Ponticulus posticus: clinical and CBCT analysis in a young Italian population

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Abstract

Aim To evaluate the prevalence, the morphological characteristics and any related symptoms of Ponticulus Posticus (PP) in young Italian patients by means of cone-beam computed tomography.

Materials and methods A retrospective study was conducted on images derived from cone-beam CT scans of an Italian population in developmental age (mean age 12.61 ± 2.69); medical history was also evaluated from medical records. The total prevalence and morphology of PP, the prevalence by gender and according to age groups were calculated. For the statistical analysis the χ^2 test was used.

Results Total prevalence of PP was 28.24%, the prevalence by gender was 35.27% for males and 21.42% for females, with statistically significant differences. PP was bilateral in 74.33%, and monolateral in 25.67%. As regards symptoms, the cases with headache were 32.43%, tinnitus 6.08%, migraine 3.38%. Dividing by age, patients aged ≤ 11 years showed headache in 25% of cases, patients aged between 12 and 14 years in 54.17% of cases and patient aged between 15 and 17 years in 20.83%.

Conclusions PP is not a rare anomaly in Italian young patients and should always be sought in the lateral cephalograms and CBCT, in patients whether or not symptomatic, irrespective of their age, for differential diagnosis and management of cranio-cervicofacial pain in developmental patients.

KEYWORDS Ponticulus Posticus, Arcuate Foramen, CBCT, Vertebral Artery, Headache.

Introduction

In human anatomy, the Arcuate Foramen, also known as Ponticulus Posticus (PP) (Latin term meaning little posterior bridge), is a bony bridge that goes from the posterior portion of the superior articular process to the lateral portion of the upper margin of the posterior arch of atlas (first cervical vertebra, or C1), and surrounding all or part of the vertebral artery [Pyo and Lowman, 1959; Sharma et al., 2010; Sekerci et al., 2015]. Several theories for its origin have been proposed: genetic mutation, post-traumatic genesis, human evolution. The PP embracing the vertebral artery and the suboccipital nerve root can be a possible cause of muscle tension headache, cochlear symptoms (tinnitus and hearing loss), vestibular symptoms (subjective vertigo), ocular symptoms (convergence deficit), syncopal crisis, throat disorders (dysphagia, dysphonia), cervicobrachial syndrome [Tubbs et al., 2007; Chitroda et al., 2013; Chen et al., 2015].

PP can be diagnosed radiographically. Although lateral radiographs and CT have been often used for PP evaluation, cone-beam computed tomography (CBCT) currently is the examination of choice. In fact, CBCT has low doses of radiation, short imaging time, and better resolution than CT. CBCT also produces data for all 2D images, including panoramic radiographs, axial, paraxial, lateral-lateral, anteroposterior radiographs, being also able to create 3D images. Today CBCT examination is increasingly required for complex cases, since they allow to obtain different types of X-ray images with a single low radiation dose [Bayrakdar et al., 2014; Lacarbonara et al., 2014].

The purpose of this study was to investigate the prevalence, the morphological characteristics and any related symptoms of the PP, using data obtained from cone-beam computed tomography (CBCT) and evaluating the medical history data from medical records in a population of Italian patients in developmental age.

Materials and methods

A study was conducted on images derived from CBCT

scans of patients aged 7 to 17 years (mean age 12.61 ± 2.69), referred to Department of Medical, Oral and Biotechnological Sciences of the University "Gabriele d'Annunzio", Chieti-Pescara, Italy, in the period 2017-2018. For all patients a CBCT scan was taken for diagnosis and treatment planning due to several problems inherent to the maxillofacial region, of which the most represented were orthodontic or temporomandibular problems.

Exclusion criteria were the following.

- Patients who had undergone an examination with FOV<24x19, because these types of examination did not allow the correct assessment of the patient's cervical region.
- Patients with previous trauma in the head and neck region or who had undergone surgery in this region.
- Cases where for patient positioning problems or for anatomical reasons, it was not possible to correctly view the zone under examination.

Parental informed consent was obtained for all patients before examination (Privacy Law DL 196/2003). The selected subjects participated voluntarily in the study.

Approval from the Ethics Committee was not required since the research was based on a clinical protocol previously approved by the Department for medical use.

CBCT images of 524 patients were evaluated, of which 258 males (49.24%) and 266 females (50.76%).

Cone Beam CT scans were obtained through a drive CBCT PAX-ZENITH 3D (Vatech), using as parameters for the execution of the examination a range of from 80 kV to 120, a range that goes from 5 mA to 10 mA, a FOV (Field of View) 24x19 amplitude (the maximum attainable with the machinery in use), exposure time of 14 to 20 seconds. The parameters were not fixed, but set by the radiology technician depending on the age and size of the patient.

The presence and morphology of PP was assessed by means of Ez3D Plus software (3D Software, Imaging Systems, VATECH Global), which produced a CBCT three-dimensional reconstruction. For each case a control rating was conducted by scrolling the sagittal view from right to left and the coronal view in the anteroposterior direction, and the data have always confirmed what was seen and evaluated with 3D viewing.

The presence of PP was evaluated for both the right and the left side of the atlas as full or partial, following the classifications of Cederberg and Stubbs [Stubbs, 1992; Cederberg et al., 2000], which provides for the presence of 4 degrees or classes as follows.

- Class or Grade 1: Absence of calcification around the vertebral artery passage (Fig. 1).
- Class or Grade 2: Presence of calcifications which extend for less than half the distance between the posterior portion of the superior articular process and the posterolateral portion of the upper margin of the posterior arch of the atlas (Fig. 2).
- Class or grade 3: Presence of calcifications which extend for more than half the distance between the posterior portion of the superior articular process and the posterolateral portion of the upper margin of the posterior arch of the atlas but which do not form a complete ring (Fig. 3).
- Class or grade 4 (full): Calcification that completely surrounds the vertebral artery passage forming a complete bone ring (Fig. 4).

Patients were divided by age groups as follows.

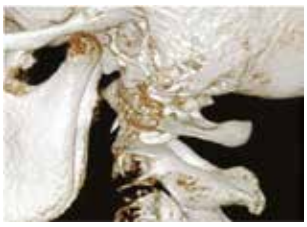

FIG. 1 Ponticulus Posticus grade 1

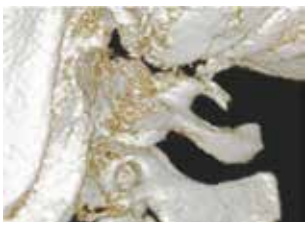

FIG. 2 Ponticulus Posticus grade 2

FIG. 3 Ponticulus Posticus grade 3

FIG. 4 Ponticulus Posticus grade 4

- Patients aged ≤ 11 years (44 patients), a period that usually precedes puberty.
- Patients aged between 12 and 14 years (57 patients), period corresponding to puberty.
- Patients aged 15 to 17 years (47 patients), the period of late puberty or post-puberty.

For patients presenting anomaly, the medical records were examined for the presence of symptoms that may be due to the presence of PP (headache, migraine, tinnitus).

It was calculated the total prevalence, the prevalence by sex and according to age groups.

As for the statistical analysis of the results the χ^2 test was used, and p value of <0.05 was considered statistically significant.

Results

The study group included 524 patients, aged 7 to 17 years (mean age 12.61 ± 2.69), of which 258 males (49.24%) and 266 females (50.76%). Presence of PP was found in 148 patients, with a total prevalence of 28.24%. Table 1 shows PP distribution by gender and side.

Using as statistical analysis χ^2 test, the differences between males and females were statistically significant at p <0.001.

Table 2 shows PP distribution by age groups considering the classification in 4 grades in relation to the side (left and right). As regards the PP distribution in groups by age, no statistically significant difference was found (p = 0.167). Similarly, no statistically significant difference (p = 0.139) were flound between various types of PP and the different groups by age.

Regarding the symptoms inferred from the medical records, headache was found in 48 cases out of 148 (32.43%), tinnitus in 9 cases (6,08%), migraine in 5 cases (3.38%).

Considering the division into groups by age, headache was found in different age groups: 12 of 48 cases (25%) in patients aged ≤ 11 years, 26 of 48 cases (54.17%) in patients between 12 and 14 years, 10 of 48 cases (20.83%) in patients aged between 15 and 17 years. No statistically significant difference was found using the χ^2 test (p = 0.326).

	Male		Female		Total	
	N	%	N	%	N	%
Absent	167	64.73	209	78.58	376	71.76
Present	**91**	**35.27**	**57**	**21.42**	**148**	**28.24**
Bilateral	72	27.9	38	14.28	110	19.08
Homogeneous	57	22.09	31	11.65	88	16.79
Heterogeneous	15	5.81	7	2.63	22	4.20
Unilateral	19	7.36	19	7.14	38	7.25
Right	8	3.1	13	4.89	21	4
Left	11	4.26	6	2.25	17	3.24

TABLE 1 Ponticulus Posticus distribution by gender and side

	7–11 years	12–14 years	15–17 years	Total
4th grade Bilateral	3	6	8	17
4th grade Unilateral Right	1	/	3	4
4th grade Unilateral Left	/	1	2	3
Total 4th grade	4	7	13	24
3rd grade Bilateral	4	6	6	16
3rd grade Unilateral Right	/	7	/	7
3rd grade Unilateral Left	/	7	/	7
Total 3rd grade	4	20	6	30
2nd grade Bilateral	8	6	7	21
2nd grade Unilateral Right	1	1	2	4
2nd grade Unilateral Left	1	1	4	6
Total 2nd grade	10	8	13	31
1st grade Bilateral	18	11	6	35
1st grade Unilateral Right	3	3	/	6
1st grade Unilateral Left	/	/	/	0
Total 1st grade	21	14	6	41
Bilateral heterogeneous	5	8	9	22
Total	**44 (29.73%)**	**57 (38.51%)**	**47 (31.76%)**	**148**

TABLE 2 Ponticulus Posticus distribution by age groups considering the classification in 4 grades and the arrangement in relation to the side (Right and Left)

Discussion

In literature there are many terms used to describe the anomaly in this study: sagittal foramen, foramen back atlantal, Kimmerle anomaly, foramen superior retro-articular, vertebral canal, retro-articular canal, arcuate foramen. However, the term most commonly used is Ponticulus Posticus [Chitroda et al., 2013]. PP is a bony bridge that extends from the posterior portion of the articular process higher than the posterolateral portion of the upper margin of the posterior arch of the atlas [Bayrakdar et al., 2014]. PP is usually reported as a simple anatomical variation. Often the areas comprising the cervical vertebrae are omitted by clinicians in the cephalometric tracings, even though the index of maturation of cervical vertebrae (CVMI) is now commonly used to interpret the growth potential of the young patients and PP is an artifact often visible [Baccetti et al., 2005].

A meta-analysis [Elliot and Tanweer, 2014], showed that PP is not a rare anomaly. The authors carried out a systematic review of the literature on X-rays, cadavers and surgical data, concluding that the prevalence of PP was 16.7%. Forty-four reports describing the presence of PP in online databases, included 21,789 cases (15,542 patients, 6,247 findings from cadavers). The total prevalence of PP was 16.7%, 16.6% in radiographic studies, 17.2% with respect to CT studies, 18.8% in findings from a cadaver. Presence of a complete foramen was found in 9.3% of cases, and an incomplete foramen in 8.7% of cases. The anomaly was bilateral in 5.4% of cases and unilateral in 7.6% of cases. In their studies no differences between males and females were found. They concluded that a careful examination of the cervical area is necessary in order to find such anomalies before undergoing any surgical treatment of atlantoaxial instability [Sekerci et al., 2015].

A study of Bayrakdar et al. [2014] on an Asian population on CBCT scans of 730 patients from 8 to 81 years, revealed a total prevalence of PP of 17.4%. The prevalence in men was 19.5% (54 out of 277), while the prevalence in females was 16.1% (73 of out 453). In this study the anomaly was observed both in young than in older patients, with a prevalence that was to rise slightly with age (14.1% in the group of younger patients 8–18 years, 21.7% in the 49–81 years group). According to our results, the PP seems to be correlated with age.

The study of Geist et al., [2-14] carried on US patients, found 151 cases of PP on 576 CBCT scans with a prevalence of 26.2%, in accordance with the present study. As kin the present study, it was found a statistically significant difference between males and females, in which the PP was found in 91 of 258 males with a prevalence of 35.27%, while it has been found in 57 of the 266 females, with a prevalence of 21:42%.

The study of Gibelli et al. [2016] is the first Italian study carried out on PP using lateral radiographs of a sample of 221 patients of Northern Italy (Como) aged between 6 and 18 years, of which 91 were males and 130 females. It was found a prevalence of 7.7% in the male sample, 9% in the female sample, with no statistically significant difference. The higher frequency was found in subjects between 15 and 18 years. These data are not consistent with those obtained in our study, since our results carry a total rate of 28.24%, higher than the 16.7% found in the study of Gibelli. The aforementioned study is the first in the field of PP in an Italian population. However, as stated by the same authors, the study presents limitations due to the small number of

patients, and the type of X-ray examination chosen. The lateral cephalometric projection does not allow a complete view of the cervical region of the skull, and consequently does not allow to discriminate between bilateral and unilateral lesion.

Our work represents the first in Europe on CBCT scans of patients in developmental age where, in addition to the radiographic analysis, a clinical analysis was also performed to search for PP-related symptoms. Presence of PP was found in 148 out of 524 patients, with a total prevalence of 28.24%, a percentage in line with other studies in the literature. The difference between males and females was statistically significant with $p < 0.001$, with a prevalence of 35.27%, in males as compared to a prevalence of 24.42% in females.

It should be emphasised that compression of the nerve and vascular structures passing through the Arcuate Foramen may result in a series of symptoms including pain in the arm, neck and shoulder, tinnitus, acute hearing loss, dizziness, the development of various types of migraine and headache, paresis or paralysis of the extremities, and syndromes of vertebrobasilar insufficiency [Koutsouraki et al., 2010; Schilling et al., 2010; Sharma et al., 2010; Kim, 2015; Sessle, 2015; Tambawala et al., 2017; Pękala et al., 2018]. The vascular branches of interest for a possible arterial compression caused by the presence of PP are intracranial branches. The meningeal branches supply blood to the bone structures and the dura mater of the cerebellar fossa. Especially important for the symptoms that it might cause owing to a spreading deficit in the inferior branch of the posterior cerebellar artery, which reaches the ipsilateral cerebellar hemisphere [Vaněk et al., 2017; Bernardi et al., 2016]. Regarding the symptoms of our study, headache was observed in 48 cases out of 148 total (32.43%), tinnitus in 9 cases (6.08%), migraine in 5 cases (3.38%). Considering the division into age groups, the frequency of headache the most frequent symptom in this study, was compared in the various age groups: patients aged ≤ 11 years showed 12 cases of headache out of 48 (25%), patients aged 12 to 14 years showed 26 cases of headache out of 48 (54.17%), patients aged 15 to 17 years showed 10 cases of headache out of 48 (20.83%). Using a χ^2 test statistical analysis, a non-statistically significant difference was found ($p = 0.326$). However, the detection of a symptom such as headache in 48 cases out of 148 may suggest a possible association with the presence of PP, taking into consideration that the study concerns patients in developmental age (average age of 12.61 ± 2.69).

Despite the many studies in the literature, the arcuate foramen is a structure that has been clinically underestimated until its use as a precise point of reference in spinal surgery has conferred it greater popularity [Young et al., 2005]. The atlantoaxial instability management technique it is characterised by reduction and melting of the atlantoaxial complex through the use of screws in the lateral masses of the vertebrae; this is a complex procedure because the region contains structures such as the epidural venous plexus and the greater occipital nerve. Injuries to this region can lead to significant bleeding and occipital neuralgia. To avoid this, surgeons recommend inserting screws upward with respect to the common point of entry, starting from the rear portion of the posterior arch of the atlas [Arslan et al., 2018]. In this "Atlas fixing" technique using the large posterior arch of the atlas as elective point of reference for the placement of the screw. When the vertebral artery runs normally above the posterior arch of C1, the positioning of the lateral mass screws is relatively simple; however, in patients with PP this anomaly can be confused with its large rear bow and for this, the erroneous positioning of the screw in a structure mistaken for another can cause vertebral artery lesions leading to stroke or even death thrombosis, embolism, or arterial dissection [Sharma et al., 2010]. Given the circumstances, it is clear that this spinal abnormality cannot be underestimated, indeed it should always be sought in the lateral cephalometric lateral and CBCT scans, particularly in patients with craniofacial symptoms without apparent cause, or in patients about to undergo reduction and melting surgery of the atlantoaxial complex through the use of screws in the lateral masses of the vertebrae.

As regards the distribution of the PP in groups by age, the results seem to indicate a higher frequency of the Class 1 type in younger patients (7–11 years), while a higher frequency of full type in older patients (15–17 years), suggesting a possible development of PP over time.

These data could also suggest an aggravation of sagittal skeletal anomalies, as demonstrated recently in a study carried out on a young Turkish population [Bayrakdar et al., 2018], in which a significant association was found between the presence of the PP and skeletal Class III, considering that the mandibular bone ends its growth around 18–20 years and the head-neck posture deformities cause malocclusion [Huggare and Cooke, 1994; Meibodi et al., 2011; Tecco et al., 2011; Adisen and Misirlioglu, 2017; Romani et al., 2018; Tecco et al., 2019; Mummolo et al., 2018; Ambu et al., 2017].

The presence of PP is independent of age, having found a significant proportion of PP in subjects below the age of 10, even in two small patients of 7 years old. It is therefore clear that the PP cannot be considered exclusively a process of calcification or ossification due to aging.

Conclusions

Ponticulus Posticus is not a rare anomaly and should always be sought in the lateral radiograph and CBCT scans, in patients of any age group, whether or not symptomatic, and for the management of craniocervicofacial pain in patients of developmental age.

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