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Prevalence of the Posterior Ponticulus and Arcuate Foramen in Patients presenting at Kenyatta National Hospital: A Cross-Sectional Radiological Study.

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ABSTRACT

Background: Complete posterior ponticuli and the resultant arcuate foramen may compress the third part of the vertebral artery and the sub occipital nerve as they cross the neural arch of the atlas. This may manifest with neurological deficits and also complicate surgical access to lesions in the craniovertebral junction. The prevalence of the ponticulus has been shown to have sexual dimorphism and population differences. The aim of this study was to determine its prevalence and distribution across the sexes in the study population. **Methodology**: This was a cross-sectional Survey of 116 patients (equal numbers of males and females) done between August and October 2021 at the Radiology Department of Kenyatta National Hospital after ethical approval. Far lateral sagittal Computed tomography scans of the Craniovertebral junction and 3D reconstructions were analyzed in PACS software. The presence and completeness of the posterior ponticulus and arcuate foramen was determined. Chi square test was used to analyze gender differences in their distribution. **Results:** The prevalence of complete posterior ponticuli was at 15.5%, with unilateral ponticuli more common than bilateral ones (twelve versus six). There were no significant gender differences in terms of distribution. **Conclusion**: Variations of the posterior arch of the atlas are relatively high in the studied population, necessitating a low threshold for imaging before surgery, and high index of suspicion in neurological deficits involving the posterior circulation of the brain.

Keywords: Arcuate Foramen, Posterior Ponticulus, Craniovertebral Junction

INTRODUCTION

The posterior ponticulus is a normal variant of the first cervical vertebrae (C1). It is a spicule of bone that spans over the groove for the vertebral artery on the posterior arch of the atlas. Complete spanning results in the formation of the arcuate foramen (1).

The origin of the posterior ponticulus is debatable. Some authors speculate it could be a remnant of the pro atlas, others think it is an ossified lateral part of the posterior atlanto occipital membrane or an accessory transverse foramen of C1(2,3).

The clinical significance of the ponticulus and the associated arcuate foramen results correlates with the degree of compression of the underlying neurovascular structures. These can range from cervicogenic headaches, sensory neuronal hearing loss, posterior cerebral circulation strokes, vertebral artery dissection and stroke, migraines without auras, and vertigo (4,5).

From a neurosurgical perspective, the presence of the ponticulus may complicate surgical approaches to the craniovertebral junction especially in the C1 lateral mass screw fixation technique for occipital atlantal instability(6).

The prevalence of the ponticulus has been stated to range between 1.3% to 45% for different populations from cadaveric and radiological studies (7,8).

This study aimed to ascertain the prevalence of the ponticulus and arcuate foramen within the Kenyan population.

METHODS

Study design: This was a single centre cross sectional study done at the Radiology department of Kenyatta National Hospital after approval by the Ethics and Research Committee. (Study approval number P221/04/2021). The study was carried out in August to October 2021.

Study population: The patient population was adults aged eighteen years or above, undergoing routine imaging of the craniovertebral junction. The exclusion criterion was patients with trauma, pathology or history of previous surgical intervention in the craniovertebral junction.

Methodology: CT scans of the craniovertebral junction in the sagittal format were checked for presence of the posterior ponticuli in a consecutive sampling manner. If present, the 3D reconstruction was done in the same setting to characterize the laterality and completeness of the ponticuli with the help of a radiologist. All CT scan images had been done with one machine, a 128 slice CT scanner (Neusoft Medical Systems, USA). The data obtained was then entered in Microsoft Excel version 2019 (Microsoft Corporation) for analysis.

RESULTS

Complete posterior ponticuli forming the arcuate foramen had a prevalence of 15.5%. 10 (8.6%) of them were found in female subjects while 8 (6.9%) were found in males. However, this difference was not statistically significant (p value = 0.3255). In terms of laterality, arcuate foramens were twice as likely to be unilateral than bilateral.

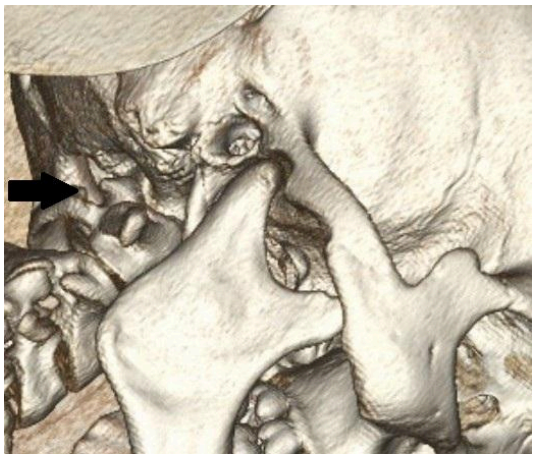
Incomplete ponticuli were more prevalent at 20.7% than complete ones at 15.5%.

Table 1: *Distribution of ponticuli in terms of completeness and laterality across males and females*

n=116	Laterality		Males	Females	Total
Incomplete Posterior Ponticulus	Bilateral		6 (46.2%)	7 (53.8%)	13
	Unilateral	Right	5 (62.5%)	3 (37.5%)	8
		Left	1 (33.3%)	2(66.7%)	3
Complete Posterior Ponticul forming Arcuate Foramen)	Bilateral		4 (66.7%)	2 (33.3)	6
	Unilateral	Right	0 (0%)	4 (100%)	4
		Left	4 (50%)	4 (50%)	8
Total Posterior Ponticuli			20 (17.2%)	22 (19%)	42 (36.2%)

Figure 1: *3D reconstruction showing complete posterior ponticuli on C1 (black arrow)*

Figure 2: *3D reconstruction showing incomplete posterior ponticuli on C1 (black arrow)*



DISCUSSION

The posterior ponticulus (little bridge) is a normal variant of the first cervical vertebrae. It is a bony spicule on the posterior arch of the atlas that spans over the groove that hosts the third segment of the vertebral artery and its venous plexus and the posterior ramus of the first cervical nerve (sub occipital nerve)(2,3,9). The foramen formed as a result is called the arcuate foramen, the retroarticular foramen, *canalis arterie vertebralis*, foramen atlandoideum or retroarticluar ring(8,10,11).

This osseous bridge of the atlas was first described in literature in the nineteenth century by Allen, Cleland and MacAlister. However, it gained mainstream prominence following the works of Kimmerle and others in the nineteen thirties to sixties (9,12,13)

Various theories regarding the origin of the ponticulus have been postulated (2,9,13,14). Ossification of the lateral edge of the posterior atlanto occipital membrane due to mechanical stresses has been advocated as one possible mechanism(6,10). However, histological studies of the ponticulus have revealed an osseous cytoarchitecture than a ligamentous one(3,9). Moreso, its presence in children has been stated to be evidence against the ossification theory which would favour more older subjects(13,14). An alternative theory suggests it could be a remnant of the pro atlas(2)

There has been a suggestion that the foramen could be a regressive structure due to its higher prevalence in lower primates compared to humans, and its decreasing prevalence in modern humans compared to their ancestors (2,9,15). Cossu et al found a higher prevalence of the ponticulus in extant mammoth species compared to their present day African elephant cousins (2). Murillo et al also found a decreasing prevalence of the ponticulus in a study involving present day humans and a 17th century skeletal collection (16).

The findings of Cossu and Murillo are contradicted by a similar study by Torrent et al who found a higher prevalence in modern day humans (13.2%) compared to a Chalcolithic archaeology collection (17).

The prevalence of arcuate foramens we got in this study is within the reported global range of 1.3% to 45.9%(7,8,18). Our prevalence of 15.6% percent is similar to a study done in South Korea by Yong Jae Cho's team. They had a prevalence of 15.5 % from a sample size of two hundred subjects (Cho, 2009). A meta-analysis done by Eliot and Tanweer on the posterior ponticulus involving 21789 subjects showed a prevalence of 17.2%, on Computed Tomography scans and cadaveric studies at 18.8%(18). Table three shows prevalence from selected published studies.

A meta-analysis that looked at the pooled prevalence of the complete ponticuli on a global scale showed a prevalence of 9.1%, with North America having a higher distribution at 11.3%, and the Asian region with the lowest prevalence at 7.5% thus hinting at geographical variation in the distribution of the osseous bridge. However, the authors were keen to note that heterogeneity of the selected studies could partly explain the results as very few studies from regions like Africa and South America were featured compared to European or Asian ones (8).

In terms of racial or tribal variations, a study carried out in South Africa didn't find any statistically significant difference in prevalence of the foramen in cadaveric specimens derived from the Sotho, Xhosa, Zulu and Caucasian populations (6).

There have been attempts to look at the prevalence of the arcuate foramen along the sexual divide. The meta-analysis by Pekela et al showed a slightly male preponderance at 10.4% to females at 7.3%. This is in contrast to other studies that show females predominance. Of note is that the distribution in terms of sex in most of these studies do not

meet statistical significance thresholds, which is similar to our findings (2,7,8,18,19)

Unilateral ponticuli and foramens tend to be more common than bilateral ones as is the case in this study (3,8,13,18). This has been postulated to be due to due to unequal mechanical stresses on the posterior arches of the atlas (10). The significance of this lies in the severity of clinical manifestations that a patient may present with, as bilateral variants may be more sinister than unilateral ones (20,21).

The presence of the posterior ponticulus has been associated with various clinical symptoms that range from neck pain, shoulder and arm pain, cervicogenic headaches, and the vertebral basilar artery insufficiency spectrum(20,22,23).

The clinical manifestations of the ponticuli depend on the degree of compression of the underlying neurovascular bundle, or the tag on the dura if tethered by fibrous or ligamentous strands to the ponticuli. These range from asymptomatic to a whole spectrum of symptoms related to vertebral artery insufficiency. Cervicogenic headaches, migraines, vertigo, sensory neuronal hearing loss, and posterior circulation strokes have been described(2,3,7,10,13,21)

From a neurosurgical perspective, the posterior ponticuli complicates surgeries designed to fix occipital atlantal instability(1,4). In the C1 lateral mass fixation screw technique as first described by Goel and Laheri, the screw is anchored through the posterior arch before being driven through the lateral mass(24). The presence of the posterior ponticulus gives the impression of a widened dorsal arch to the surgeon, thus the temptation of using screws of larger sizes. This places the vertebral artery and its venous plexus at risk of iatrogenic injury with disastrous consequences that range from exsanguination to posterior circulation stroke.

Table 3: *Prevalence of Posterior ponticuli in selected studies*.

Author	**Year**	**Population**	**N**	**Prevalence (%)**
Arslan(19)	2018	Turkey	200	14.3
Cirpan(10)	2017	Turkey	257	15.38
Chen(22)	2015	Taiwan	500	7%
Cho (25)	2009	Korea	2008	15.5
Karau(7)	2010	Kenya	108	14.2
Pękala (8)	2017	Global	55985	9.1
Rahman (28)	2022	Egypt	864	12.6%
Sanchiz(6)	2023	South Africa	120	13.3%
Sharma(27)	2010	India	858	4.3%
Vanek(26)	2015	Czech	511	14.3%
Present Study	2021	Kenya	116	15.5

LIMITATIONS

Being a monocentric study, the findings may not be generalizable to the rest of the population. Furthermore, the limited study period and sample size may not adequately capture the real distribution of the ponticuli in the general population.

CONCLUSION

The posterior ponticulus and the arcuate foramen have a relatively high prevalence in the study population. Its presence can present with neurological manifestations thus calling for neurologists and other medical practioneers to have a high index of suspicion whenever diagnostic challenges are encountered in the head and neck region. It is also imperative that surgeons be aware of the possibility of the existence of the ponticulus, and that pre operative assessment should include high resolution imaging of the Craniovertebral Junction, with multiplanar reformats and 3D reconstruction to avoid iatrogenic complications during surgery.

RECOMMENDATIONS

This study looked at the prevalence of the posterior ponticuli and arcuate foramen. Further studies can be done to correlate specific clinical manifestations in the setting of atlantal variations.

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ETHICAL STANDARDS

The study complied with the ethical requirements of the University of Nairobi and Kenyatta National Hospital Ethics and Research committee, and the Declaration of Helsinki on human subject research.

DISCLOSURES

The authors have no conflict of interest to declare.

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