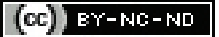


Prevalence and Morphological Characteristics of Occipito-Atlanto-Axial Fusion among South Indian Population: A Cross-sectional Study

KHUSHALI RAI¹, SHARADA B MENASINKAI²

ABSTRACT

Introduction: The anatomy of the cervical vertebrae, along with the atlanto-occipital joint, allows for free flexion, extension and rotation, which occurs almost entirely in the first two cervical vertebrae. Assimilation of the atlas and axis is a rare or uncommon abnormality recorded in anatomical, morphological and radiological studies.

Aim: To determine the prevalence and morphological characteristics of occipito-atlanto-axial fusion in the South Asian population.

Materials and Methods: A cross-sectional study was conducted in the Department of Anatomy at Adichunchanagiri Institute of Medical Sciences, Mandya, Karnataka, India from May 2024 to November 2024. A total of 250 dry skulls were examined for fusion between the occiput and the cervical vertebrae and the findings were recorded. In the skulls that showed fusion, the Anteroposterior (AP) diameter and Transverse Diameter (TD) of the foramen magnum were measured using a Tesa Swiss-made digital vernier caliper accurate to 0.01 mm. Measurements of the diameters of the foramen magnum were recorded in centimeters

and the prevalence of occipito-atlanto-axial fusion was expressed in terms of frequency and percentage.

Results: Out of the 250 skulls, only one exhibited occipito-atlanto-axial fusion (0.4%). The fusion points were at the superior and inferior articular surfaces of the atlas with the occipital condyle and the superior facet of the axis, respectively. The anterior arch of the atlas was not fused in the middle; however, it was fused laterally on the borders of the Foramen Magnum (FM). The AP measurement of the foramen magnum was 3.3 cm and the TD measurement was 3.5 cm.

Conclusion: Understanding the bone fusion between the cranial base and the first and second cervical vertebrae is essential. Such skeletal aberrations may result in sudden unexpected death due to compression of critical structures, such as the brainstem and vertebral arteries. Hence, a detailed understanding of occipitocervical synostosis is important for neurosurgeons and radiologists to prevent and avoid possible complications and achieve optimal operative results.

Keywords: Foramen magnum, Occipitocervical, Synostosis, Vertebrae

INTRODUCTION

Assimilation of the occipital bone, atlas and axis is a rare abnormality recorded in anatomical, morphological and radiological studies. It can lead to various neurological signs and symptoms due to the narrowing of the foramen magnum and compression of the brainstem, cervical part of the spinal cord and vertebral artery, as these structures pass through the foramen magnum [1].

The atlanto-occipital joints are a pair of ellipsoid-type synovial joints. Each joint is formed by the superior articular facets of the lateral mass of the atlas vertebra and the condyle of the occipital bone. The movements permitted at the atlanto-occipital joints are flexion and extension around the transverse axis (nodding) and lateral flexion around the anteroposterior axis (abduction). Hence, they are referred to as the "joints of 'yes'" or "joints of 'no'" expression, respectively [2].

The median atlanto-axial joint is a pivot joint formed by the articulation between the dens (or odontoid process) of the axis and the anterior arch of the atlas. The atlas, carrying the globe of the head, rotates around the dens of the axis. During rotation, the pivot remains fixed while the ring rotates. At the same time, the atlas vertebra descends somewhat onto the axis vertebra while translating at the lateral atlanto-axial joints [2].

The lateral atlanto-axial joints are plane synovial joints formed by the inferior articular facet of the atlas vertebra and the superior articular surface of the axis vertebra. Atlanto-axial fusion could occur due to the ossification of the anterior longitudinal ligament during adulthood [2].

The central arch element (cartilaginous ring) is always wider along its upper border than along its lower border [3].

After birth, the growth of the atlas is rapid. At the end of the first year, the TD was 36 mm and the AP diameter was 20 mm. At the end of the second year, the TD was 42 mm, and the AP was 20 mm. At the end of the third year, the TD was 45 mm and the AP was 26 mm. At the end of the fourth year, the TD was 52 mm and the AP was 30 mm. At the end of the sixth year, the TD was 60 mm and the AP was 30 mm. At the end of the eighth year, the TD was 63 mm and the AP was 47 mm [3]. From this point onward, growth is slower. The average TD of the adult male atlas is 74 mm and the AP is 45 mm. In the average adult female, the TD is 70 mm and the AP is 42 mm [3]. Hence, detailed knowledge of occipitocervical synostosis is important [4]. Hence, present study aimed to determine the prevalence of occipito-atlanto-axial fusion in the South Asian population, predominantly in Southern India.

MATERIALS AND METHODS

A cross-sectional study was conducted in the Department of Anatomy at Adichunchanagiri Institute of Medical Sciences, Mandya, Karnataka, India in Mandya from May 2024 to November 2024.

Inclusion criteria: A total of 250 skulls used for routine osteology demonstration classes for first MBBS students were included in the study.

Exclusion criteria: Broken skulls were excluded from the study.

Study Procedure

The skulls that showed occipito-atlanto-axial fusion were examined. The AP diameter and TD of the foramen magnum were measured using a Tesa Swiss-made digital vernier caliper accurate to 0.01 mm

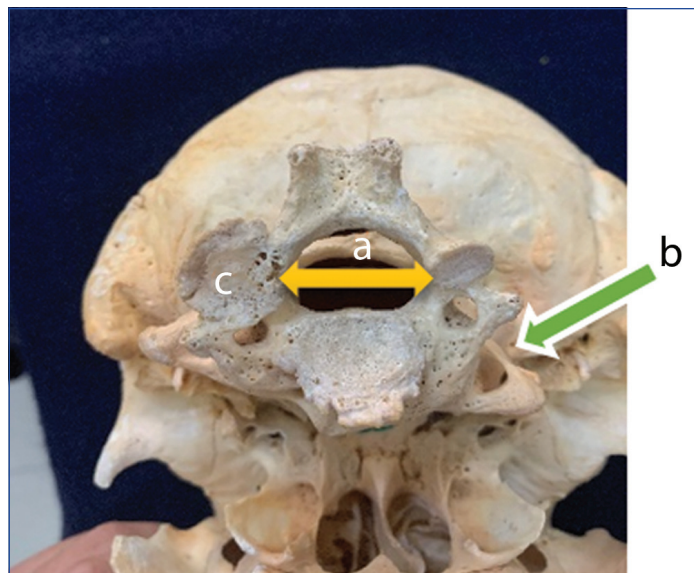
in the skulls that exhibited fusion. The TD was measured directly using the vernier caliper, while the AP measurement was taken by passing a thin straight wire between the small unfused area of the occipital bone and the atlas. The length of the wire was then recorded. The measurements were performed by two different observers and the mean of the two measurements was calculated.

STATISTICAL ANALYSIS

Statistical analysis was conducted using the Statistical Package for the Social Sciences (SPSS) version 20.0. Measurements of the diameters of the foramen magnum were recorded in centimeters, and the prevalence of occipito-atlanto-axial fusion was expressed in terms of frequency and percentage.

RESULTS

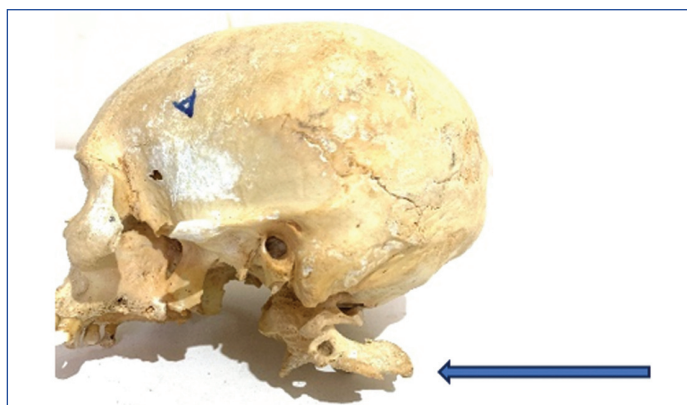
The bones were thoroughly studied, and photographs were taken (see [Table/Fig-1-3]). The following observations were made: The hypoglossal canal was in its normal position. The superior articular facets of the atlas were completely fused with the occipital condyles, as were the inferior articular facets with the superior facets of the axis vertebra. The anterior arch of the atlas vertebra was partially fused with the basi-occiput, leaving a gap between the two bones. The posterior arch of the atlas vertebra exhibited complete non fusion with the occipital bone and, to a certain extent, encroached upon the foramen magnum, dividing it into two compartments. The groove for the vertebral artery was not well defined on both sides. The odontoid process of the axis vertebra was not articulating with the facet on the anterior arch of the atlas vertebra. On the right side, the inferior articular surface of the axis vertebra was rounded and normal, while the left side's inferior articular surface was oval and depressed. The transverse processes of the atlas and axis vertebrae were normally developed and that of the atlas was free from the base of the skull. The foramen transversarium of the axis vertebra was normal on both sides. Measurements of the foramen magnum were recorded: the TD of the foramen magnum was 3.5 cm and the AP diameter was 3.3 cm.



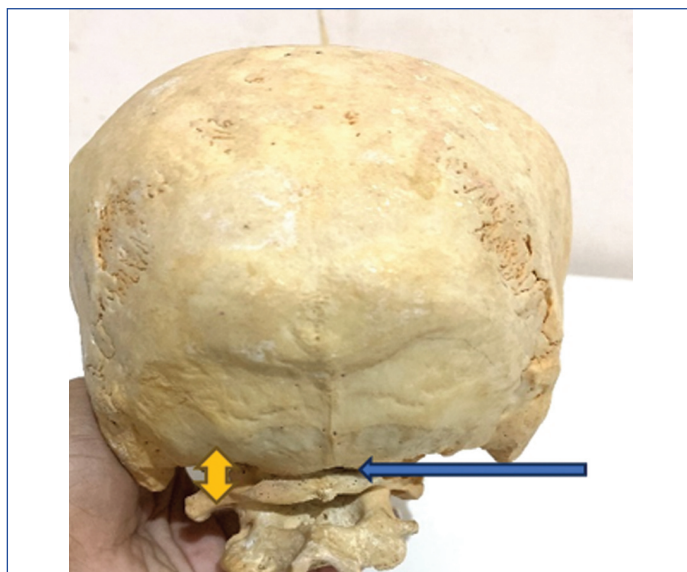
[Table/Fig-1]: Shows the inferior view of the skull: a) Transverse diameter of foramen magnum (yellow arrow); b) The atlas vertebrae is slightly displaced to the right (green arrow) and the axis vertebrae in normal alignment to the atlas; c) The left-side inferior articular surface of the axis vertebra was oval and depressed.

DISCUSSION

While going through the literature, authors did not come across an exactly similar description of the assimilation of the atlas vertebra with the occipital condyles and superior articular facets of the axis vertebra. Present case shows fusion of all three bones with certain asymmetric features. The standard dimensions for the foramen magnum range between 28-38 mm for the sagittal diameter and



[Table/Fig-2]: Shows the lateral view of the skull. The atlas and axis vertebrae are fused at the articular facet of one another, the bifid spinous process of the axis vertebra is seen (blue arrow).



[Table/Fig-3]: Shows the posterior view of the skull. The posterior arch of the atlas shows complete non fusion with occipital bone (blue arrow). Transverse processes not fused (yellow arrow).

between 25-40 mm for the transverse diameter [3]. Hence, in this case, there is less chance of neurologic defect, as the diameter of the foramen magnum is within the normal range; however, there may be an anomaly/compression in the path of the vertebral artery, along with neck rigidity/stiffness.

Embryological basis: The development of definitive vertebrae is intersegmental. The basilar part of the occipital bone is continuous with the precervical sclerotomes. Thus, during embryogenesis, the caudal half of the last occipital sclerotome combines with the rostral half of the first cervical sclerotome to form the skull base. The first cervical vertebra and odontoid process are formed by the fusion of the caudal half of the first cervical and the rostral half of the second cervical sclerotomes. Fusion is the result of disruption during the merging process [5].

Clinical importance: Due to the fusion of the occiput and atlas vertebra, there will be a caudal shift of the mobile segment between the atlas and axis vertebrae. This causes stress and restricts the range of movement. There may be overstretched supporting myoligamentous structures, leading to failure. The stress on the ligaments causes loosening of the atlanto-axial joint and progressive subluxation, with inclination to one side and neck rotation to the opposite side with slight flexion [6].

Occipito-cervical fusion has a varied presentation ranging from asymptomatic features to, neurovascular deficits to sudden death. Hence the knowledge of the condition is important in treatment of patients [7].

The incidence of occipito-atlanto-axial fusion in the present study was compared [Table/Fig-4] [1,8-10].

S. No.	Author year	Country	Sample size	Number of skulls	Observations	AP (cm)	Transverse (cm)	%
1	Mudaliar RP et al., (2013) [1]	Bangalore	200	2	Atlanto occipital fusion	2.5 2.6	2.1 2.9	1
2	Sharma Dk (2017) [8]	Bhopal	192	2	Atlanto occipital fusion	3.3 2.6	2.5 1.9	1
3	Cruz Lbv et al., (2023) [9]	Brazil	117	1	Anterior arc fusion, post arch incomplete fusion	3.3	2.8	0.85
4	Hanusun N HH et al., (2024) [10]	Delhi	24	1	Atlanto occipital fusion	3.2	1.8	4.1
5	Rai K and Menasinkai SB (2025)	South India	250	1	Occipito-atlantoaxial fusion	3.3	3.5	0.4

[Table/Fig-4]: Summary of the findings of the literature about the measurement of foramen magnum and prevalence of Atlanto occipital fusion [1,8-10].

The atlanto-occipital fusion was first described by Rokitansky in 1844 and demonstrated roentgenographically by Schuller in 1911 [11]. According to reports, the incidence of atlanto-occipital fusion ranges from 0.14 to 0.75% of the population [12]. As research has advanced, it has been found that the prevalence ranges from 0.08 to 2.79% of the general population. Males and females are equally affected, but there may be differences among races [13].

Skrzt J et al., reported features of atlanto-occipital fusion, noting that there was complete fusion of the anterior arch and incomplete fusion of the posterior arch in one skull from the Polish population. The AP measurement of the FM was 3.8 cm, and the TD measurement was 3.4 cm [6].

Limitation(s)

The sample size was not sufficient to provide an accurate percentage of fusion of the occiput with the atlas and the fusion of the first and second cervical vertebrae in the South Indian population. The skull bones were collected from our college department museum and from first-year MBBS students; hence, the bones may belong to the local region only.

CONCLUSION(S)

For neurosurgeons handling neurological difficulties resulting from compression of the spinal cord, orthopaedic surgeons dealing with diseases of the upper cervical spine and anaesthetists addressing the causes of failure of cisternal puncture, knowledge of assimilation may be of great relevance. Radiologists who diagnose cervical spine anomalies and physiotherapists who treat neck discomfort also need to be aware of this issue.

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