

# Multiple anomalies in the atlanto-occipital joint (*articulation atlanto-occipitalis*)

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**ABSTRACT:** Contemporary populations exhibit numerous skeletal anatomical variations and the atlanto-occipital joint (*articulation atlanto-occipitalis*) is often the location of such variations. A female skeleton dated at 4000 BC and excavated at Meroe in the Sudan provides an example of numerous variations in the basilar skull and cervical vertebrae. These variations consist of the presence of a bilateral atlanto-occipital joint with a third trochanter, a unilateral arcuate atlas foramen and huge axial nutrient foramina.

**KEY WORDS:** anatomical anomalies, Sudan, atlanto-occipital joint

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## Introduction

Significant anatomical variety and malformations quite often occur in the area of the atlanto-axial joint (*articulation atlanto-occipitalis*). Malformations are manifested by neuralgia, paresis or hearing and balance disorders. The *foramen processus transverse* form a transit canal for the most important vertebral artery and venous plexuses (Bayley 1974; Snell 2007; Standing 2009). Under normal conditions, the vertebral artery exits the canal at C2 and enters the foramen magnum through a groove in the posterior arch

of the atlas, but where additional bone bridges occur the artery can be exposed to pressure or complete obstruction. When assimilation of the atlas occurs, the dimensions of the occipital foramen magnum decrease in its antero-posterior aspect, causing hypertension symptoms (Mac Rae 1953; Dorne and Lander 1986), and when the axis develops from several independent ossification centres, incomplete union of the dens constitutes a serious clinical problem. When examined radiologically, the dens is interpreted as being fractured. A further malformation involves basilar impres-

sion of the skull where osseous material is present. Knowledge of the location of these changes is an important diagnostic element for specialists; not only those who work in the field of neurology but also otolaryngologists and pulmonologists (Wysocki et al. 2003; Pamphlet et al. 1999).

## Materials and methods

During the 2006 excavation season, an almost complete skeleton was found at Meroe approximately 6 km north-east of the Kabushiya station near Shendi in the Sudan. The skeleton came from the meroitic tumuli. Excavations were performed at the area of a nobles' burial ground in the vicinity of the fourth cataract. The Meroitic kingdom developed independently from Egypt which passed successively under Persian, Greek, and Roman domination, and the height of its power occurred in the second and third centuries BC (Adams 1977). The skeleton was discovered by a Sudanese mission from the Polish Academy of Science and studied in the Polish anthropological laboratories in Siedlce and Warsaw. The remains of almost all bones were present and excellently preserved. The gender was determined by the Phenice method (Buikstra and Ubelaker 1994) and age estimated by pubic symphysis morphological changes, as in Brooks and Suchey (1990) and by standard changes in auricular surface topography (Buikstra and Ubelaker 1994; White and Folkens 2000). The skeleton was determined female with assessed age at death of 20–30 years.

## Results and Discussion

Data analysis revealed the following variations: (1) bilateral presence of a joint

connecting the third occipital condyle to the atlas transverse process (Fig. 1–2), a unilateral posterior bridge of the atlas (Fig. 3) and huge osseous axial canals (Fig. 4).

Human cervical and proximal thoracic vertebrae constitute areas where particularly intense transformations during phylogenesis cause frequent variations mostly affecting the atlas (Mac Rae 1953; Bayley 1974). Atlas osseous bridging which forms a closed ring over the vertebral artery is one frequent phenomenon (Fig. 3). The foramen restricted by the posterior bridge is alternately referred to in publications as the foramen sagitale, arcuate foramen, retro-articular canal, posterior atlantoid foramen, foramen retro-articulare superior or the Kimmerly anomaly (Pyo and Lowman 1959; Bergman 1967; Lamberty and Zivanovic 1973; Klausberger 1975; Taitz et al. 1979 and Taitz and Nathan 1986). However, Poplewski (1925) uses the term 'transverse foramen' for this malformation. According to different authors, the arcuate foramen occurs in 1.14%–29.2% of populations, and it is observed in 8.4–10.5% of Poles (Bergman 1967; Klausberger and Samec 1975; Taitz and Nathan 1986 and Mitchell 1998). Concomitant symptoms include headache from pressure on the vertebral artery and sympathetic plexus stimulation. Here, surgical treatment is required, including vertebral artery sympathectomy. Baso-vertebral strokes have also occurred when too vigorous head movements were made. It is noted here that the additional osseous canals most likely functioned as nutrient pathways.

Assimilation of the atlas provides permanent atlanto-occipital union (Lander et al. 1991; Mcalister 1993) but this union is usually incomplete and covers only the anterior atlantal arch and the



Fig. 1. Atlas assimilation with occipital condyles

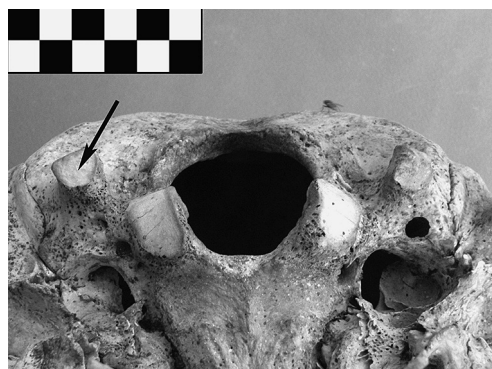


Fig. 2. The cranial base with third occipital condyle

anterior edge of the foramen magnum. Dislocation of the atlanto-axial joint has been observed in approximately 60% of cases. The axial dens can assume abnormal shapes or be dislocated to different extents. In approximately 50% of cases, this is accompanied by union of the C2/C3 vertebrae (Lander et al. 1991); and it is interesting that this type of assimilation is present in some physiological anaemias (Welsh et al. 2013). The malformations may be accompanied by developmental anomalies such as the central and lateral neck cysts and fistulas typical in the 1<sup>st</sup> and 2<sup>nd</sup> branchial arches. This defect is sometimes concomitant with Arnold-Chiari syndrome, related to

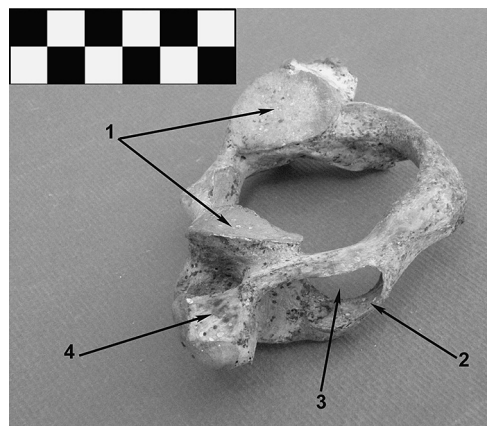


Fig. 3. Unilateral posterior bridge of the atlas (1 – superior articular facet, 2 – bridge, 3 – additional foramen and 4 – foramen transversum)

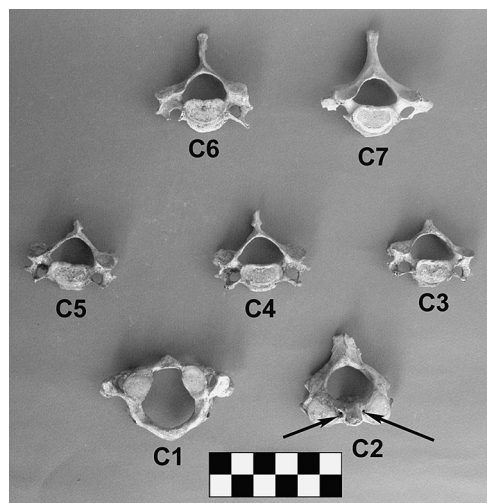


Fig. 4. Axis vertebrae with osseous canals

dislocation of brain structures into the spinal canal (Welsh et al. 2013, Zderkiewicz and Kaczmarczyk 2007) and is also correlated with other bone malformation such as spina bifida or myelomeningocele (Bell et al. 1980). Spina bifida was present in our subject but it is not described here because it exceeds the scope of this article. However, it is of genetic origin and may be concomitant with hernia,

often correlated with sleep apnoea (Laska 1980), and occurs more often in women. In rare cases, assimilation of the atlas may cause complete obstruction of the vertebral artery (Sartor et al. 1974), and it is often accompanied by lateral neck cysts and fistulas.

The occipital vertebra (*vertebra occipitalis*), also referred to as the pro-atlas, is an additional vertebra located between the atlas and the occipital bone (Fig. 1). This variation is accompanied by a third condyle (Fig. 2) which may be located at the anterior edge of the foramen magnum and form articulation with the pro-atlas. The third condyle is sometimes mistaken for a detached dens or *os odontoideum*, but these constitute different malformations. This third condyle contributes to foramen magnum stenosis, as occurs with the *os odontoideum*. The occipital vertebra is commonly observed in Down syndrome patients. It is accompanied by atlanto-occipital subluxations, where dislocations of such a poorly stable joint can be life-threatening, even in mild injuries. Symptoms related to this type of malformations include upper limb paresthesias with hypo-aesthesia of digital pulps, other paraesthetic symptoms, distinctive decrease in muscular strength or balance disorders. The basic symptoms of persistent headache and vertigo accompany all these individual pathological changes. A correlation has also been confirmed between cervical vertebrae malformations and cardiac defects (Bajley 1974; Nowiński 2004). It is paramount in clinical practice that these types of changes are submitted to differential diagnosis to distinguish them from fractures occurring in advanced rheumatoid arthritis.

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### Author contribution

HMP initiated the research, examined skeletal material, wrote first version of the manuscript. UW and JW reviewed literature for research and took photos of skeletal malformations. JT examined skeletal material, reviewed and approved the final manuscript.

### Conflict of interests

The authors declare that there is no conflict of interests.

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