

Anatomical variants of the cervical vertebrae and the first thoracic vertebra in man

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Anatomical variants of the cervical part of the human spine were investigated. Morphological variants were studied on 100 cervical vertebrae (37 female and 63 male). The greatest variability was demonstrated by the first cervical vertebra or atlas. The presence of some accessory bony arches embracing the vertebral artery was observed, namely the posterior bridge restraining the arcuate foramen (13.8%) and the lateral bridge restraining the transversovertebral foramen (2%). Split posterior (3%) or anterior (1%) arches of the atlas were also encountered in this material. The superior articular face of the atlas divided into two parts was found in 47.8%. Variants of the remaining cervical vertebrae were limited only to the presence of a division of the transverse process foramina or their incomplete closure. Some of these anatomical variants may be a cause of certain clinical symptoms which have previously been described in the literature.

key words: cervical vertebrae, anatomy, variants, human

INTRODUCTION

The vertebral column is a part of the axial skeleton of man which has to perform particular tasks. Firstly it forms a stable support for the head, providing it with significant mobility, which ensures access to the indispensable stimuli for the senses of sight, hearing and balance. The secondary, cervical part of the vertebral canal contains a cervical segment of the spinal cord which forms here the cervical callosity. In addition, the cervical skeleton is also a bony framework for the vertebral arteries in their course from the aortic arch to the cranial fossa. As a result of the large number of tasks performed by this part of skeleton, any disorder affecting it may lead to significant lowering the quality of life [1, 13]. The vertebrae of the cervical part of the vertebral column demonstrate the greatest variability. These are among the true vertebrae, the smallest and the

most delicate [1]. The first cervical vertebra, the atlas, differs in structure from all the other cervical vertebrae and is also the most variable vertebra in man [1]. The variability of the atlas and axis and other cervical vertebrae is passed over in most basic anatomy and clinical textbooks. There is scant information concerning these issues embedded in a few publications in the available literature. Some anatomical variants of the atlas, especially the bony bridges embracing the vertebral artery, may be of great clinical importance and probably cause vertigo and neurological disturbances. The aim of this study was to investigate the variability of the morphology of the cervical vertebrae and the first thoracic vertebra. Knowledge of this variability is important for physicians such as: otolaryngologists, neurologists and orthopaedists, who in everyday practice are in contact with disorders of the spine

and their consequences [1, 5, 13]. In addition, progress in radiology has enabled some fine structures, so far unavailable for traditional image evaluation, to become visible in CT scans and these are of considerable clinical importance.

MATERIAL AND METHODS

A hundred adult, human vertebral columns from the skeletal collection of the Department of Historical Anthropology, Warsaw University, were the subject of this study. The skeletons represented the region of Kielce and originated from the period of the XII and XIII centuries. During anatomical examina-

tion variants involving the basic and qualitative features of the cervical vertebrae were determined and analysed.

RESULTS

The results of the morphological observations of the material studied are presented in Table 1. Complete observation of all the features under investigation was not possible on all the vertebrae owing to the considerable damage to some vertebrae, where, for example, only fragments are preserved, there has been disintegration or important fragments have been broken off. In addition, not all the verte-

Table 1. Non-metrical features of cervical vertebrae and the first thoracic vertebra

The structure studied and its features		Male		Female	
		Left	Right	Left	Right
Posterior bridge and vertical foramen and their variants (N = 58 M, 37 F)	Vertebral artery groove	49	48	33	33
	Fully developed vertical foramen	9	9	4	4
	Posterior bridge perforated	1	1	0	1
	Postglenoid process	19	20	11	11
	Posterior process	1	1	1	1
Transversovertical foramen of C1		1	1	1	1
Dorsal foramen or impression of C1	Dorsal impression	7	10	4	2
	Dorsal foramen	0	1	5	4
Variants of arches of C1	Deficit of posterior arch		0		3
	Deficit of anterior arch		0		1
	Posterior tubercle	Lacking	12		15
		Present	25		14
			16		4
Transverse vertebral foramen of C1 (N = 55 M, 37 F)	Closed	53	54	35	34
	Opened	2	1	2	3
	Accessory	0	1	0	0
Superior articular fossule of C1 (N = 54 M, 36 F)	Single	48	50	34	33
	Divided	6	4	2	3
Opened transversal vertebral foramen of C2 (N = 62 M, 33 F)		0	0	1	0
Divided transversal vertebral foramen of C3 (N = 50 M, 21 F)		2	2	0	0
Divided transversal vertebral foramen of C4 (N = 51 M, 23 F)		6	9	0	1
Divided transversal vertebral foramen of C5 (N = 60 M, 26 F)		14	11	7	4
Divided transversal vertebral foramen of C6 (N = 60 M, 31 F)		28	32	12	11
Transversal vertebral foramen of C7 (N = 62 M, 30 F)	Divided	10 (+1 triple)	7	6	4
	Lacking	0	1	0	0
Present transversal vertebral foramen of Th1 (N = 62 M, 29 F)		0	1	0	0

bral columns studied contained all seven cervical vertebrae. This fact has been noted each time in Table 1 as a number of observations.

Variants and structural defects of the atlas vertebra

In the material studied there was considerable variability in the morphological variants of the atlas. Variability concerning the same structures, connected in related groups, was observed and jointly described. The occurrence of accessory bony processes, arising from the posterior arch, lateral masses or transverse process, were observed in a considerable number of the vertebrae. In some cases full bony bridges were formed across the particular morphological structures of the atlas. The postglenoid process (observed in a total of 31.4% of the specimens) was an element rising from and behind the superior articular fossa, suspended over the groove of the vertebral artery (Fig. 1). This structure was formed, to varying degrees, from a small bony process up to an almost full bony bridge (the posterior bridge). The postglenoid process could be accompanied by the posterior process, occurring on the posterior arch of atlas (4 cases in the material examined). The full posterior bridge with the closed arcuate foramen situated beneath it occurred one-sided or bilaterally (15.7% for males and 10.8% for females, together amounting to 13.8%). The lateral bridge is a bony trabecula directed upwards and laterally and runs from the lateral mass of the atlas towards the posterior lamina of its transverse process. The lateral bridge, and limited by it the transversovertebral for-

men of the atlas, was found in 4 specimens (1.7% for the male vertebrae and 2.7% for the female ones). Both bridges were full and the foramina closed. Cases of incomplete lateral bridges, and consequently split transversovertebral foramina, were not observed. Processes, more rarely bony bridges located on the lateral surface in the anterior segment of the posterior arch, limited the so-called dorsal impressions or foramina. The area of the posterior arch between these processes was distinctly depressed, forming a groove (Fig. 2). This situation was observed in 17 (14.6%) of the male specimens and in 7 (9.4%) of the female specimens. In cases where the aforementioned bony protrusions were joined, a foramen was formed, which was observed on one side on one male vertebra (0.9%) and one-sided or bilateral on 9 specimens (12.2%). The transverse process of the atlas had its transverse foramen in each specimen studied. On 3 male vertebrae (2.7%) and 5 female vertebrae (6.7%) an anteriorly split foramen of the transverse process was found. This phenomenon was invariably an effect of reduction of the anterior lamina of the transverse process and never of the posterior lamina. In one case, on a male vertebra, on the right side, a kind of accessory foramen of the transverse process was observed. However, this did not lie in the horizontal plane, as happens with the foramen proper, but in the frontal plane, penetrating the anterior lamina of the transverse process (Fig. 2). This variant has not as yet been described in the available literature. Variants of the anterior and posterior arch of

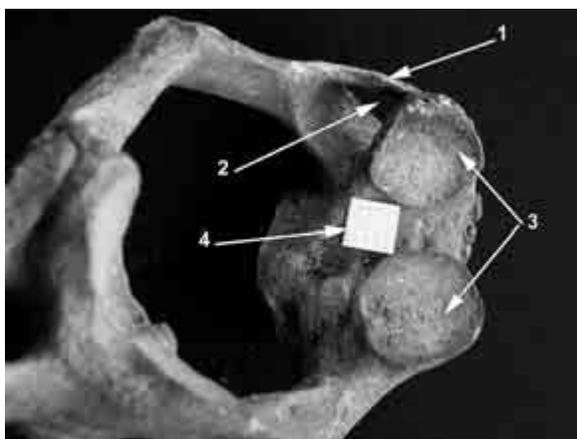


Figure 1. First cervical vertebra — sight of superior surface. Surface of superior articular fossa wholly divided into two separate components. Anterior bridge and arcuate foramen; 1 — posterior bridge, 2 — arcuate foramen, 3 — superior articular surface, 4 — millimetre measure.

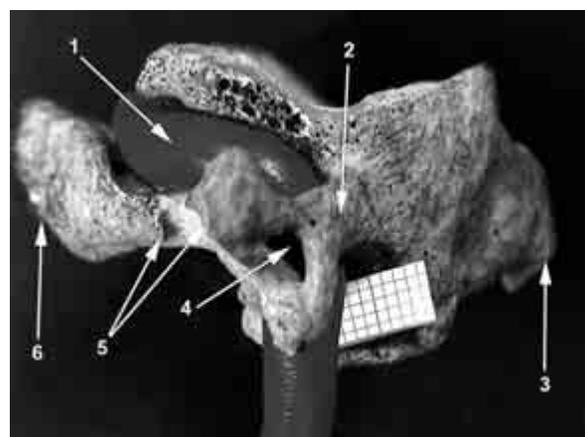


Figure 2. First cervical vertebra — viewed from above and from the right side. Anterior lamina of the transverse process perforated by an accessory foramen communicating with the foramen of the transverse process, through which a plastic model of the vertebral artery has been passed; 1 — model of vertebral artery, 2 — anterior lamina of transverse process, 3 — anterior arch, 4 — foramen in anterior lamina of transverse process, 5 — bony projection limiting so-called dorsal impression, 6 — posterior arch.

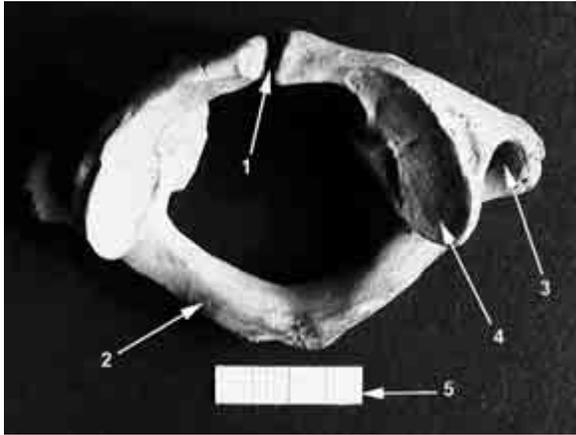


Figure 3. First cervical vertebra — viewed from above. Defect of anterior arch. Absence of tubercle on posterior arch; 1 — slit within anterior arch, 2 — posterior arch, 3 — foramen of transverse process, 4 — superior articular fossa, 5 — millimetre measure.

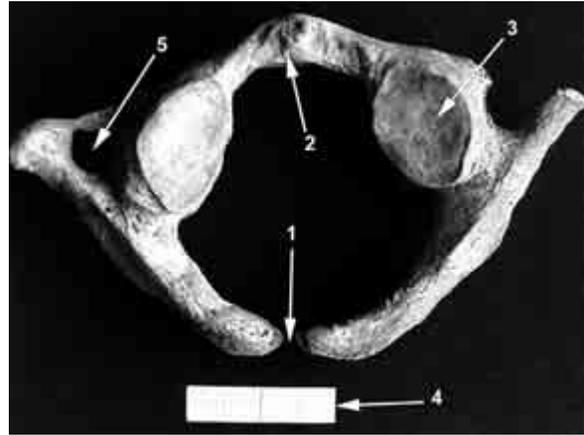


Figure 4. First cervical vertebra — viewed from behind. Defect of posterior arch. Destroyed fragment of transverse process on right side; 1 — slit within posterior arch, 2 — anterior arch, 3 — inferior articular facet, 4 — millimetre measure.

the atlas were relatively frequent. A defect of the anterior arch, leading to its complete splitting, was encountered only once on one of the female vertebrae (Fig. 3), which is 2.7%. In one more case, also on a female vertebra, a partial splitting was observed of the anterior arch in the form of a small slit separating the lower part of the anterior tubercle. This variant was termed a "divided anterior tubercle". A further defect of the posterior arch, thrice encountered, occurred solely on the female vertebrae (8.1% of female specimens and 3.2% in relation to the examined material as a whole). The defect in each of the 3 cases was located in the vicinity of the median line (Fig. 4). However, no defect was founded located on any of the lateral parts of the arch. On the posterior arch a considerable variability was demonstrated by the posterior tubercle, which could be examined on 53 male and 34 female vertebrae. Some of vertebrae were so severely damaged in the extent of the posterior arch that they were not considered during this part of the study. Of the female vertebrae 3 demonstrated a congenital defect of the posterior arch and although, for obvious reasons, these had no posterior tubercle, they have been classified as a separate subgroup. On 12 male (22.6%) and 16 female (47.1%) vertebrae the posterior tubercle was not present (Fig. 3). This difference between the sexes was statistically significant. In the situation in which the posterior tubercle occurred, it was, in the majority of cases, single or, more rarely, double, particularly in women. A single tubercle was observed in 26 cases in men (47.2%) and 14 in women (41.2%). A double posterior tubercle was observed more fre-

quently in men (16 cases, 30.2%), than in women (4 cases, 11.8%). The superior articular fossa of the atlas displayed various morphological forms, which were, however, not classified in the present study, in which attention was concentrated more on the question of whether this fossa had a distinctly marked division on two separate articulation surfaces or whether this division was absent or incomplete. The divided fossa was observed on 10 sides of the male vertebrae (9.2%) and on 5 sides of the female vertebrae (6.9%). The division of the fossa was two-fold: in some cases (7 in the male and 3 in the female) the divided element was a narrow groove separating the fossa on the anterior part from that on the posterior. In the remaining cases (3 male and 2 female) there two separate fossae were observed, an anterior and a posterior, with the distance between them being fairly substantial (Fig. 1).

Variants and structure defects of the remaining vertebrae

Anatomical variants of the axis were infrequent in the material studied. The only substantial variant was a split foramen of the transverse process, observed on 1 female vertebra, owing to a defect in the posterior lamina of the left-side process. The foramen itself frequently took the form of a canal several millimetres long, although this feature, being linearly variable, was not analysed. The vertebrae C3-C7 were analysed jointly, as the variants observed here concerned only the occurrence of the divided or single foramina of the transverse processes. This divided foramen was most frequent at the level of

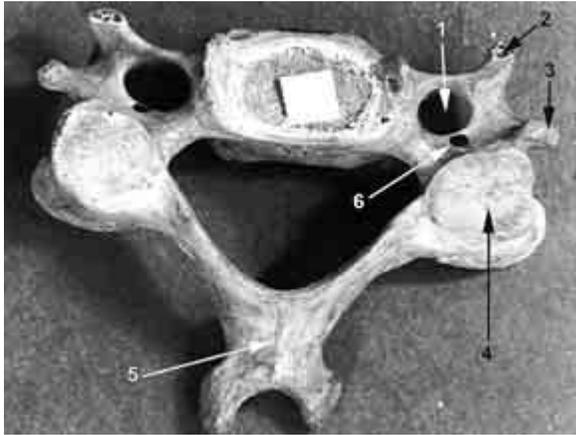


Figure 5. Vertebra C5 — viewed from above. Foramen of transverse process twofold divided on uneven components: anterior and posterior; 1 — anterior foramen of transverse right process, 2 — tubercle anterior of transverse right process, 3 — tubercle posterior of transverse right process, 4 — right superior articular facet, 5 — spinous process, 6 — posterior foramen of right transverse process.

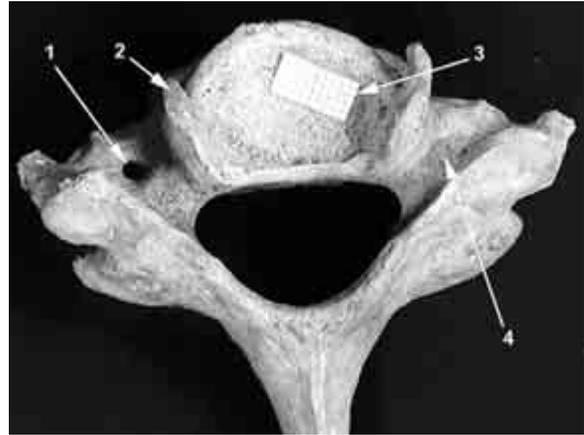


Figure 6. Vertebra C 7 — viewed from above. Foramen of transverse process on left side of very small diameter; about on right side; 1 — foramen of left transverse process, 2 — bony vegetation of character of degenerative changes, 3 — millimetre measure, 4 — right transverse process without foramen.

C6 (45.6%), and rarest at the level of C3 (2.8%). The manner of division of the foramen into two components was variable. The most frequent element of division was a thin bony lamina (Fig. 5), while, more rarely, it assumed the shape of a thick slat running as a string of the foramen. Sometimes simply an accessory foramen of the transverse process, situated forwardly and laterally from the main foramen, was observed. In 1 case, concerning vertebra C7, the foramen of the transverse process was triplicated, and in one case it did not occur (Fig. 6). Both observations concerned the male vertebra of the right side. On one male thoracic vertebra, Th1 on the right side, a foramen of the transverse process was observed. Although this was small in diameter, it was located typically. The transverse process on this side was distinctly broader than on the opposite side and resembled the transverse process of cervical vertebra.

DISCUSSION

The vertebrae of the cervical part and the proximal thoracic part of the human vertebral column are the area undergoing the most intense transformation during phylogeny, leading to many anatomical variants [1, 13]. Splitting of the posterior arch occurs, according to various authors, in the range of 0.4–6.9% and in the Polish population in the range of 2.6–2.8% [3, 17]. The value obtained in this study (3.2%) is, therefore, within the limits given by other authors. These variants may, at times, be mistakenly taken as fractures, especially when radiological ex-

aminations of the spine are performed on a patient after injury [5, 12]. The occurrence of bony bridges in the atlas, forming a closed ring over the vertebral artery, is a frequent phenomenon. The foramen confined by the posterior bridge is termed in the literature the perpendicular foramen, arcual foramen, retroarticular canal, posterior foramen, foramen retroarticulare superior or Kimmerle's anomaly [1, 6, 9, 13, 14, 18, 22]. This foramen is termed by Poplewski [18] the transverse foramen. The arcual foramen occurs, after various authors, in the range of 1.14–29.2% and in the Polish population in the range of 8.4–10.5% [3, 9, 14, 17, 22]. The incidence of this foramen in our material (13.8%) is higher than reported by Polish authors, but is still within the variability range for other nations and races. The higher incidence of this foramen on female vertebrae (though not statistically significant) was also observed by Mitchell, but only in white races [15]. The foramen may be split, which corresponds to the situations in which the postglenoid process and/or posterior process occur. The postglenoid process, in Bergman's material present in up to 54%, was observed by Poplewski only in 42.5%. Our data (31.4%) are closer to those of Le Double for Frenchmen (21%, citation after Poplewski [18]). The posterior bridge in our material occurred perforated by a small foramen or foramina, which confirms the observations of Bergman [3]. The second of the bony bridges of the atlas vertebra is the lateral bridge or transverse bridge limiting the transversovertebral foramen. The lateral bridge is described in literature as ponticulus

posticus or atlas bridging or retrocondylar vertebral artery ring [3, 16, 17, 22]. The lateral bridge, according to various authors, occurs in the range 2–3.8%, which is in agreement with our results [3, 16, 17, 23]. The coexistence of the posterior and the lateral bridges of the atlas is frequent and such vertebrae are found in 2.1–6.82% of the population [13, 15]. In both cases of lateral bridge formation in the material studied the posterior bridge was also found. The superior articular fossule of the atlas is often divided into two asymmetric fields, the anterior and the posterior, and is accompanied by the divided articular surface of the occipital condyle. This variant occurs, according to various authors, in the range 0–16% (Dubreuil, Hasebe, Le Double, Macalister, Varaglia, citation after Poplewski [18]), while in the Polish population is observed in 10.5% [17]. The value obtained in the present study, is entirely comparable with the data referred to. The splitting of the transverse foramen of the atlas has been observed by various authors in 3.6–15.2% of cases (Le Double, Hasebe, Loth, Macalister, citation after Poplewski [18]). Poplewski [18] reported that the incidence of this variant is 15.2%, while Bergman [3] gave the value 12%, both values being considerably higher than those obtained in our studies. This difference can be explained by the differing composition of the population examined, since Poplewski had studied material originating from Central Poland, while Bergman investigated material from the south-westerly regions of Poland. The so-called dorsal foramina or impresses, were found by Poplewski in up to 49.5%, and Valeanu in 67.8%, which is significantly higher than in our material [17, 25]. This discrepancy could be explained by different criteria for recognising this structure. The morphology of the typical cervical vertebrae was characterised by a fairly significant variability, mainly involving the structure of their superior articular processes, of the foramina of the transverse processes or their posterior arches [1]. The opened foramen of the transverse process of the axis occurs, after various authors, in from 1 to 4.3% of cases [3, 23, 24]. Split foramen of the transverse process was found in 1 of the vertebrae at the level C4. There is no mention of this fact in the available literature. The relatively frequent occurrence of various forms of division of the foramen of the transverse process within typical vertebrae is worthy of notice. The double foramina most often appeared in our material at the level C5–C7, similarly to the observations of Taitz and Nathan, while, at the same time, both foramina differed considerably in their diame-

ters [21]. Absence of a foramen of the transverse process of C7 occurred on one of our vertebrae. The lack of foramen on one or both sides, but at the level of C4 and C6 rather than that of C7, was also observed by Taitz and Nathan [21]. A triple foramen was found only at the level of C7. The aforementioned authors did describe a case of a triple foramen but this was at the level of C6 (although the authors published only a figure, without any description of this phenomenon). A foramen of the transverse process found on one vertebra from the level Th1 is evidence for the cervicalisation of this vertebra. No detailed description nor any picture of this rare variant could be found in the available literature. The morphological features of the vertebrae examined showed no essential differences in statistical tests, with the exception of features of the posterior tubercle of the atlas. This can be attributed to an insufficiency of specimens in relation to the considerable variety of the features studied and their variability. This situation may be an indication that other morphological features of the arches of the atlas manifest sexual dimorphism. However, their variants are so rare that only very numerous material could afford adequate data for non-parametric statistics.

Anomalies of the vertebral artery, accompanying the variants of the cervical spine and base of the skull, are reported in the literature. It should be added that a substantial clinical significance is being ascribed to these anomalies by several authors [11, 14, 19, 20]. The posterior bridge of the atlas can press the vertebral artery during movements of bending and straightening or rotation of the neck causes disturbances in arterial flow with symptoms of Barre-Lieou syndrome [12, 19, 20]. This variant is also considered as one of the causes of cervical vertigo syndrome, so-called base-vertebral stroke and is even given as one of the possible reasons for the syndrome of infant sudden death [2, 4, 7, 8, 10, 11, 16]. A double foramen of the transverse process with an appreciable disproportion in the diameter of its compartments or the lack of a foramen on one of the vertebrae may indicate a splitting of the vertebral artery and its renewed joining or the necessity of bypassing a given vertebra, as has been confirmed by radiological studies [8, 19, 20].

It should be underlined that the different variants and developmental defects of the atlas often occur together, especially in families by hereditary transmission [11]. These variants could be accompanied by other defects within the vertebral column, such as deformation of the skull base, particularly

within the Turkish saddle, extended styloid process or cervical ribs. The developmental variants of the cervical vertebrae, especially C1 and C2, may produce a series of disorders such as headache, vertigo, buzzing in the ears, paresis or paralysis of the extremities. These developmental disorders should always be taken into account during the planning of the diagnostic process in obese patients with disturbances within the organ of hearing or the labyrinthine sense [14].

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