

SYSTEMATIC MDCT ASSESSMENT OF POSTERIOR ARCH DEFECTS OF THE ATLAS IN THE POPULATION OF NORTHEASTERN ROMANIA

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Abstract

Introduction: The atlas, or first cervical vertebra (C1), plays a crucial role in the craniovertebral junction. Unlike typical vertebrae, it lacks a vertebral body and is instead made up of two lateral masses connected by the anterior and posterior arches. Additionally, C1 is often associated with various congenital abnormalities, including defects in the posterior arch (PAD). The goal of our study is to characterize the defects of the C1 posterior arch, to identify the prevalence of this developmental anomaly in the population of north-eastern Romania and to objectivise the association with other C1 malformations. **Materials and Methods:** Our retrospective study encompassed 715 patients who underwent cranio-cerebral CT scans between May 2022 and August 2024. Two experienced radiologists reviewed the DICOM files. **Results:** In our cohort, we identified posterior arch defects (PADs) of the atlas in 1.95% of patients (14 out of 715). Our analysis revealed no significant differences related to sex, with the cases being equally distributed between seven women and seven men. The age group distribution was also similar, further supporting the notion that PADs are incidental findings. Although 4 out of 14 cases of PADs were associated with other malformations, statistical significance was not achieved. **Conclusions:** Posterior arch defects of the atlas are relatively common congenital malformations in the population of north-eastern Romania. The most frequent morphological form is median dehiscence, which aligns with Type A. These defects do not show a sex or age predominance, consistent with their classification as congenital malformations.

Keywords: atlas, posterior arch defects, cervical vertebra, dehiscence, craniovertebral junction, congenital malformations, vertebral anomalies

1. Introduction

The craniovertebral junction has been a region of interest since ancient times. Within it, the first cervical vertebra (C1) stands out with a fundamental functional role. It consists, on the one hand, in supporting the cephalic extremity and, on the other hand, in performing rotational movements along the axis. Initially C1 was called astragalus, similar to the bone that

supports the tibial pillar. The Italian anatomist Jacopo Berengario di Carpi used the name Atlas in 1522. Although the reason for the name was not mentioned, it is considered similar to the titan Atlas who supports the globe of heaven on his shoulders, C1 supports the human cephalic extremity. Another metaphorical hypothesis consists in the idea that mythological warriors like Atlas are

between earth and heaven [1].

From a morphological point of view, atlas is an atypical vertebra. It consists of two lateral masses joined by an anterior arch and respectively by a posterior arch. The lateral masses articulate cranially with the occipital condyles and caudally with the upper articular processes of the axis. From the lateral faces, the transverse processes come off, which have similar characters to those of the other cervical vertebrae. On the medial aspects, there are roughnesses for the insertion of the transverse ligament. The anterior arch is shorter and presents on its ventral face the anterior tubercle and on the dorsal face an articular surface for the axis tooth. The posterior arch is longer than the anterior one and presents the posterior tubercle on its dorsal side. The ventral face is smooth and corresponds to the vertebral hole. On the upper edge, it shows two furrows through which the vertebral arteries pass on their way to the occipital foramen [2-5].

The first cervical vertebra is the seat of many congenital malformations. Some of them are accompanied by clinical manifestations, while others are not. The latter are occasionally detected following imaging investigations [3]. Posterior arch defects of the atlas (PAD) is a type of *spina bifida occulta*. It is not accompanied by changes in the paravertebral muscles or defective parts of the central nervous system [6]. Instead, it can be associated with genetic syndromes such as Down syndrome, with skeletal dysplasia or with Conradi syndrome [7]. Similar to other malformations in the cephalic and cervical regions, such as abnormalities of dentition development, deviated nasal septum, concha bullosa, migration of ethmoid cells, ponticulus posticus, retrotransverse

foramen or occipitalization of C1, PAD is highlighted during cranial-cerebral and cervical computer tomographic scans [3, 6-15].

The goal of our study is to characterize the defects of the C1 posterior arch, to identify the prevalence of this developmental anomaly in the population of north-eastern Romania and to objectivise the association with other C1 malformations.

2. Materials and Methods

We conducted a retrospective study in which we included patients who underwent cranio-cerebral CT scans for various neurological symptoms. 715 patients were investigated in the period May 2022 - August 2024 using the Toshiba Aquilion 16 MDCT Scanner. Being a retrospective study, the patients followed a diagnostic protocol according to the pathology upon admission, no additional protocols being necessary. All patients signed the informed consent. The Ethics Committee of the Iasi Clinical Recovery Hospital (12/16.02.2024) approved the study. The images were stored as DICOM files and were processed using Radiant DICOM Viewer. To exclude any bias, two experienced radiologists interpreted the images independently and in case of divergent results, the final decision was made by consensus.

2.1 Inclusion and exclusion criteria

We selected all patients over 3 years old. If PAD persists above this limit is considered pathological. Until this age, the bone defect can be closed by endochondral calcification [7]. We excluded patients with traumatic marks and those who underwent

interventions at the cervical spine level. In addition, we excluded image sets that presented any type of artifacts or those that did not capture the atlas in its entirety.

2.2 Statistical analysis

The collected data were statistically analyzed using Microsoft Excel 2016. We reported the continuous variables in the form of mean $\pm$ standard deviation. For categorical variables we used descriptive statistics. Dichotomous variables were compared between groups using the Chi-square test and presented in four-cell tables. Statistical significance is correlated with a $p < 0.05$.

3. Results

3.1 Baseline characteristics of patients

The study conducted by us included 715 patients aged between 6 and 95 years with a mean of 57.88 ± 20.10 (Table 1). The retrospective analysis included the craniocerebral MDCT examinations obtained after applying the inclusion and exclusion criteria. Our cohort consisted of 381 women (7 to 95 years old, mean 59.31 ± 20.48) and 334 men (6 to 92 years old, mean 56.25 ± 19.56) respectively.

Table 1 - descriptive statistics: age	
Mean	57.88531469
Standard Error	0.751988472
Median	62
Mode	64
Standard Deviation	20.10778365
Sample Variance	404.3229633
Kurtosis	-0.50059871
Skewness	-0.517259314
Range	89
Minimum	6
Maximum	95
Sum	41388
Count	715
Confidence Level(95.0%)	1.476372979

3.2 Prevalence of the atlas posterior arch defects

We identified posterior arch defects in 14 patients out of 715, representing 1.95% (Figure 1). From the point of view of gender distribution, the absolute value was distributed equally, 7 patients were men and 7 were women. There was not a significant statistical correlation between the gender and posterior arch dehiscence of the atlas as obtained from the Chi-square Test ($p > 0.05$) (Table 2). In addition, no statistical differences were found regarding the age of patients identified with PADA. By age group, 3 patients were in the 3 to 30 age range, 6 patients in the 31 to 60 age range and the remaining 5 patients in the 61 to 95 age range (mean = 48.35 ± 25.19).

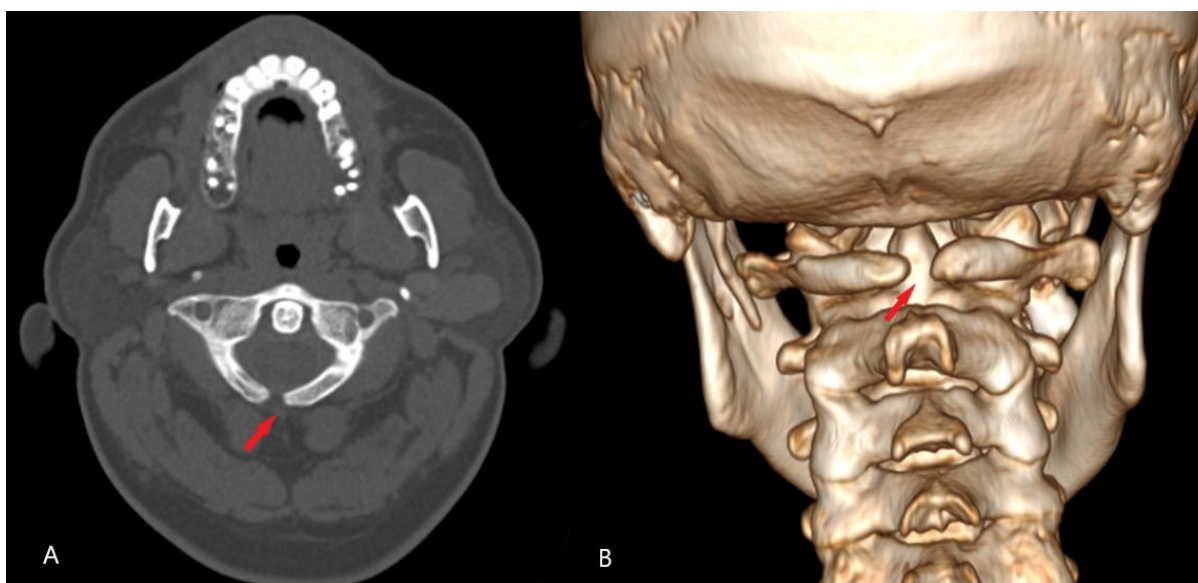


Figure 1. A – axial view. B – 3D reconstruction of the occipito-atlodian region, posterior view. Red arrow pointing the dehiscence of the atlas posterior arch.

Table 2. Distribution of PAD by gender

	Dehiscent C1	Non-dehiscent C1	Sum	p-value
Male	7	327	334	p>0.05
Female	7	374	381	
Total	14	701	715	

3.3 The association of PAD with other congenital atlas malformations

In general, we observed that PAD is not associated with other malformations of the atlas, in 10 of the 14 cases it was singular ($p>0.05$). Our study identified several cases that associated PAD with other malformations. One case associates PAD with bilateral incomplete *ponticulus posticus*. The second case is somewhat more complex, associating PADA with

right side complete *ponticulus posticus* and C1 occipitalization (Figure 2). Another interesting case consists of the association of the defect of the posterior arch of the atlas with the dehiscence of the anterior arch and the dehiscence of the hyoid body. The last case associates PAD with the existence of a bone bridge that connects the left articular process of C1 with the transverse one.

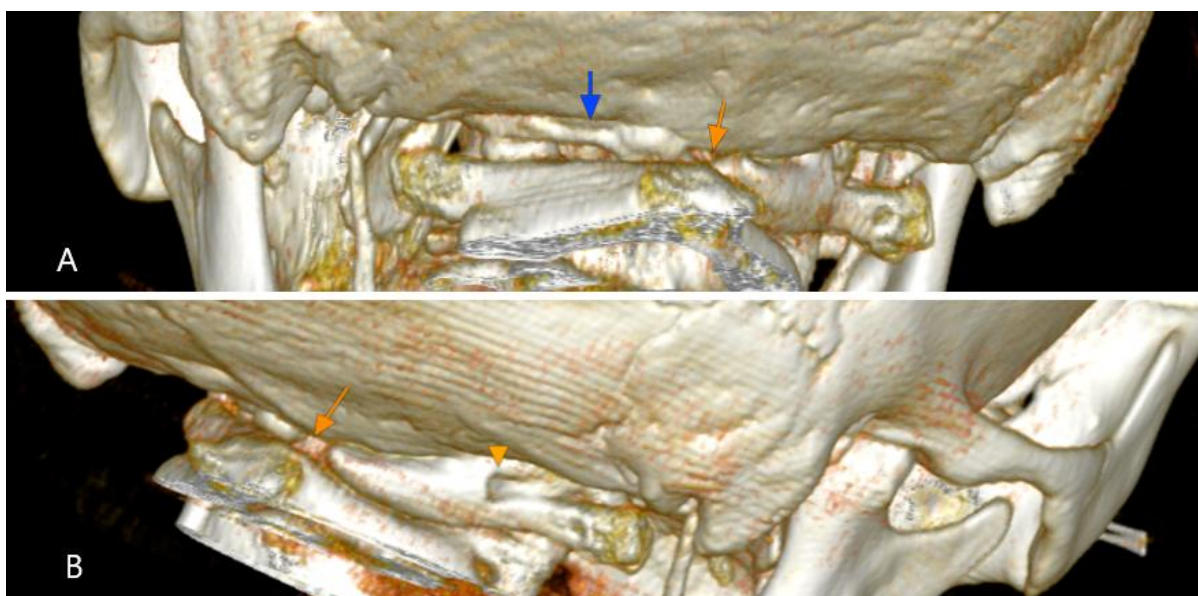


Figure 2 (A+B): 3D reconstruction of the occipito-atlodian region, posterior view: orange arrow – dehiscence of the atlas posterior arch; blue arrow – C1 occipitalization; orange arrow head – *ponticulus posticus*.

4. Discussions

Bone seen as tissue is considered an extremely dynamic biological system, comprising a series of tightly regulated and synergistic anabolic and catabolic processes that lead to a metabolic homeostasis corresponding to skeletal structures [16].

Initially, ossification abnormalities of the cervical spine were primarily linked to craniofacial syndromes. More recently, imaging studies have revealed an association between occipito-cervical junction malformations and malformative syndromes such as Down, Turner, and Klippel-Feil syndromes [17]. There is limited data in the scientific literature regarding the prevalence of atlas malformations, particularly posterior arch dehiscence. In this context, our study stands out due to the large sample size, which enables us to obtain significant statistical data.

The embryological development of the atlas involves processes of chondrogenesis and endochondral

ossification. Three primary ossification centers have been identified and a fourth accessory present in only 2% of individuals. The primary centers are responsible for the ossification of the anterior arch and the lateral masses, respectively. The posterior arch is also formed from the lateral primary centers. The accessory center, when present, is responsible for the ossification of the median segment of the posterior arch, respectively the posterior tubercle [18,19]. Klimo P Jr. et al. [18] supports the idea that PAD occurs more likely through a defect in chondrogenesis than through an ossification defect.

Currarino G. et al. [20] classified the defects of the posterior arch of the atlas into five morphologic types:

Type A - median cleft

Type B - unilateral defect

Type C - bilateral defect

Type D - absence of the posterior arch associated with persistence of the posterior tubercle

Type E - agenesis of the posterior arch and posterior tubercle.

To our knowledge, there are limited studies that evaluate the posterior arch of the atlas, with most being case reports or case series [19,21-24]. Prevalence data are derived from studies involving a small number of cases. For instance, Choi et al. [19] reported the presence of type A in 5.4% of the population, while the remaining types (B-E) accounted for a total of 0.69%. In their MDCT study involving 22 volunteers, Marinković S et al. [25] identified posterior arch dehiscence in one patient, representing 4.5% of the sample. The prevalence of PAD in our study is 1.95% of the patients included. Of these, the majority (12 out of 14) are classified as type A, while the remaining two (2 out of 14) are type B. No cases of types C-E were identified. Our findings align with those reported by Xie et al. [26], who observed a prevalence of 0.74% in the Chinese population, as well as with the results of Avinash et al. [27], who recorded a prevalence of 1.7% in the Indian population. Some studies have reported a high prevalence of posterior arch defects of the atlas, with figures reaching up to 5.16%. For instance, Pandey et al. [28] found a prevalence of 3.6% in a group of 250 patients, while Hyun et al. [29] reported a prevalence of 5.16% in a cohort of 3273 patients in the USA. In Europe, Guenkel et al. [30] reported an incidence of posterior arch defects of the atlas of 3.55% in a cohort of 1069 patients from Switzerland. Furthermore, in their meta-analysis, they reported a mean prevalence of posterior arch defects of 2.07% (95% CI, 1.22%–2.92%), which is very similar to the value observed in the current study.

Regarding morphological types,

most of the studies we reviewed highlight the predominance of Type A, followed by Type B at a considerable distance. Types C-E are generally considered rare occurrences rather than common findings [29-33]. As mentioned earlier, these findings are consistent with our results, where 12 out of 14 (1.67%) cases of PAD were classified as Type A, and only 2 out of 14 (0.27%) were classified as Type B.

Although there is a numerical difference between female and male patients (374 vs. 327), our study shows no gender predisposition. The age group distribution supports the congenital nature of PAD and indicates that, in most cases, it is discovered incidentally. These findings are consistent with those reported by Xie et al. [26], Pandey et al. [28], and Sanchis-Gimeno et al. [33].

Defects in the posterior arch of the atlas can be associated with malformations of other cervical vertebrae, as well as with conditions such as cleft palate, cleft lip, and malocclusions, including skeletal deep bite, skeletal mandibular overjet, and horizontal maxillary overjet. This statement is supported by the fact that both the vertebral body and the basilar portion of the occipital bone originate from the paraxial mesoderm, influenced by notochordal inductions. [3,4,34-38]. Sonnesen and Kjaer [34] established a connection between PAD, cranial base angle, and maxillary inclination. These two parameters influence the position of the upper jaw in relation to the skull base, which in turn affects the development of overjet and underbite malocclusions. They also play a role in the formation of skeletal Class II or Class III malocclusions.

The most important part of managing this patient is to offer them the

opportunity to regain functions [39]. Clinicians rely on both the cranial base angle and maxillary inclination to assess the patient's skeletal pattern and formulate treatment plans for orthognathic surgery, braces, or other orthodontic interventions. Alterations in these angles may suggest underlying skeletal issues that should be addressed to correct bite problems or improve facial aesthetics. For a successful treatment, a supportive, professional, approach should be followed when working with those patients to accept the adequate dental treatment [40, 41].

5. Conclusions

Posterior arch defects of the atlas are relatively common congenital malformations in the population of north-eastern Romania. The most frequent morphological form is median dehiscence, which aligns with Type A. These defects do not show a sex or age predominance, consistent with their classification as congenital malformations. Additionally, posterior arch defects of the atlas are often associated with other cervical and craniofacial abnormalities.

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