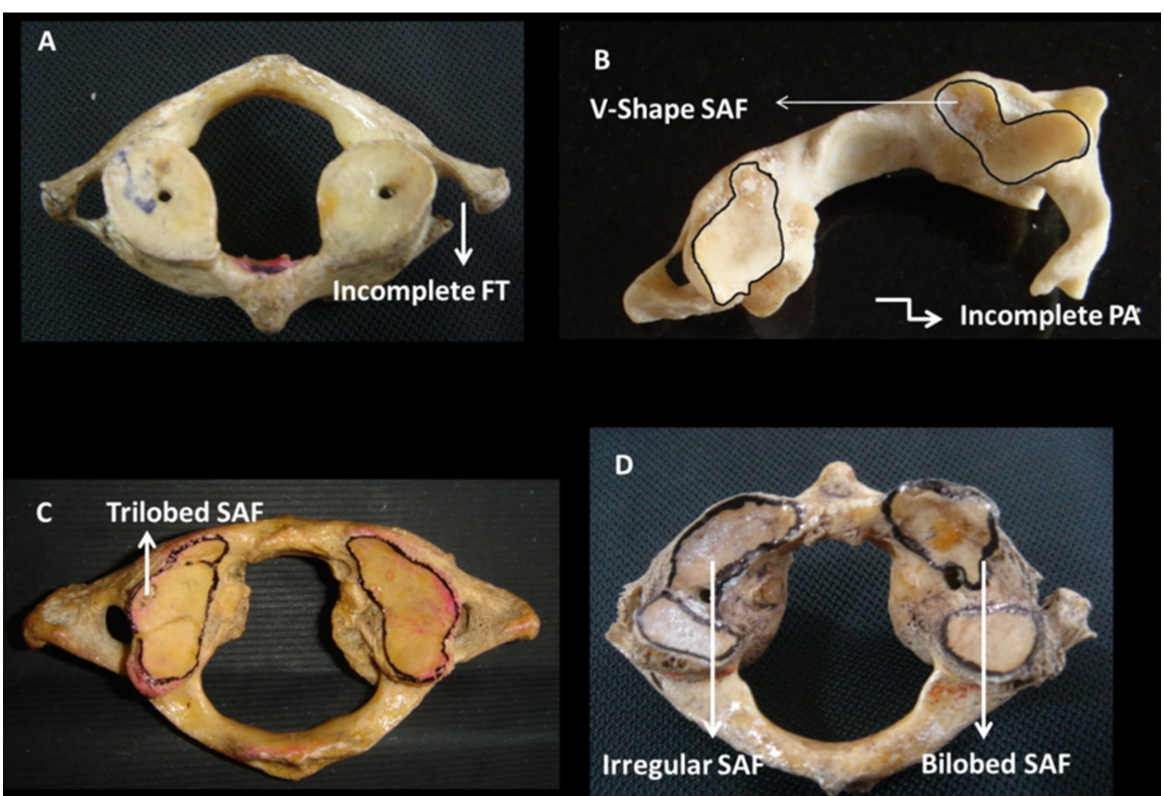

Figure 4. Photograph A) Showing incomplete foramen transversarium (FT) B) Showing v- shape superior articular facet (SAF) and incomplete posterior arch (PA) C) Showing trilobed superior articular facet (SAF) D) Showing bilobed and irregular superior articular facet (SAF).

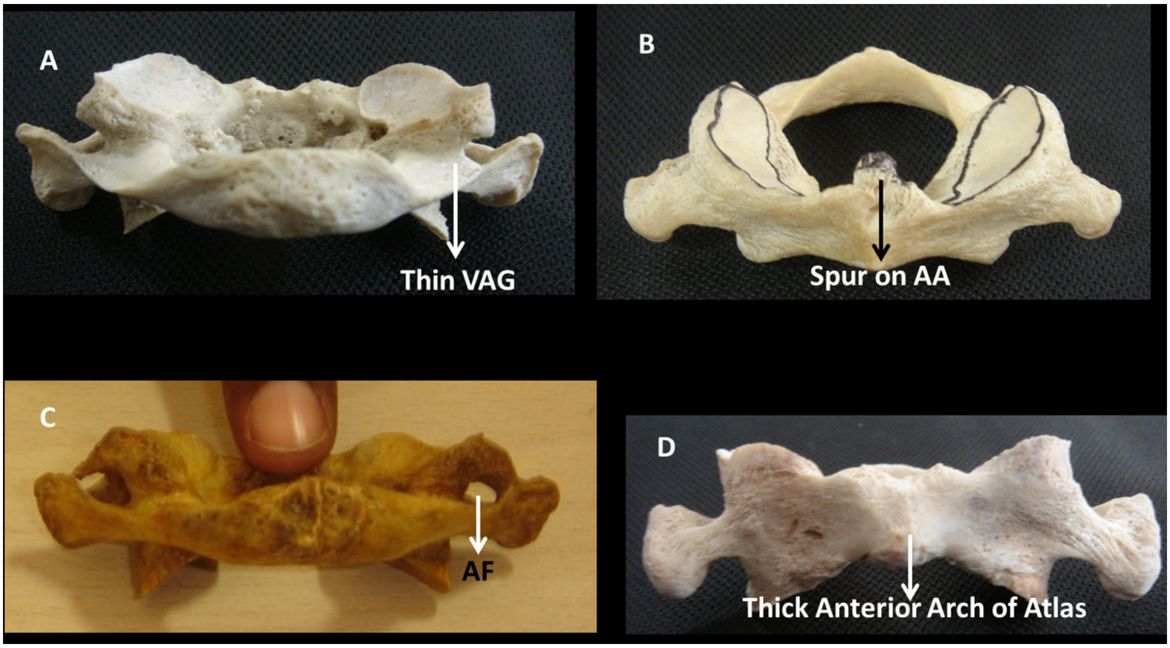

Figure 5. Photograph A) Showing thin vertebral artery groove (VAG) B) Showing spur on anterior arch (AA) C) Showing abnormal foramina (AF) D) Showing thick anterior arch of atlas.

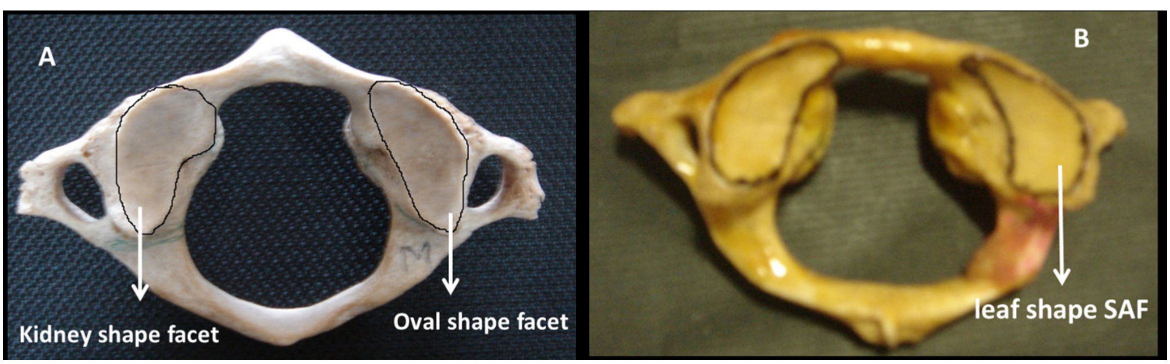

Figure 6. Photograph A) Showing kidney and oval shape superior articular facet (SAF) B) Showing leaf shape superior articular facet (SAF).

4 Discussion

Surgical procedures and instrumentation for management of unsteady cervical spine has increased in recent days. Traumatic, congenital or neoplastic conditions continue to progress, hence more information about bones and adjacent anatomy is necessary.

The measurements done in this study may be helpful in avoiding and reducing complications such as vertebral artery injury, spinal cord injury, and cranial nerve damage during a C1 stabilizing operation.

The mean width of atlas were 7.25 cm, the mean distance between both lateral-most edge of the transverse foramen were 5.76 cm, the mean distance between both medial most edge of the transverse foramen were 4.52 cm, the mean distance from midline to the lateral most edge of the vertebral artery groove were 2.30 cm, the mean distance from midline to the medial most edge of the vertebral artery groove were 1.28 cm, the maximum transverse dimension of the vertebral canal were 2.77 cm, the maximum A-P dimension of the vertebral canal were 3.04 cm while Göksin Sengül and Hakan Hadi Kadioglu found the mean width of atlas as 7.46 cm, the mean distance between both lateral-most edge of the transverse foramen as 5.95 cm, the mean distance between both medial most edge of the transverse foramen as 4.86 cm, the mean distance from midline to the lateral most edge of the vertebral artery groove as 1.60 cm, the mean distance from midline to the medial most edge of the vertebral artery groove as 1.03 cm, the maximum transverse dimension of the vertebral canal as 2.87cm, the maximum A-P dimension of the vertebral canal as 4.62 cm (SENGÜL and KADIOGLU, 2006).

The mean length of the superior articular facet on right and left side were 2.15 and 2.18 cm respectively, the width of the superior articular facet on right and left side were 1.18 and 1.15 cm respectively, the length of the inferior articular facet on right and left side were 1.80 and 1.79 cm respectively, the width of the inferior articular facet on right and left side were 1.46 and 1.52 cm respectively, while Göksin Sengül and Hakan Hadi Kadioglu results were ,the mean length of the superior articular facet on right and left side as 1.99 and 1.86 cm respectively, the width of the superior articular facet on right and left side as 0.96 and 0.98 cm, the length of the inferior articular facet on right and left side as 1.71 and 1.75 cm, the width of the inferior articular facet as 1.46 cm (SENGÜL and KADIOGLU, 2006) .

Our present study determines that all the inferior facet of atlas was circular in shape except one in which was irregular, whereas Göksin Sengül and Hakan Hadi Kadioglu eventuated the shape of inferior articular facet as circular or drop shaped (SENGÜL and KADIOGLU, 2006).

Commonest shape of superior articular facet in our study were oval in 42.8% of specimens while Göksin Sengül and Hakan Hadi Kadioglu, Lalit M et al. verdict turned out with Oval-shaped superior facets in 72%, 56.6% of specimens respectively [2,4]. We concluded with kidney shape in 7.1% and they ended with 28% & 40% of specimens respectively. In the present study we fetched figure of 8 shaped superior articular facet in 31.4% of specimens while Lalit M et al. acquired in 33.3% of specimens (LALIT, PIPLANI, KULLAR et al., 2011).

The superior articular facet of the atlas with a different shape i.e. an oval, kidney shape, figure of 8, leaf like, triangular is also an indication of the further restriction of the movements at the atlanto-occipital joint (LALIT, PIPLANI, KULLAR et al., 2011).

Division of one facet into two or a tendency towards it is indicated by the presence of a constriction or a groove or both. These grooves may give rise to pressure facets which are smooth circular impressions which are present on the medial sides of the articular surfaces. These pressure facets indicate a greater pressure at these sites during movement at the atlanto-occipital joints (LALIT, PIPLANI, KULLAR et al., 2011).

Atlas bridges, also called ponticles, are bony outgrowths occurring on the atlas vertebra over the third segment of the vertebral artery, converting its groove into a sulcus, incomplete or complete foramen (KARAU, OGENG'O, HASSANALI et al., 2010).

These bridges may indicate ossification of the posterior atlanto-occipital membrane .

The posterior bridge is found dorsal to the lateral mass on the posterior arch of the atlas and when complete, forms the retroarticular canal also called a Kimmerle's variant or arcuate foramen. Lateral bridges, are less common than the posterior and may also exist as complete foramina, called the supratransverse foramina (KARAU, OGENG'O, HASSANALI et al., 2010).

Supratransverse foramina were seen in 5.7% of specimens in our study while Taitz C and Nathan H, Karau Bundi P et al. found it in 3.8%, 3.9% of cases respectively (TAITZ and NATHAN,1986; KARAU, OGENG'O, HASSANALI et al., 2010).

In the present study retroarticular canal were seen in 5.7% of specimens while Sarita Sylvia et al., Taitz C and Nathan H, Wysocki J et al., Bilodi AK and Gupta SC, Manjunath KY found it in 1 specimen bilaterally out of 50 cases, with figures of 7.9%, 13.8%, 14.7% and 11.7% of cases respectively (SYLVIA, KULKARNI and HATTI, 2007; TAITZ and NATHAN, 1986; WYSOCKI, BUBROWSKI, REYMOND et al., 2003; BILODI and GUPTA, 2005; MANJUNATH, 2001) .

Karau Bundi P et al. distinguished retroarticular canal in 14.6% and 13.6% on the right and left sides respectively (KARAU, OGENG'O, HASSANALI et al., 2010).

Occurrence of atlas bridges especially complete and incomplete ones predispose to vertebrobasilar insufficiency and cervicogenic syndromes especially in neck movements. The observation of atlas bridge foramina proposes that they are an important cause of vertebral artery compression (SYLVIA , KULKARNI and HATTI, 2007).

Satheesha Nayak B concluded a case of abnormal foramina on posterior arch ,synonymous feature was distinguished in our study in 1 atlas vertebra (NAYAK, 2008).

Incomplete posterior arch variation is of significant importance to orthopedician, as its co-existence with fractures may result in instability in the cervico-occipital region and recognition of this variant early in life may prevent serious neurological deficits in subjects having any defects in the posterior arch, by restricting their neck movements and activities like strenuous sports (KAUSHAL, 2011).

And it is also important to consider such anatomical variation in surgery of spine.

Conflict of interest: We declare that we have no conflicts of interest. There is no financial help from the organizing reaserch committee.

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