Original Article

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SOME ANATOMICAL AND MORPHOMETRIC OBSERVAIONS IN THE TRANSVERSE FORAMINA OF THE ATLAS AMONG KENYANS

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SUMMARY
The transverse foramen, which transmits the vertebral vessels, is the result of special formation of the cervical transverse processes. It is formed by a vestigial costal element fused to the body of the originally true transverse process of the vertebra. In the atlas, where the vertebral artery exits the transverse foramen to enter the cranium, many bony variations have been described, and some are attributable to tortuosity of the vessel, as well as stress forces on the neck. The transverse foramen of the atlas has not been studied in terms of shape, morphometry, presence or absence and bilateral differences. This may shed light on the side differences in neck and vertebra-basilar pathology. A hundred and two atlases obtained from the Osteology Department of National Museums of Kenya were observed for presence, shape and variations of the transverse foramen. Accessory transverse foramina were noted, as well as missing foramina. Anteroposterior and mediolateral diameters of the foramina were taken and the area calculated. Out of the 102 vertebra studied (204 foramina transversaria), 8 incomplete foramina were observed, 6 on the right side and 2 bilateral. There were 4 double transverse foramina observed, 1 on the left and 3 on the right side. All atlases had foramina transversaria. The foramina categorized into types 1 to 5 using a recognized criterion. On the right side, type 4 was predominant (40.2%), while on the left, types 2 and 5 were predominant (39.2% each). Morphometrically, the right and left transverse foramina had mean cross-sectional area of 36.30mm^2 and 37.20mm^2 respectively. The presence of variations in the foramen transversaria is predominant on the right side. Further, the right foramina have a smaller cross-sectional area. These should be taken into account during posterior cervical approaches, as well as during evaluation of cervicogenic syndromes.
Key words: Atlas vertebrae, transverse foramina, morphometry

INTRODUCTION
Observations have been made on the variability of size, form, distribution and absence of one or more of the foramina transversaria of the spinal column (Anderson, 1968). Fewer studies have focused specifically on the functional morphology of the atlas, which is an atypical cervical vertebra (Aiello and Dean, 2002). The transverse foramen of the atlas conducts the vertebral artery as it enters the occipital triangle and subsequently the cranial cavity. In the third part of the vertebral artery, where it exits the transverse foramen of the atlas into the occipital triangle, many bony variations have been described among Kenyans (Karau et al., 2010a). These foramina have been found to have smaller cross-sectional areas compared to the ipsilateral transverse foramina (Karau et al., 2010b). However, variations in the transverse foramen of the atlas, in view of the complex anatomy of the occipital region is scantily studied.

While the cause of variations on the size and shape of foramina transversaria is not well known, it is postulated to be developmental, or related to variations in the course of the vertebral artery. Hadley, (1958) and Hyyppa, (1974) reported that tortuosity of the vertebral artery may cause bone erosion-and may be a factor in the size of the foramina. Sandikcioglu et al. (1994) correlated human atlas morphology with head and neck posture. Thus, the presence of other bony variations, as well as the prevalence of neck syndromes and injuries necessitates the study of the atlas transverse foramina. The side differences,

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morphometry and anomalous variations are important to the spinal surgeon, neurosurgeon as well as the radiologist in determining the aetiology, side predilection and vascular variations in the atlanto-occipital region.

MATERIALS AND METHODS

Dry atlas specimens obtained from the Osteology Department of National Museums of Kenya were used in this study. A total of 102 specimens were obtained, for subjects aged 25 to 75 years. Broken or incomplete atlases were excluded. The specimens were examined for presence and absence of transverse foramina. Double or triple foramina were noted for the right and left sides. The shapes of the foramina were classified into 5 categories using the criteria by Taitz et al. (1978). According to the shape and direction of the main diameter, the foramina transversaria were classified into five types (the vertebra were studied as seen from above in an A-P direction, the body of the vertebra facing the examiner): type 1 round, type 2 elliptical with main diameter (length) anteroposterior, type 3 elliptical with main diameter transversal (breadth), type 4 elliptical with main diameter oblique, from right to left, type 5 elliptical with main diameter oblique, from left to right. Mediolateral and anteroposterior diameters were taken as shown below (Figure 1). All diameters were taken on the inner aspect of the foramen and measurement done twice to reduce intra-observer error. The orientation of the main diameter was noted depending on the measurements. The cross-sectional area of the transverse foramina were calculated using the formula for an ellipse:

Area = pi ($D_1/2 \times D_2/2$)

Where D_1= horizontal length of the foramen

D_2 = vertical length of the foramen.

Pi = 3.14.

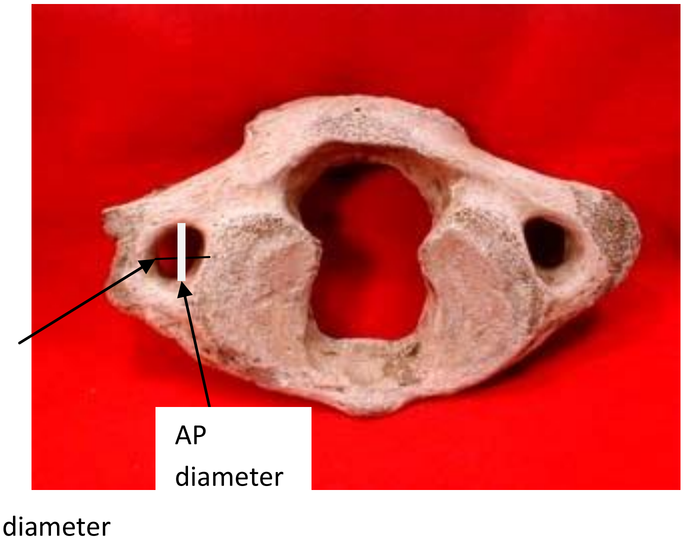

Fig.1.0 The anteroposterior and mediolateral diameters of the transverse foramen of the atlas

RESULTS

All the specimens had foramina transversaria.

Incomplete foramina: 8 incomplete foramina transversaria were observed, 6 on the right side and 2 bilateral (Fig 2). In all the cases, the transverse foramina were almost complete with a bony bridge over it leaving a small gap in the original transverse foramen. It was observed that the atlases with double foramina had either one of the foramina incomplete or other bony bridges over the posterior arch.

Double foramina: We observed 4 double transverse foramina, 1 on the left and 3 on the right side (Fig 3). In all cases, the Type 2 and 4 foramina were predominant on the right side (29.4% and 40.2%), while type 2 and 5 were commonest on the left side (39.2% and 39.2%). Bilaterally, type 2 foramina were the commonest, comprising 68.6% of all the shapes. The bilateral differences were however not statistically significant

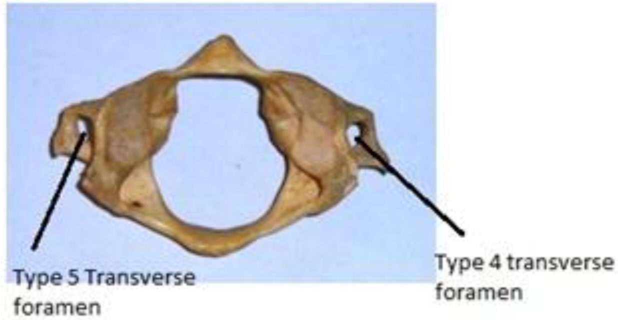

Figure 2: A right sided incomplete transverse foramen and an accessory foramen

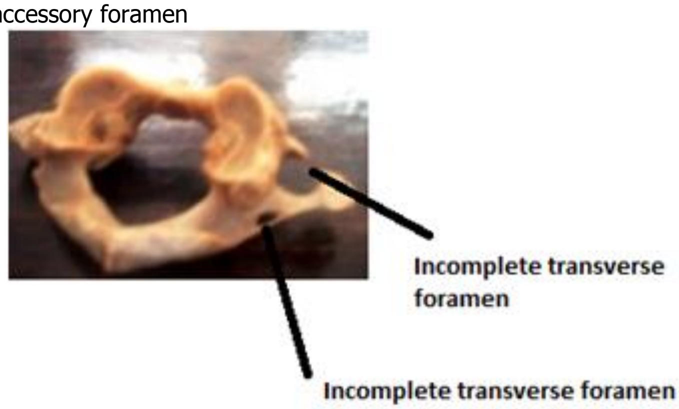

Figure 3: Type 4 transverse foramen on the right side and type 5 on the left of atlas vertebrae

Shape of the foramina transversaria

Table 1: Table showing the different categories of shape of transverse foramina and their incidence

Shape and direction of axes	Right side	Left side
Type 1 o	10 (9.8%)	12 (11.8%)
Type 2 0	30 (29.4%)	40 (39.2%)
Type 3	5 (4.9%)	2 (2%)
Type 4	41 (40.2%)	8 (7.8%)
Type 5	16 (15.7%)	40 (39.2%)

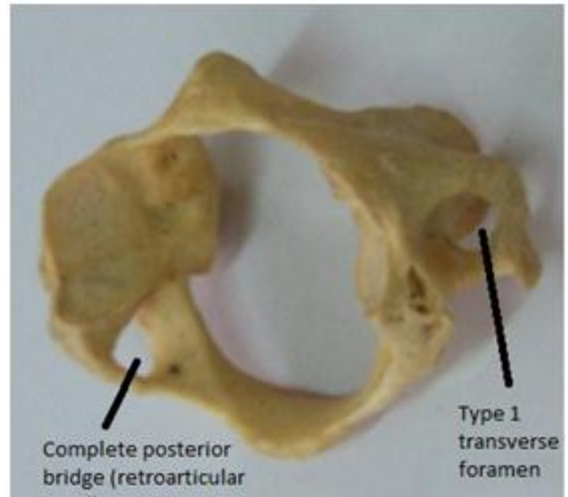

Fig 4.0 Atlas with type 1 foramina and bony bridges over the course of vertebral artery

Morphometry

The mean anteroposterior diameter was 7.05mm (7.57mm for males and 6.73mm for females). The mean mediolateral diameter or horizontal diameter was 6.50mm (6.63mm in males and 6.41mm in females). The gender difference in the anteroposterior diameter was significant at p=0.01, while that of the mediolateral diameter was insignificant at p=0.495. There was significant difference between the mediolateral and anteroposterior diameters (p=0.004). The mean area of the right transverse foramina was 36.30mm^2 while the mean area for the left was 37.20mm^2. There was no statistically significant gender or bilateral asymmetry.

DISCUSSION

The transverse foramen was observed in all the atlas specimens used in the current study. Our literature search did not reveal incidences of absent transverse foramina. However, Taitz et al., (1978) reported absence of the transverse foramen at C4 and C6 vertebrae. It has been postulated that an absent transverse foramen could mean absence of the vertebral artery, or an anatomical variation where the artery runs along the transverse process without entering the foramen (Taitz et al., 1978).

The current study has found incomplete transverse foramina in 8 cases, with a right sided predilection. In most of the cases, there was an incomplete bony bridge forming the groove for the vertebral vessels. There is scant literature on past studies on this. However, it is documented that tortuosity of the vertebral artery may cause bony erosion, or impede complete formation of the transverse foramen (Hadley, 1995; Hyyppa, 1974). Further, developmental changes could account for the variations observed. Previous authors have cited stress and posture in the erect human as factors responsible for shaping bony architecture of the neck region (Taitz et al., 1986). The occurrence of incomplete transverse foramina of the atlas should be noted by radiologists, as these can be easily confused with acquired anomalies. There is scanty literature on the reasons for right sided predilection. It is however been found that atlas bridges are more common on the right side, and the cross-sectional area of the retroarticular canal and transverse foramina is smaller on the right than left side (Karau et al., 2010a). It is therefore possible that the current finding of incomplete transverse foramina on the right side is related to erosion by the vertebral artery due to presence of atlas bridges.

Double foramina were observed in 4 cases (3.9%). In concordance with other variant features of the atlas, 3 of the double foramina were seen only on the right side. Several authors have reported double or triple foramina in the cervical vertebrae, without specific reference to the atlas. Das et al. (2005) in a cadaveric study reported an incidence of double foramina of 1.5%, while Taitz et al. (1978) reported an incidence of 7%. There was a high incidence of double foramina in the Jewish population of the Roman-Byzantine era, of 8.6% (Nagar et al., 1999). These variations are possibly linked with duplication of the vertebral artery (Kaya et al., 2011). Kowada et al. (1973) observed fenestration of the vertebral artery occurring at the atlanto-occipital joint in 24 cases and intracranially in 9 cases. However, occurrence of multiple transverse foramina may not necessarily indicate vertebral artery variations, as one may be occupied by veins and nerves. Embryologically, fusion of costal elements of the atlas may explain the formation of multiple transverse foramina. As shown in table 2, there are population and ethnic differences in the incidence of double foramina. These may be attributable to possible genetic differences, and also carrying heavy loads on the head, which has been associated with various bony bridges on the neck region.

Table 2. Showing prevalence of double transverse foramina in different study populations.

Author	Year	Prevalence of double 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
Present study	**2012**	**3.9%**	**102**	**Kenyans**

In our study, we categorized the shape of the transverse foramina according to the criteria by Taitz et al (1978). We found that majority of the foramina on the right side had type 4 shape, while the left side had types 2 and 5. This is in concordance with Taitz and workers (1978) who found type 4 on the right side in 57.6% of the vertebrae, and type 5 foramina in 48.5% on the left side. The shapes of the foramina have a correlation with the tortuosity and size of the vertebral artery. Tortuosity and size of the vertebral artery is in turn dependent

on loading forces and stresses in the neck region (Dhall et al., 1993).
The anteroposterior diameter was significantly larger in males than females on the right side. This is at variance with the findings of Hasan et al. (2001), who found that the ventrodorsal and mediolateral dimensions of the foramina transversaria did not differ significantly. Tubbs et al. (2007a) calculated the area of the transverse foramina although he did not give the dimensions he used. The vertebral artery covers about two thirds of the minimal diameter and more than half of the maximal diameter of the transverse foramen (Abd et al., 1995). In the present study, the anteroposterior diameter on the right side was significantly larger than the mediolateral diameter. This may be attributed to osteophytes that narrow the mediolateral diameter (Barbara et al., 2005). This may predispose to compression of the vertebral artery and dissection (Barbara et al., 2005).
The mean cross-sectional area of the right transverse foramina was 36.30mm^2 while that of the left was 37.20mm^2, with no gender or side differences. This is significantly higher than that measured among Iranians (Tubbs et al., 2007a) and Americans (Tubbs et al., 2007b). Epstein (1969) found the arteries of the left side are bigger than those of the right. This is in agreement with our observations that the left transverse foramina are generally larger than the right.
In conclusion, this study has revealed existence of many variations in the transverse foramina of the atlas. The area of the left transverse foramina has been found to be bigger than that of the right. This anatomy could partly explain the anatomical basis of cervicogenic pains. Further, data provided in the present study is useful in interpretation of radiographic features of the atlanto-occipital region, as well as surgical access.

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REFERENCES

1. Abd el-Bary TH, Dujovny M, Ausman JI. 1995. Microsurgical anatomy of the atlantal part of the vertebral artery. Surg. Neurol 44:392-401.

2. Aiello L, Dean C. 2002. An introduction to human evolutionary anatomy. London: Academic Press. p 210–218.

3. Anderson JE. 1968. Skeletal anomalies as genetic indicators on the skeletal biology of earlier human populations. Symposium of the Society for the Study of Human Biology, 8, 135-147.

4. Barbara C, Erik B, Elke V, Katharina DH, Dirk C. 2005. Extrinsic factors for compromised blood flow in the vertebral artery: anatomical observations of the transverse foramina from C3 to C7. Surg Radiol Anat 27: 312-316.

5. Das Srijit, Suri R, Kapur V. 2005. Double Foramen Transversaria: An Osteological Study with Clinical Implications. Int Med J 12:311-313

6. Dhall U, Chhabras S, Dhall JC. 1993. Bilateral asymmetry in bridges and superior articular facets of atlas vertebra. J.Anat Soc India 42:23-7.

7. Epstein BS. The Spine. A Radiological Text and Atlas. 1969. 3 rd ed.Philadelphia: Lea and Febiger, 24,25,65

8. Hadley LA. 1958. Tortuosity and deflection of the vertebral artery. Am J Roentgenology 80:306-312

9. Hasan M, Shukla S, Sıddiqui AMS, Singh D. 2001. Posterolateral tunnels and ponticuli in human atlas vertebrae. J Anat 199: 339-343.

10. Hyyppa SE, Laasonen EM, Halonen V. 1974. Erosion of cervical vertebrae caused by elongated and tortuous vertebralarteries. Neuroradiology 7:49-51.

11. Karau PB, Ogeng'o JA, Hassanali J, Odula PO. 2010b.Morphometry and variations of the bony ponticles of the atlas vertebrae (c1) in Kenyans. Int J Morphol 28:1019-1024.

12. Karau PB, Ogeng'o JA, Hassanali J, Odula P. 2010a. Anatomy and prevalence of atlas vertebrae bridges in a Kenyan population: An osteological study. Clin Anat 23: 649-653.

13. Kaya S, Yilmaz ND, Pusat S, Kural C, Kirik A, Izci Y. 2011. Double foramen transversarium variation in ancient Byzantine cervical vertebrae: preliminary re port of ananthropological study. Turk Neurosurg 21:534-8.

14. Kowada M, Takahashi M, Gito Y, Kishikawa T. 1973. Fenestration of the vertebral artery. Report of 2 cases demonstrated by angiography. Neuroradiology 6: 110-112.

15. Nagar Y, Taitz C, Reich R. 1999. What can we make of these fragments? Excavation at "Mamilla" Cave, Byzantine period,Jerusalem. Int J Osteoarchaeol 9:29-38.

16. Sandikcioglu M, Skov S, Solow B. 1994. Atlas morphology in relation to craniofacial morphology and head posture. Eur J Orthod 16:96–103.

17. Taitz C, Nathan H. 1986. Some observations on the posterior and lateral bridge of the atlas. Acta Anat (Basel) 127 (3):212-7.

18. Taitz C, Nathan H, Arensburg B. 1978. Anatomical observations of the foramina transversaria. J Neurol Neurosurg Psychiatr 41:170-176

19. Tubbs RS, Johnson PC, Shoja MM, Loukas M, Oakes W. J.2007b. Foramen arcuale: anatomical study and review of the literature. J. Neurosurg. Spine 6:31-4.

20. Tubbs RS, Shoja MM, Shokouhi G, Farahani RM, Loukas M, Oakes WJ. 2007a. Simultaneous lateral and posterior ponticles resulting in the formation of a vertebral artery tunnel of the atlas: case report and review of the literature. Folia Neuropathol., 45:43-6.