



# Lateral and posterolateral foraminal variations of the atlas: A meta-analysis

Przemysław A. Pękala<sup>a,b</sup>, Brandon Michael Henry<sup>a,b,\*</sup>, Jakub R. Pękala<sup>a,b</sup>, Karolina Saganiak<sup>a,b</sup>,  
Dominik Tattera<sup>a,b</sup>, Jerzy A. Walocha<sup>a,b</sup>, R. Shane Tubbs<sup>c</sup>, Krzysztof A. Tomaszewski<sup>b</sup>

<sup>a</sup>International Evidence-Based Anatomy Working Group, Krakow, Poland

<sup>b</sup>Department of Anatomy, Jagiellonian University Medical College, Krakow, Poland

<sup>c</sup>Seattle Science Foundation, Seattle, WA, USA

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## ABSTRACT

The lateral (LF) and posterolateral (PLF) foramina are anatomical variants of the atlas. Both variants have been implicated in multiple neurological conditions including vertebrobasilar insufficiency, with symptoms such as dizziness, syncope, auditory and visual disturbances and paresis. The aim of this study was to conduct a systematic meta-analysis on the prevalence and anatomical characteristics of the LF and PLF. An extensive search of the major electronic databases was conducted to identify all studies that reported relevant data on the LF and PLF. No date or language restrictions were applied. Data on the prevalence, type (complete and incomplete), side, gender, and laterality of the LF and PLF, when available, were extracted and pooled into a meta-analysis. A total of 33 studies ( $n = 10,190$  subjects) were included in the quantitative analysis. The overall pooled prevalences of complete LF and PLF were 2.6% (95%CI: 2.1–3.1) and 1.2% (95%CI:0.6–2.0), respectively, while the overall pooled prevalence of the incomplete LF was 2.7% (95%CI:1.3–4.4) and the incomplete PLF was 0.7% (95%CI:0.0–1.8). When there was a complete PLF, a contralateral PLF (complete or incomplete) was found in 32.8% of cases. The geographical distribution of both variants was variable. The findings of this study provide an evidence-based foundation of anatomical knowledge of the two variants of the atlas. We recommend that physicians consider the possible role of the LF and PLF during the diagnosis of various neurological disturbances, especially in situations when all other possible explanations for the symptoms have been excluded.

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## 1. Introduction

The first cervical vertebra is atypical in form as it has no body or spinous processes. The atlas is formed by anterior and posterior arches with two lateral masses and two transverse processes. The posterior arch contains a groove on its superior surface through which the V3 segment of the vertebral artery, venous plexus, and the dorsal ramus of the first cervical spinal nerve traverse [1,2]. This is a clinically important area, as any structural or developmental aberration in it can cause circulatory and neurological deficiencies [3]. Sporadically, this groove can be converted into a posterior bridge (ponticle) – an osseous prominence that when complete is also called the foramen arcuale [4]. Another bony bridge, called the lateral foramen (LF) [Fig. 1A,B], can potentially be formed when the lateral mass extends sideways to the posterior root of the transverse process, forming an additional foramen for the vertebral artery, above and behind the transverse foramen [3,5]. A long list of names has been proposed in the literature to describe this variation, including: ponticulus lateralis, lateral ponticuli, lateral bridge of the atlas [5]. Occasionally, when the posterior and lateral foramina coexist, a structure called the posterolateral foramen (PLF) is formed [Fig. 1C,D] [4]. Each of the structures can form a complete bridge, fully encircling the traversing vessels, or can occur in an incomplete form.

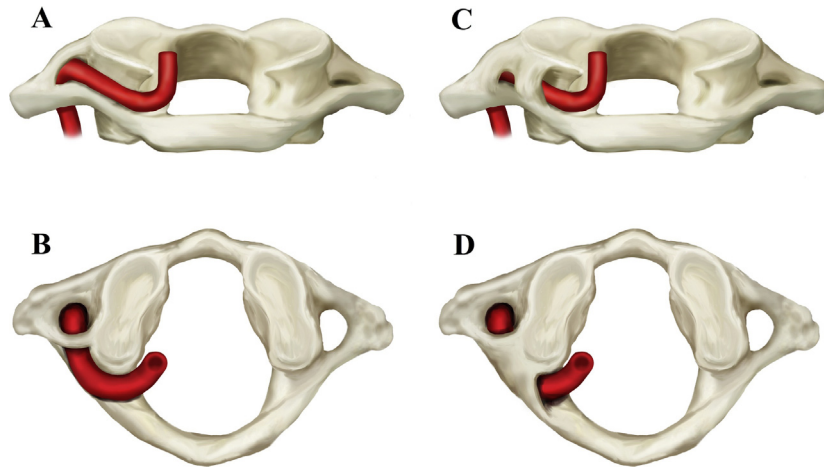
These bony outgrowths can indirectly diminish the blood flow to the affected area by the external pressure exerted on the verte-

bral artery as it passes from the transverse foramen of the atlas to the foramen magnum of the skull [6]. This can occur especially during excessive rotatory movements carried out during therapeutic manipulation of the cervical spine, or during yoga exercise or chiropractic cervical manipulation [3,7]. Strokes due to vertebral artery compromise following rotation of the cervical spine have been named bowhunter's strokes. As more than 50% of head rotation occurs at the atlantoaxial joint, the vertebral artery is more vulnerable at this level [6]. Previous studies have suggested that compression of the vertebral artery by anatomical variants of the atlas can be one mechanism leading to vertebrobasilar insufficiency [4,5,7]. This condition results from a decreased blood supply to the brain stem, cerebellum and occipital cortex and can elicit a range of symptoms including dizziness, syncope, auditory and visual disturbances, and paresis [8]. Moreover, many cases have been reported in which removal of the bony bridges of the atlas led to the elimination of vertebrobasilar insufficiency [9,10]. Irritation of the sympathetic fibers traveling along the vertebral artery, such as might occur at a PLF or LF, could lead to irritation of the sympathetic fibers traveling along the vertebral artery. Finally, surgical approaches to the craniocervical junction often necessitate removal of the posterior arch of the atlas. If the vertebral artery is tethered by such anomalous foramina as the PLF or LF, then unwanted traction might occur during surgical removal of the posterior arch.

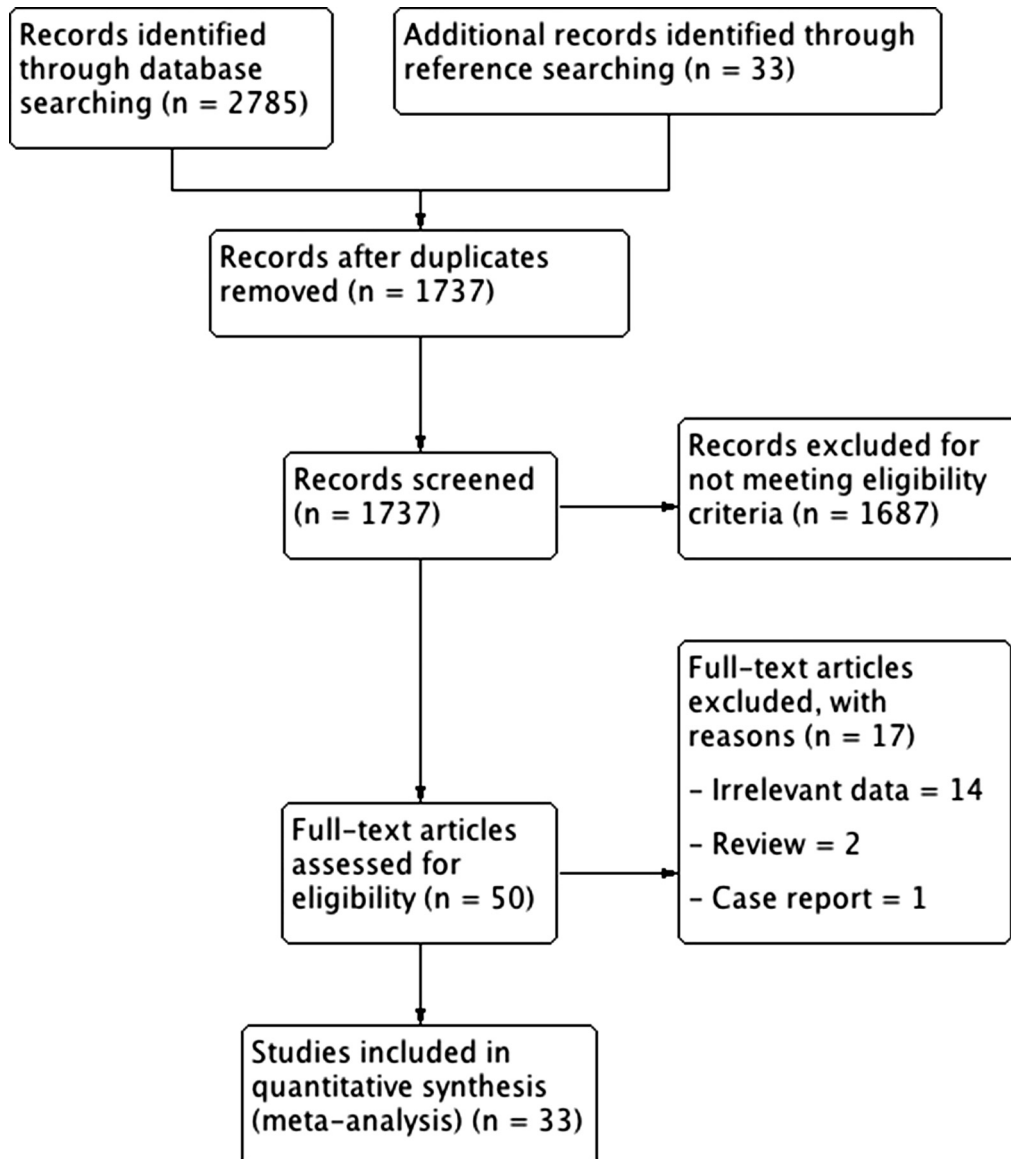
To the best of our knowledge, there has been no comprehensive analysis of the data reported from anatomical studies of these variants. The aim of our study was to perform a meta-analysis on the prevalence of these atlas variations, i.e. the LF and PLF, in order to provide an evidence-based foundation of anatomical knowledge for physicians to consider during the diagnosis of various neurological disturbances.

\* Corresponding author at: Department of Anatomy, Jagiellonian University Medical College, 12 Kopernika St, 31-034 Krakow, Poland.

E-mail address: [bmhenry55@gmail.com](mailto:bmhenry55@gmail.com) (B.M. Henry).



**Fig. 1.** Types of lateral and posterolateral foramina of the Atlas. (A) The atlas with a complete lateral foramen – posterior view. (B) The atlas with a complete lateral foramen – superior view. (C) The atlas with a complete posterolateral foramen – posterior view. (D) The atlas with a complete posterolateral foramen – superior view.



**Fig. 2.** Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) flowchart of study identification, evaluation and inclusion in the meta-analysis.

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