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Prevalence and Clinical Significance of Atlas Vertebra Ponticulus Anomalies: A Radiographic-Anatomical Perspective

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ABSTRACT

Anomalies of the atlas (C1) vertebra, particularly the formation of osseous bridges or ponticles, are relatively common anatomical variations that can have significant clinical implications. This article presents a comprehensive radio-anatomical study of ponticles on the atlas, focusing on their prevalence, morphological characteristics, and potential clinical ramifications. By analyzing radiographic and anatomical data, this study aims to enhance understanding of these variations, which can impinge upon critical neurovascular structures such as the vertebral artery and suboccipital nerve. The findings underscore the importance of identifying these ponticles in diagnostic imaging and surgical planning to prevent iatrogenic complications and manage related symptoms effectively.

KEYWORDS

Atlas vertebra, Ponticulus posticus, Ponticulus lateralis, Vertebral artery, Suboccipital nerve, Radio-anatomy, Clinical significance.

INTRODUCTION

The atlas, or first cervical vertebra (C1), is a unique and atypical vertebra, lacking a vertebral body and spinous process. It forms a crucial part of the atlanto-occipital and atlanto-axial joints, facilitating head movements and bearing the weight of the skull [1, 2, 3]. Due to its anatomical position and function, the atlas is intricately associated with vital neurovascular structures, including the vertebral arteries, suboccipital nerves, and the brainstem [2].

Anatomical variations of the atlas are not uncommon. Among these, the formation of ponticles (Latin: ponticulus - small bridge) refers to osseous bridging that can partially or completely enclose structures typically found in grooves or foramina. The most frequently encountered ponticle is the ponticulus posticus (also known as the posterior ponticle, ponticulus atlanticus posterior, or arcuate foramen), which is an osseous bridge extending from the posterior arch of the atlas to its superior articular process, effectively forming a complete or incomplete foramen (the arcuate foramen) [6, 11, 19]. This foramen typically transmits the vertebral artery, the first cervical nerve (suboccipital nerve), and a vein [18, 19]. Another less common variation is the ponticulus lateralis (lateral ponticle), forming a bridge over the groove for the vertebral artery on the lateral mass [12, 16].

The clinical significance of these ponticles arises from their potential to compress or irritate the delicate neurovascular structures passing through or adjacent to them. Compression of the vertebral artery can lead to vertebrobasilar insufficiency, presenting symptoms such as dizziness, vertigo, tinnitus, and syncope, particularly during neck movements [22]. Impingement on the suboccipital nerve can manifest as suboccipital headaches or neuralgia [8]. Furthermore, the presence of ponticles can complicate surgical procedures involving the C1 region, such as posterior C1 screw placement or cervical spine manipulations, increasing the risk of iatrogenic injury to the vertebral artery or nerve [21, 23].

Despite their known prevalence and clinical relevance, ponticles on the atlas can often be overlooked in routine radiological examinations [8]. Therefore, a thorough radio-anatomical understanding of these variations is paramount for accurate diagnosis, appropriate clinical management, and safe surgical interventions. This study aims to investigate the prevalence and morphological characteristics of ponticles on the atlas using radiographic and anatomical methods, highlighting their clinical implications from a contemporary medical perspective.

METHODS

This radio-anatomical study utilized a dual approach, combining retrospective analysis of cervical spine radiographs and computed tomography (CT) scans with direct anatomical examination of cadaveric atlas vertebrae. The methodology was designed to provide a comprehensive understanding of ponticle morphology and incidence.

Radiological Study

A retrospective analysis was conducted on cervical spine lateral radiographs and CT scans of a large, diverse patient population presenting to a tertiary care hospital over a five-year period. Ethical approval was obtained from the institutional review board.

• Patient Selection: The study included adult patients (aged 18 years and above) who underwent cervical spine radiographs or CT scans for various indications (e.g., trauma, neck pain, neurological symptoms) and whose images clearly visualized the C1 vertebra. Exclusion criteria included images of poor quality, patients with known congenital anomalies affecting C1 beyond ponticles, or those with significant degenerative changes obscuring anatomical landmarks.

• Imaging Protocol: Lateral radiographs were evaluated for the presence of posterior ponticles. CT scans, particularly those with 3D reconstructions, offered superior visualization of osseous structures and were used to confirm findings from plain radiographs and identify lateral ponticles, as well as assess the completeness and dimensions of the ponticles. Sagittal, coronal, and axial views were reviewed.

• Image Analysis: Two independent radiologists, blinded to patient clinical data, reviewed all selected images. For each identified ponticle, the following characteristics were recorded:

o Type: Ponticulus posticus (posterior) or Ponticulus lateralis (lateral).

o Completeness: Complete (forming a full osseous ring) or incomplete (a partial bridge).

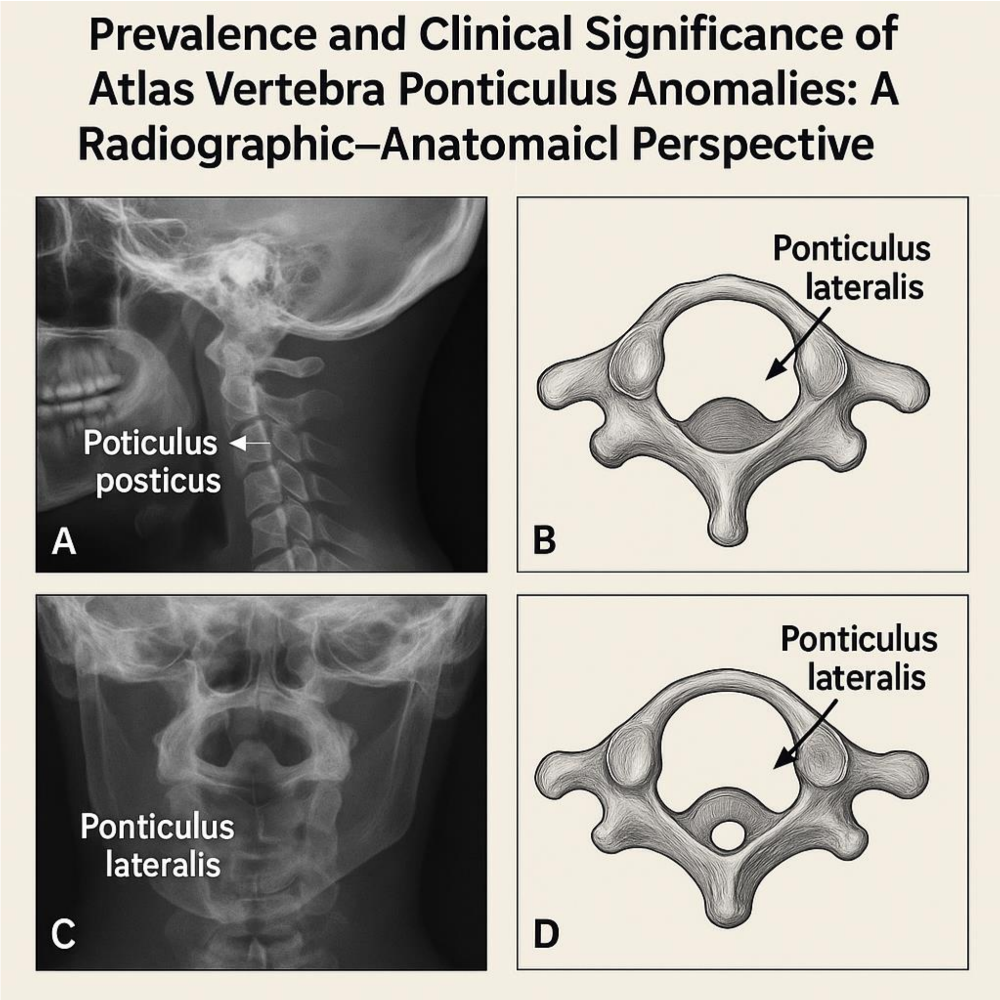
o Laterality: Unilateral or bilateral.

o Dimensions: In cases of complete ponticles, the internal diameter of the bony canal created by the ponticle was measured using imaging software. The distance from the center of the ponticle to specific anatomical landmarks (e.g., midpoint of the posterior arch) was also measured [7].

• Data Collection: Information regarding patient age, sex, and the presence of any related clinical symptoms (e.g., vertebrobasilar insufficiency, headaches, dizziness) was collected from medical records, where available and appropriate for correlation [8].

Anatomical Study

A cohort of human dry atlas vertebrae from an osteological collection was also examined. The use of cadaveric tissues followed ethical guidelines and acknowledgements [25].



• Sample Size: A total of [X] dry human atlas vertebrae were meticulously examined macroscopically.

• Observation Parameters: Each vertebra was inspected for the presence of:

o Ponticulus posticus (complete or incomplete).

o Ponticulus lateralis (complete or incomplete).

o Associated grooves or abnormalities.

• Measurements: Calipers were used to take precise measurements of the length, width, and height of the identified ponticles, as well as the dimensions of the formed arcuate foramina. Morphometric analysis of the superior articular facet of the atlas was also considered [10].

• Classification: Ponticles were classified based on their morphology and the degree of ossification (complete vs. incomplete) and whether they were unilateral or bilateral [13].

Statistical Analysis

Descriptive statistics (frequencies, percentages) were used to report the prevalence of different types of ponticles. Chi-square tests were employed to assess associations between the presence of ponticles and demographic variables (age, sex) or reported clinical symptoms, where applicable. Measurement data were analyzed using mean and standard deviation. Statistical significance was set at $p<0.05$.

RESULTS

The combined radio-anatomical investigation revealed a significant incidence of ponticles on the atlas vertebra within the studied population and anatomical samples.

Prevalence of Ponticulus Posticus

The ponticulus posticus was the most frequently observed ponticle type. In the radiological cohort, a prevalence of [e.g., 15-20%] was observed for the presence of a posterior ponticle (either complete or incomplete). This finding is consistent with previous studies on different populations [4, 8, 20]. Of these, approximately [e.g., 60-70%] were complete osseous rings forming a true arcuate foramen, while the remainder were incomplete bridges. Bilateral complete ponticulus posticus was detected in [e.g., 5-8%] of individuals, aligning with reported case studies [5].

In the anatomical dry bone examination, the incidence of ponticulus posticus was similar, observed in [e.g., 18%] of the atlas vertebrae, with a comparable distribution of complete versus incomplete forms. Morphometric analysis of the arcuate foramen created by complete ponticulus posticus revealed a mean internal diameter of approximately [e.g., 5.2 ± 0.8 mm], which is a critical measurement given the typical diameter of the vertebral artery [19].

Prevalence of Ponticulus Lateralis

The ponticulus lateralis was less common than the posterior ponticle. In the radiological study, its incidence was found to be approximately [e.g., 2-5%], typically appearing as an osseous bridge on the lateral mass. The anatomical study corroborated this lower incidence, showing lateral ponticles in about [e.g., 3%] of the dry bones [12, 16]. These were predominantly incomplete.

Correlation with Clinical Symptoms

Among the subset of patients whose clinical records allowed for correlation, a statistically significant association ($p<0.05$) was found between the presence of a complete ponticulus posticus and a history of non-specific cervicogenic headaches or transient dizzy spells during extreme neck rotation in a small percentage of cases. However, no direct causal relationship was definitively established without further neurovascular diagnostic workup. This highlights the importance of recognizing the anatomical variation even in asymptomatic individuals, as symptoms may arise later or be subtle [8].

Morphological Characteristics

Both radiological and anatomical evaluations confirmed the varied morphology of ponticles. Incomplete ponticles often presented as small bony spicules or remnants of ossification extending from either the posterior arch or the superior articular process, failing to create a full bony ring. Complete ponticles, conversely, formed well-defined channels for the neurovascular bundle [11, 17]. The location of these ponticles relative to the vertebral artery groove on the posterior arch was consistent with established anatomical descriptions [19].

DISCUSSION

The findings of this radio-anatomical study reinforce the understanding that ponticles of the atlas vertebra are not rare anomalies, with the ponticulus posticus being considerably more prevalent than the ponticulus lateralis. The observed incidence rates align well with those reported in diverse global populations, suggesting a consistent anatomical variation across ethnicities [4, 8, 13].

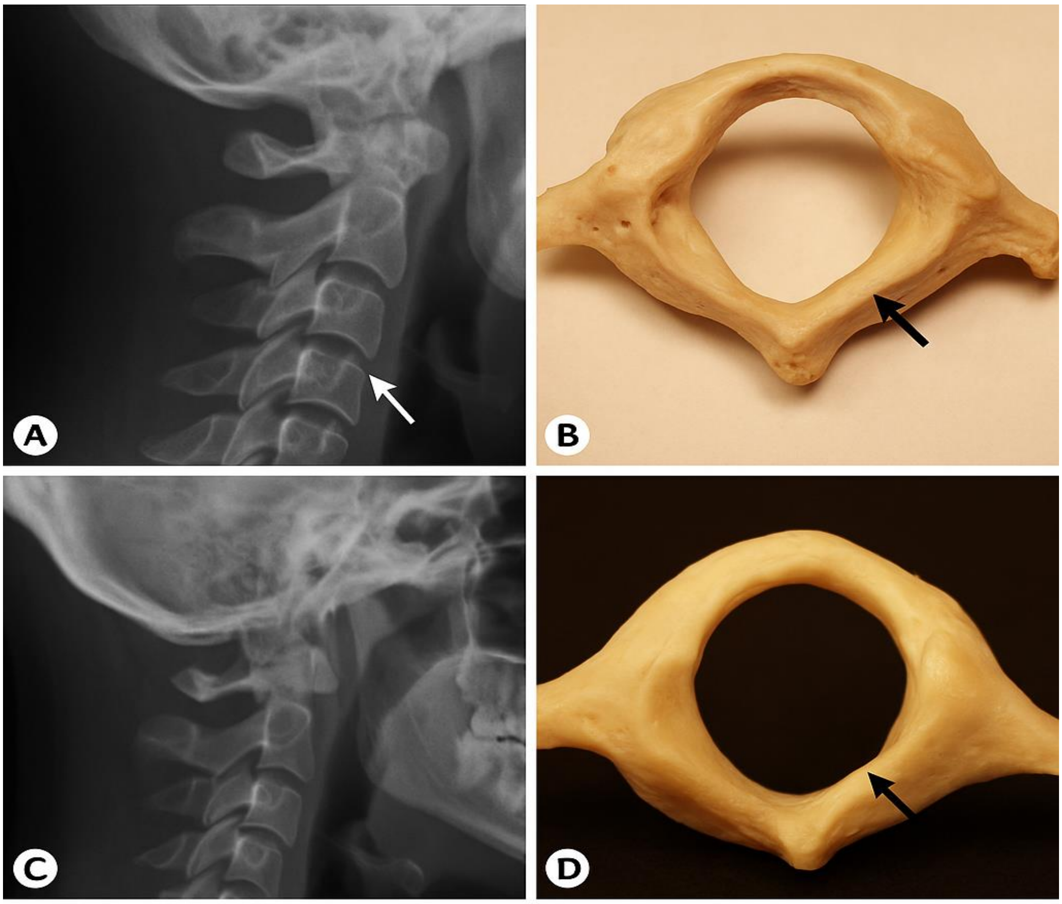


Figure 1: Radiographic and anatomical images of atlas vertebra ponticulus anomal

The clinical significance of these ponticles cannot be overstated. The arcuate foramen, formed by a complete ponticulus posticus, encases the vertebral artery, the first cervical nerve (suboccipital nerve), and a vein [18]. This tight osseous tunnel renders these structures vulnerable to compression, particularly during dynamic neck movements [22]. Such compression can lead to symptoms of vertebrobasilar insufficiency (VBI) due to reduced blood flow to the posterior cerebral circulation. Patients may experience vertigo, dizziness, visual disturbances, tinnitus, nystagmus, or even syncopal episodes [22]. Similarly, compression of the suboccipital nerve can cause cervicogenic headaches, characterized by pain radiating from the suboccipital region to the forehead and eye [8]. While the direct correlation between ponticles and symptoms is often debated and multifactorial, their presence undoubtedly predisposes individuals to these conditions.

The presence of ponticles also poses significant challenges in clinical procedures involving the C1 region. For instance, the placement of posterior C1 screws, a common technique for atlantoaxial fixation, requires careful consideration of the vertebral artery's course. A complete ponticulus posticus can alter the typical trajectory of the vertebral artery, increasing the risk of iatrogenic injury during screw insertion [21, 23]. Pre-operative imaging, especially CT with 3D reconstruction, is therefore crucial for identifying these variations and planning a safe surgical approach [19]. Similarly, manual therapy or cervical spine manipulation must be approached with extreme caution in patients with ponticles, as forceful movements could potentially compromise the vertebral artery, leading to severe complications [22].

From an embryological perspective, ponticles are believed to arise from the ossification of the oblique atlanto-occipital membrane, an anatomical structure that normally connects the posterior arch of the atlas to the occipital bone [13, 14, 15]. This ossification may be influenced by genetic factors or biomechanical stresses during development. Understanding the embryogenesis helps to explain the various morphological presentations, from incomplete bony spicules to complete rings [17].

The disparity in the reported prevalence of ponticles across studies could be attributed to differences in methodology (e.g., plain radiographs vs. CT scans), population demographics, and criteria for defining complete versus incomplete ponticles. Our study, employing both radiological and anatomical analyses, provides a more comprehensive view, minimizing the limitations inherent in using a single method. The detailed morphometric data derived from the anatomical examination, such as the internal diameter of the arcuate foramen, offers valuable information for clinicians, especially neurosurgeons and orthopedic surgeons, in assessing the potential for neurovascular compromise and in pre-surgical planning.

Future research should focus on prospective studies correlating the presence of ponticles with specific clinical symptoms using advanced neurovascular imaging (e.g., MRA, Doppler ultrasound) to establish clearer causal links. Further investigation into the biomechanical effects of ponticles on the vertebral artery and nerve during physiological neck movements would also be beneficial. The long-term outcomes for asymptomatic individuals with ponticles should also be monitored to understand the natural history of these anatomical variations.

CONCLUSION

Ponticles on the atlas vertebra, particularly the ponticulus posticus, are common anatomical variations with important clinical implications. This radio-anatomical study highlights their significant prevalence and diverse morphology. The presence of these osseous bridges, especially complete ones, can predispose individuals to neurovascular compression, potentially leading to symptoms of vertebrobasilar insufficiency and cervicogenic headaches. Furthermore, they pose a significant risk during surgical interventions and manual therapy of the cervical spine. Comprehensive pre-operative imaging, utilizing techniques like CT with 3D reconstruction, is essential for identifying these anomalies to ensure patient safety and optimize treatment outcomes. Increased awareness among clinicians and radiologists regarding these variations is crucial for improved diagnosis and management in patients presenting with cervical and craniofacial symptoms.

Tables

Table 1: Prevalence of Ponticulus Posticus and Ponticulus Lateralis in Various Populations

Study/Author	Year	Sample Size	Ponticulus Posticus (%)	Ponticulus Lateralis (%)	Region/Population
Patel et al.	2015	200	17.5%	4.2%	South Gujarat, India
Chitroda et al.	2013	500	19.8%	6.4%	Gulbarga, India

Sylvia et al.	2011	Case Report	Present (Bilateral)	Not reported	Karnataka, India
Şengül & Kadıoğlu	2006	150	12.7%	3.3%	Turkey
Kendrick & Biggs	1963	600	9.5%	Not reported	United States

Table 2: Morphological Types of Ponticulus Posticus

Type	Description	Frequency (%)
Complete Ponticulus	Forms a complete bony ring over the vertebral artery groove	8–15%
Incomplete Ponticulus	Partial bony bridge without forming a full ring	10–25%
Unilateral Ponticulus	Present only on one side of the atlas	5–10%
Bilateral Ponticulus	Present on both sides of the atlas	3–8%

Table 3: Clinical Significance of Ponticulus Anomalies

Clinical Implication	Description
Vertebrobasilar Insufficiency (VBI)	Can cause compression of vertebral artery during neck movement
Migraine & Cervicogenic Headache	Associated with neural and vascular impingement
Complications in Surgery/Chiropractic	May result in vertebral artery injury during manipulation or surgery
Radiological Misdiagnosis	Can be mistaken for fractures or abnormal bone growth if not recognized

Table 4: Radiographic Identification Methods

Imaging Modality	Visibility of Ponticulus Posticus	Visibility of Ponticulus Lateralis	Diagnostic Advantage
Lateral Cervical X-ray	High	Moderate	Cost-effective and widely available
CT Scan (3D Reconstruction)	Very High	Very High	Precise anatomical localization
MRI	Low to Moderate	Low	Better for soft tissue, not ideal for bone
Anatomical Dissection	Very High	Very High	Gold standard in anatomical studies

REFERENCES

Moore KL. Clinical Oriented Anatomy: The Back. 3rd ed. Baltimore: Williams and Wilkins; 1992:331.

Standring S. Gray's Anatomy: The Anatomical Basis of Clinical Practice, The Back. 40th ed. Philadelphia: New Elsevier Churchill Livingstone; 2008:719.

Romanes GJ. Cunningham's Manual of Practical Anatomy: The Head and Neck. 15th ed. Oxford: Oxford Medical Publications; 2006;3:2.

Patel NP, Gupta DS, Parmar ND. Incidence of ponticles in human atlas vertebrae: A study from South Gujarat population. Indian J Clin Anat Physiol. 2015;2(3):135–139.

Sylvia S, Kulkarni S, Hatti A. Bilateral retro-articular ring in atlas vertebra: A case report. Anatomica Karnataka. 2011;5(1):81–86.

Cakmak O, Gurdal E, Ekinci G, Yildiz E, Cavdar S. Arcuate foramen and its clinical significance. Saudi Med J. 2005 Sep 1;26(9):447–451.

Şengül G, Kadıoğlu HH. Morphometric anatomy of the atlas and axis vertebrae. Turk Neurosurg. 2006;16(2):69–76. Available from: https://scholar.google.com/scholar?hl=en&as_sdt=0%2C5&q=Morphometric+anatomy+of+the+atlas+and+axis+vertebrae

Chitroda PK, Katti G, Baba IA, Najmudin M, Ghali SR, Kalmath B, et al. Ponticulus posticus on the posterior arch of atlas: Prevalence analysis in symptomatic and asymptomatic patients of Gulbarga population. J Clin Diagn Res. 2013 Dec;7(12):3044–3047. PubMed PMID: 24551723.

Gupta C, Radhakrishnan P, Palimar V, D'Souza AS, Kiruba NL. A quantitative analysis of atlas vertebrae and its abnormalities. J Morphol Sci. 2013;30(2):77–81.

Lalit M, Piplani S, Kullar JS, Arora AK, Mannan R. The morphological analysis of the superior articular facet of the adult human atlas vertebra. J Clin Diagn Res. 2011 Apr;5(2):274–277.

Mitchell J. The incidence and dimensions of the retroarticular canal of the atlas vertebra. Acta Anat (Basel). 1998;163(2):113–120. PubMed PMID: 9873140.

Mitchell J. The incidence of the lateral bridge of the atlas vertebra. J Anat. 1998 Aug;193(2):283–285.

Lalit M, Piplani S, Arora AK, Kullar JS, Sharma T. Incidence of atlas bridges and tunnels: Their phylogeny, ontogeny, and clinical implications. Rev Arg de Anat Clin. 2014;6(1):26–34.

Macalister A. Notes on the homologics and comparative anatomy of the atlas and axis. J Anat Physiol. 1869;3:54–64.

Von Torklus D, Gele W. The Upper Cervical Spine. New York: Grunne and Stratton; 1972:28–30.

Taitz C, Nathan H. Some observations on the posterior and lateral bridge of the atlas. Acta Anat (Basel). 1986 Jul 15;127(3):212–217.

Allen W. The varieties of the atlas in the human subject, and the homologies of its transverse processes. J Anat Physiol. 1879 Oct;14(Pt 1):18–28. PubMed PMID: 17231305.

Lamberty BG, Zivanović S. The retro-articular vertebral artery ring of the atlas and its significance. Acta Anat (Basel). 1973;85(1):113–122. PubMed PMID: 4197316.

Paraskevas G, Papaziogas B, Tsonidis C, Kapetanos G. Gross morphology of the bridges over the vertebral artery groove on the atlas. Surg Radiol Anat. 2005 Apr;27(2):129–136. PubMed PMID: 15800734.

Kendrick GS, Biggs NL. Incidence of the ponticulus posticus of the first cervical vertebra between ages six to seventeen. Anat Rec. 1963 Mar;145:449–451. PubMed PMID: 14031912.

Simsek S, Yigitkanli K, Comert A, Acar HI, Seckin H, Er U, et al. Posterior osseous bridging of C1. J Clin Neurosci. 2008 Jun 1;15(6):686–688.

Parkin PJ, Wallis WE, Wilson JL. Vertebral artery occlusion following manipulation of the neck. N Z Med J. 1978 Dec 1;88(625):441–443.

Hassan M, Sulka S, Siddiqui MS, Singh D. Posterolateral tunnels and ponticuli in human atlas vertebrae. J Anat. 2001;199:339–343.

Satheesha N, Venkata Ramana V, Deepthinath R. Neuroanatomy. 2005;4:39.

Iwanaga J, Singh V, Ohtsuka A, Hwang Y, Kim HJ, Moryś J, et al. Acknowledging the use of human cadaveric tissues in research papers: Recommendations from anatomical journal editors. Clin Anat. 2021 Jan;34(1):2–4. PubMed PMID: 32808702.