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ORIGINAL COMMUNICATION

Anatomy and Prevalence of Atlas Vertebrae Bridges in a Kenyan Population: An Osteological Study

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Atlas bridges are bony outgrowths over the third segment of the vertebral artery. They may exist as incipient, incomplete, or complete bridges, converting the groove into a deep sulcus, incomplete, or complete foramen respectively. These bridges and their associated foramina display bilateral and sex differences in their prevalence and type. Occurrence of these bridges may predispose to vertebrobasilar insufficiency and Barre–Lieou syndrome. The coexistence of lateral and posterior bridges as well as side predilection is not clear in either sex. Their relative occurrence may also point to some evolutionary patterns. We studied the prevalence, side predilection, coexistence, and anatomical features of atlas bridges using 102 dry atlases (49 males and 53 females) obtained from the osteology department of the National Museums of Kenya. Complete posterior bridges occurred in 14.7% and 13.7% on the right and left sides, respectively. A lateral bridge was found in 3.9% of cases on the right side only. There was positive correlation in the coexistence of the bridges. A retrotransverse foramen was found in 13% of cases. This study has found that posterior and lateral atlas bridges occur in association especially on the right side. Complete bridges were more prevalent in females and were more often present on the right side. This pattern seems to mirror the sexual predilection of vertebral artery compression syndromes. Gender roles may have an influence on the occurrence of these bridges and therefore the syndromes as well. Clin. Anat. 23:649–653, 2010.

Key words: vertebral artery; atlas bridges; foramina; Kenyan; gender

INTRODUCTION

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 (Williams et al., 1995). These bridges may indicate ossification of the posterior atlanto-occipital membrane (Romanus and Tovi, 1964), regression (Lamberty et al., 1973), or remnants of the proatlas (Taitz and Nathan, 1986). The posterior bridge is found dorsal to the lateral mass on the posterior arch of the atlas (Le Minor et al., 2004) and when complete forms the retroarticular canal (Mitchell, 1998a) or arcuate foramen (Von Torklus and Gele, 1972). Lateral bridges are less common than the posterior and may also exist as complete foramina called the supratransverse foramina (Le Minor, 2004). When complete posterior or lateral bridges occur, a foramen may exist on their roof called the retrotransverse foramen (Le Minor, 1997). This transmits the occipital nerve and small veins (Paraskevas et al., 1999). Simultaneous occurrence of posterior and lateral bridges is rare (Taitz and Nathan, 1986).

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The retroarticular canal has a prevalence of 1.14–37% (Mitchell, 1998a,b; Cakmak et al., 2005; Tubbs et al., 2007a). Incomplete posterior bridges have a prevalence of 24.43% (Paraskevas et al., 2005). Complete lateral bridges with associated foramina are reported in 1.8% (Hasan et al., 2001) and 12.24% (Mitchell, 1998b). A retrotransverse foramen has been found in 72% of the atlas vertebrae with complete posterior bridges (Paraskevas et al., 2005).

Bilateral differences have been reported in atlas bridges (Lamberty and Zivanovic, 1973; Paraskevas et al., 2005). Complete posterior bridges are classified as right-only, left-only, or bilateral (Lamberty et al., 1973). The lateral bridge has been reported to show side predilection. Some workers have found bilateral (Le Minor and Trost, 2004), whereas others have found unilateral lateral bridges (Paraskevas et al., 2005). Reports on the side predilection of incomplete posterior and lateral bridges are however scarce. The aim of this study was to study the occurrence of atlas bridges of all types in both genders in an adult Kenyan population, to explain their prevalence, co-occurrence, and side predilections. This is important in interpreting compression syndromes in the neck region.

MATERIALS AND METHODS

One hundred and two human atlas vertebrae (49 males and 53 females) aged 25–75 years obtained from the National Museums of Kenya Osteology department after ethical approval was granted. The bones mostly belong to the Central Kenya Bantu groups. Incomplete and broken atlas vertebrae and those without sex labels were excluded from this study.

The various types of bridges were studied using the definitions outlined:

Posterior bridge is a bony outgrowth over the groove for the vertebral artery located dorsal to the lateral mass on the posterior arch of the atlas (Le Minor and Trost, 2004). The posterior bridge can be complete when it forms a canal, incomplete when the bony bridge forms half or more of the ring, and incipient when less than half of the bony bridge is formed (Mitchell, 1998a). The lateral bridge is identified as a lateral bony outgrowth from the superior articular facet to the posterior root of the transverse process and when complete forms the supratransverse foramen (Lamberty and Zivanovic, 1973). The retrotransverse foramen is a small foramen located on the upper portion of the complete posterior or lateral bridge (Le Minor, 1997).

Posterior arches of 102 atlas vertebrae were examined for the presence of posterior bridges. They were classified as complete, incomplete, and a sulcus (incipient). The complete retroarticular canal was classified as right-only, left-only, and bilateral.

The lateral mass was examined for the existence of a lateral bridge, which was also classified as complete, incomplete, or absent. Bony bridges forming complete and incomplete posterior bridges were examined for the presence of the retrotransverse foramen. The data was analyzed using the Statistical Package for Social Sciences software version 15.0 for the existence of associations and the sex differences.

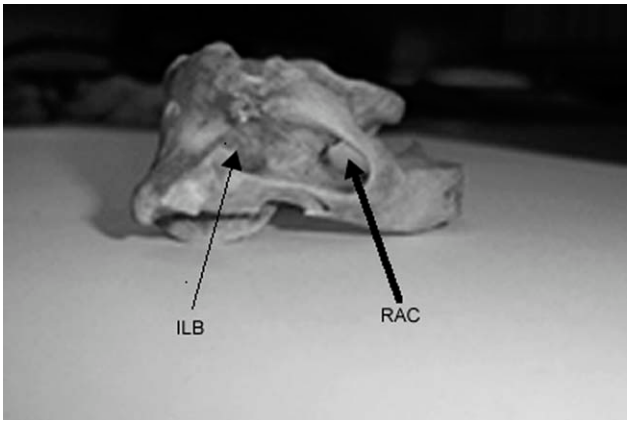

Fig. 1. A complete posterior bridge forming a retroarticular canal (RAC), and an incomplete lateral bridge (ILB).

RESULTS

The retroarticular canal was present in 29 sides (14.2%) of the cases (see Fig. 1). The right side had a slightly higher incidence of retroarticular canal than the left. It was more prevalent in females than males at 11.2 and 3%, respectively. Supratransverse foramina were found in four atlases on the right side only (an incomplete supratransverse foramen is shown in Fig. 1). The retrotransverse foramen was present in 15.7% (16 atlases) on the right and 9.8% (10 atlases) on the left side (see Fig. 2). Table 1 shows the prevalence of the various forms of atlas bridges on both sides in males and females. Generally, complete bridges were more prevalent in women and on the right side. Lateral bridges were relatively rare, with none found on the left side. In all cases on both sides, the retrotransverse foramen was complete. Although the presence of complete bridges was lower on the left than right posterior arch, these differences were not statistically signifi-

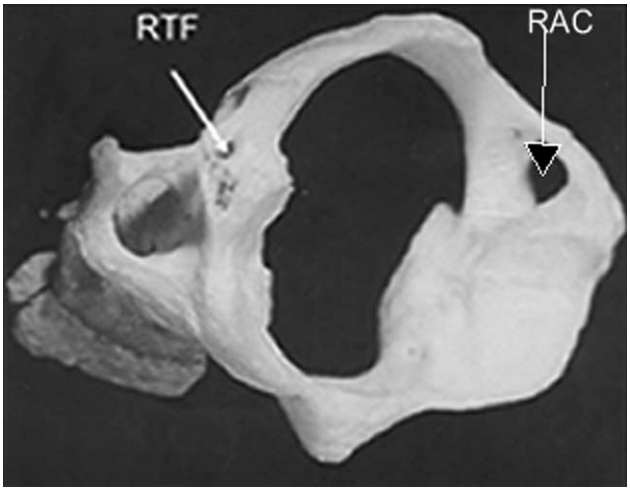

Fig. 2. A retroarticular canal (RAC) and a retrotransverse foramen (RTF) on the roof of posterior bridge.

TABLE 1. Prevalence of Posterior, Lateral Bridges, and Retrotransverse Foramina on the Right and Left-Posterior Arch of Atlas Vertebrae

Bridge type	Males	Females	Total	% prevalence
Posterior bridge				
Complete (RAC)	3 (3)	12 (11)	15 (14)	14.7% (13.7%)
Incomplete	21 (23)	19 (20)	40 (43)	39.2% (42.2%)
Sulcus	25 (23)	22 (22)	47 (45)	46.1% (44.1%)
Lateral bridge				
Complete (STF)	1 (0)	3 (0)	4 (0)	3.9% (0)
Incomplete	8 (8)	12 (11)	20 (19)	19.6% (18.6%)
Absent	40 (41)	38 (42)	78 (83)	76.5% (81.4%)
Retrotransverse foramen				
Present	4 (2)	12 (8)	16 (10)	15.7% (9.8%)
Absent	45 (47)	41 (45)	86 (92)	84.3% (90.2%)

RAC, retroarticular canal; STF, supratransverse foramen. Numbers in brackets represent figures for the left posterior arch.

cant ($P = 0.60$). Using the side classification by Lamberty et al. (1973) for the retroarticular canal, this study showed that the bilateral type had the highest prevalence with 10.7%.

There was positive correlation between the occurrence of the complete posterior and lateral bridges and the retrotransverse foramen on the right side. All complete lateral bridges occurred in atlases with complete posterior bridges. Retrotransverse foramina occurred in association with complete posterior bridges ($P = 0.044$). Specimens with complete posterior bridges therefore had high likelihood of having lateral bridges and retrotransverse foramina.

DISCUSSION

This study identified a retroarticular canal in 14.2% of the Kenyan population derived mainly from Central Kenya. This is within the range described by previous authors in different populations. Dry bone, radiographic, and dissection studies have been used in study of the complete posterior bridge, with radiographic studies giving less detail (Lamberty and Zivanovic, 1973). Table 2 shows the prevalence in various populations.

Our observations suggest there is a higher prevalence of retroarticular canal in females than males, at 11.2 and 3%, respectively. This supports the findings of Taitz et al. (1986) who found a prevalence of 9.2% in white females, compared to 8% in white males. Mitchell (1998a) reported for white and black females' prevalence of 10.4% and for white and black males 6.3 and 10%. These results are at variance with those for Paraskevas et al. (2005) who in Greeks reported a prevalence of 11.1% in males and 9.3% in females. It is possible that the higher prevalence in females compared to males is related to external mechanical factors, such as the custom of carrying heavy objects on the heads (Taitz and Nathan, 1986). This might not explain the observed higher prevalence in white females compared to males, raising the possibility of other predisposing factors apart from mechanical factors. It has been shown that estrogen accelerates ossification (Weise et al., 2001), and this could offer an addition explanation to the higher prevalence of the bridges in females. Considering that females in Kenya are more involved in such activities than males, this could offer a plausible explanation for the difference. Although the prevalence of the retroarticular canal is higher in blacks than in whites (Mitchell, 1998a),

TABLE 2. Comparison of the Prevalence of Complete, Incomplete Posterior, and Complete Lateral Bridges Among Different Study Populations

				Prevalence (%)		
Author	Sample size	Population	Material used	Complete posterior bridges	Incomplete posterior bridges	Lateral bridges
Sun, 1990	69	Chinese	Radiographic	7.4		
Mitchell, 1998a	1354	South Africans	Dry bones	9.8		
Cederberg et al., 2000	255	North Americans	Radiographic	11		
Le Minor et al., 2004	500	French	Dry bones	14.2		1.8
Erdogan et al., 2004	351	Turkish	Radiographic	5.1		
Paraskevas et al., 2005	176	Northern Greeks	Dry bones	10.2		
Tubbs et al., 2007b	60	Iranians	Dissectional	5		
Stubbs, 1992	1000	North Americans	Radiography		6	
Taitz et al., 1986	672	Americans/Indians	Dry bones		25.9	3.8
Cakmak et al., 2005	60	Turkish	Radiography		6.3	
Hasan et al., 2001	350	North Indians	Dry bones			1.8
Mitchell, 1998b	180	South Africans	Dry bones			12.24
Present study	102	Kenyans	Dry bones	14.2	40.7	3.9

there are no significant population differences in its prevalence.

A bilateral type of retroarticular canal was found in 10.7% of the cases, left-only in 5.8%, and right-only in 4.9%. This trend agrees with the findings among South Africans that the bilateral type is highest at 6.2% (Lamberty and Zivanovic, 1973). According to Ĕrdogan et al. (2004), the right-only is more prevalent. Our findings are at variance with the findings among Northern Greeks where the left-only type was observed to be the most prevalent at 5.11% and among American whites where the left-only type has the highest incidence of 7.7% (Lamberty and Zivanovic, 1973). In a study of bones from a medieval burial site, the unilateral types were more prevalent than the bilateral type (Yossi et al., 1999). According to Paraskevas et al. (2005), the side predilection of the retroarticular canal has no anatomical explanation. We suggest that external factors play a role, for instance, which side bears more loads. Dhall et al. (1993) observed atlas bridges, mostly on the left side, correlated with the larger superior articular facet on that side. They hypothesized that this asymmetry in the occurrence of bridges may be due in part to unequal weight-bearing as a result of commonly left-tilted head posture. It has also been postulated that the side with a stronger sternocleidomastoid tends to tilt the head to the opposite side.

This study has demonstrated an incomplete posterior bridge in 40.7% of cases, which is significantly higher than that observed by previous workers. The equivalent of incomplete posterior bridge in radiography is the class III type, which represents calcification of the arcuate ligaments half or more over the groove for the vertebral artery (Cederberg et al., 2000). The comparison of our findings with previous studies is shown in Table 2.

The observed higher prevalence of the incomplete posterior bridge in dry bone studies compared to radiographic is attributed to the fact that radiography gives less detail (Ĕrdogan et al., 2004). Interpopulation diversity may also be a reason for the differences observed.

This study has supported findings by Paraskevas et al. (2005) that in case of a unilateral complete posterior bridge, the contralateral groove is deeply excavated. This may be due to dilatation of the contralateral vertebral artery produced by the ipsilateral compression of the artery within the bony bridge (Paraskevas et al., 2005).

We identified a sulcus on the groove for the vertebral artery in 45.6% of the cases. Our definition of the retroarticular sulcus corresponds with class I and II descriptions on radiographs (Cederberg et al., 2000). The prevalence was found to be 82%, and this may be attributed to the study method (dry bone inspection as opposed to radiological). The other factor might be the disparity in the sample sizes.

Existence of posterior atlas bridges has been implicated in vertebrobasilar insufficiency (Gawlik et al., 1974; Wight et al., 1999), vertebral artery dissection (Cushing et al., 2001), cervicogenic syndromes, and Barre–Lieou syndrome (Cakmak et al., 2005). It has been shown that patients presenting with cervicogenic syndromes have a significantly higher prevalence of retroarticular canal than normal ones (Cakmak et al., 2005). The same workers have shown that patients with retroarticular canals have a higher headache ratio than those with incomplete bridges. Existence of a sulcus on the groove for the vertebral artery allows it to glide during neck movements, as opposed to deep grooves or complete foramina where it is compressed (Limousin et al., 1980).

We postulate that women in Kenya are more likely to suffer from these compression syndromes reflecting the higher prevalence of the posterior atlas bridges found in this study. It also strengthens the assertion that vertebral artery compression should always be ruled out in patients presenting with cervicogenic pains.

Lateral Bridge

Complete lateral bridges, forming supratransverse foramina, were found in 3.9% of the cases in this study, with all on the right side. Of the four complete lateral bridges on the right side, three were from females and one male.

The findings of this study support those of previous workers that complete lateral bridges are less common compared to the posterior bridges (Taitz and Nathan, 1986; Mitchell, 1998b). The higher prevalence observed by Mitchell may be attributed to sample selection, that is, use of only atlas vertebrae with complete posterior bridges, whereas the other studies looked at the prevalence in all atlases. Our findings support those of Paraskevas et al. (2005) that the lateral bridges are unilateral in occurrence. All the lateral bridges in this study were 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%. In the population studied, incomplete lateral bridges were observed in 19.6%. Taitz et al. (1986) observed a prevalence of 31%, whereas Mitchell (1998b) observed a prevalence of 87.7%. The high prevalence in the latter is attributed to the fact that only atlases with complete posterior bridges were used. Comparison of the prevalence of complete lateral bridges in various study populations is shown in Table 2.

Presence of complete lateral bridges means that the vertebral artery and its accompanying nerves and venous plexi must pass through an additional foramen after exiting the transverse foramen of first cervical vertebra and before entering the foramen magnum (Mitchell, 1998b). Extreme rotations of the neck may cause compression of the vertebral artery in people with lateral atlas bridges (Bolton et al., 1989). This anatomical factor should thus be considered in therapeutic manipulation of the neck (Mitchell, 1998b).

Retrotransverse Foramen

Our study has demonstrated a retrotransverse foramen in 15.7% on the right side and 9.8% on the left side. This is in agreement with Le Minor et al. (2004), who found a retrotransverse foramen in 14.2% of the atlases. It transmits the occipital nerve

and a vein connecting atlanto-occipital and atlanto-axoidian venous sinus (Paraskevas et al., 2005). Presence of a retrotransverse foramen is an indicator that the vertebral artery and accompanying structures are compressed (Paraskevas et al., 2005). Its appearance can be related to the acquisition of erect posture and attendant modifications on regional venous circulation (Le Minor and Trost, 2004).

Simultaneous Occurrence of the Atlas Bridges

A strong positive correlation in the coexistence of the two types of bridges existed. In 3.9% of the study population, the two bridges occurred together. In all cases, lateral bridges occurred in association with complete posterior bridges, whereas, in over 90% of the cases, retrotransverse foramen occurred in association with complete posterior bridges. This has been observed in previous studies: the lateral bridge in association with complete posterior bridge (Mitchell, 1998a,b; Paraskevas et al., 2005) and retrotransverse foramen in association with complete posterior bridges (Paraskevas et al., 2005). The retrotransverse foramen occurs in 72.2% of the cases in atlases with complete posterior bridge (Paraskevas et al., 2005). The simultaneous occurrence of the two bridges and retrotransverse foramen is largely unreported, although it might give a clearer picture of the population at risk of vertebral artery compression.

Atlas bridges have been reported in children aged 2 years (Buna et al., 1984), suggesting that these structures are regressive and disappearing phenomenon (Lamberty and Zivanovic, 1973). Some workers suggest that the lateral and posterior bridges are remnants of the proatlas or occipital vertebra (Taitz and Nathan, 1986). Atlas bridges are a common occurrence in other vertebrates (Lamberty and Zivanovic, 1973). The retrotransverse foramen is however uniquely found in humans and is missing in nonhuman primates despite the common occurrence of other atlas bridges.

CONCLUSION

Our results for the Central Kenya population, which resembles those reported in other populations, indicate a higher prevalence of atlas bridges on the right side and in females. The practice of carrying heavy loads on the tilted head by the Kenyan woman may partly explain this observation. Patients presenting with vertebrobasilar insufficiency, vertebral artery dissection, and cervicogenic syndromes should be evaluated to explore the possibility of the presence of atlas bridges as etiological factor.

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