

**ORIGINAL RESEARCH**

# An Osteological Study of Cervical Vertebral Synostosis with its Embryological Significance & Clinical Implications

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### ABSTRACT

**Introduction:** Inappropriate fusion of adjacent vertebrae results in Block vertebrae or Spinal fusion or vertebral synostosis. It can occur at any vertebral levels from cervical to Sacral. Vertebral synostoses are of interest not only to anatomists but also to radiologists, orthopaedicians, neurologists, forensic pathologist etc. Our aim is to find out the incidence of cervical vertebral synostosis at different levels in cervical region. **Methods:** The present study was conducted on 40 dried adult vertebral columns and 150 dry specimens of assorted cervical vertebrae obtained from the Anatomy department of Medical College Baroda, Vadodara, Gujarat & Teerthanker Mahaveer Medical College, Moradabad. The vertebrae of the cervical regions were studied to see if there is any abnormal fusion between contiguous vertebral bodies, pedicles, laminae, spines or transverse processes. **Results & Observation:** In the present study, two different types of fused Cervical vertebrae were identified. Assimilation of Atlas: Fusion of atlas with occipital bone of Skull and Cervical Vertebral Synostosis at C2-C3 Vertebral level. The features of these block vertebrae were analyzed in detail and photographed from different aspects. The Phylogenetic, embryological, clinical implication and incidences of such synostosis as reported by various authors have been discussed in this paper. **Conclusion:** The block vertebrae in cervical regions of vertebral column can lead to a variety of symptoms or may be asymptomatic, depending upon the degree of compression exerted by them on adjoining structures like spinal nerves, blood vessels or spinal cord. It may cause restricted movements, premature degenerative changes and associated neurological and musculoskeletal abnormalities.

**Key Words:** Cervical Vertebral synostosis, Block Vertebra, Vertebral anomalies, Spinal fusion.

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### INTRODUCTION

Inappropriate fusion of vertebrae results in block vertebrae or spinal fusion or vertebral synostosis. It can occur at any vertebral levels from cervical to sacral. The fusion may be congenital due to incomplete segmentation of sclerotomes at certain levels or may be acquired due to a number of other causes like tuberculosis, juvenile rheumatoid arthritis or trauma [1]. The vertebral fusion was also found to be associated with various congenital syndromes like Klippel-Feil syndrome, fetal alcohol syndrome, Arnold Chiari malformation, Turner and Down's syndromes [2]. 75% of vertebral fusions occur in cervical region [3]. The fused or blocked vertebrae act as a single unit & function as one. Cervical vertebral fusion if accompanied by spinal canal stenosis needs

appropriate treatment and care, to avoid any complications. Comprehensive awareness of the occurrence of the fused cervical vertebrae is must during upper cervical spine surgery and anesthetic procedures.

### MATERIAL AND METHODS

The present study was conducted on 40 dried adult vertebral columns (280 cervical vertebrae) and 150 dry specimens of assorted cervical vertebrae available in the osteology section of Department of Anatomy of Medical College Baroda, Vadodara, Gujarat & Teerthanker Mahaveer Medical College & Research Centre, Moradabad, India. The vertebrae of the cervical regions were studied to see if there is any abnormal fusion between contiguous vertebral bodies,

pedicles, laminae, spines or transverse processes. The base of 60 dry adult human skulls were also observed for the presence of Atlanto-occipital fusion.

All the fused vertebrae & skulls which showed atlanto-occipital fusion were studied in detail and their photographs were taken from anterior, posterior, right lateral and left lateral aspects.

**Inclusion criteria-** All intact adult dry human cervical vertebrae & skull were included.

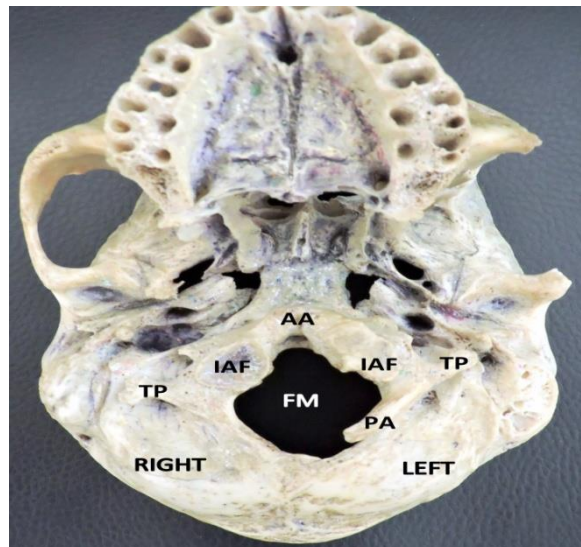
**Exclusion criteria-** Vertebrae with incomplete ossification, neonatal, damaged and broken vertebrae & skull were excluded from the study.

**RESULTS & OBSERVATION**

In the present study we identified 2 specimens of block vertebrae belonging to cervical region among 40 vertebral columns and 150 dry specimens of assorted cervical vertebrae and 60 adult human skulls.

**Assimilation of Atlas: Fusion of atlas & Occipital bone**

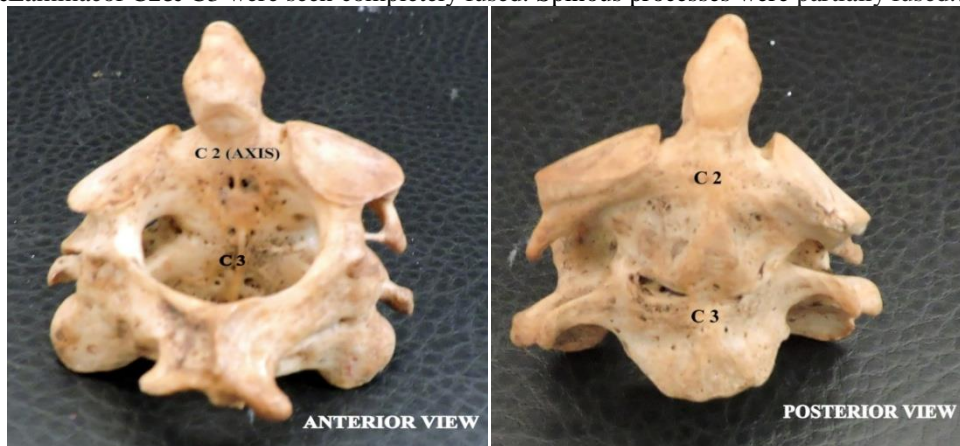
In this case anterior arch of the atlas was well developed & completely fused with the occipital bone. The posterior arch of the atlas was incomplete in the midline, left portion was completely formed & not fused with occipital bone while right portion of the arch was not distinct & merged with occipital bone. The transverse processes of the atlas were not fused to the occipital bone. The lateral masses of the atlas were fully developed and both the left and right superior articular facets of the atlas were completely fused with the corresponding occipital condyles. Inferior view of skull showed inferior articular facet of atlas instead of occipital condyle, Foramen magnum was irregular in shape. The inferior articular facets of the atlas were asymmetrical. Left inferior articular facet was rough and irregular in shape while right inferior articular facet was smooth and oval in shape. (Figure 1)



**Figure 1: Base of Skull with fused atlas vertebrae AA- Anterior Arch, IAF- Inferior Articular Facet, PA- Posterior Arch, TP- Transverse process FM- Foramen Magnum**

**Cervical Vertebral Synostosis**

Cervical Vertebral Synostosis was found at the level of C2-C3 cervical vertebrae. The vertebral bodies, articular processes & Laminae of C2 & C3 were seen completely fused. Spinous processes were partially fused. (Figure 2)



**Figure 2 Anterior & Posterior views of Fusion of C2 - C3 cervical vertebrae**

## DISCUSSION

Kulkarni V [4] found 1 case of Assimilation of Atlas i.e. Fusion of atlas with basiocciput among one hundred and thirty six skulls (0.7%). In this case anterior arch and transverse process of atlas was well developed but posterior arch was totally absent & the occipital condyles of basiocciput were replaced by inferior articular facet of atlas.

Radhika et al(2013) [5] reported 2 cases (1%) skulls which show occipitalization of atlas, out of the 200 adult human dry skulls. In one case posterior arch of the atlas was incomplete in the midline, while in other posterior arch was fully developed.

In the present study we noted only one case of fused atlas with the occipital bone out of 60 skulls, the posterior arch of the atlas was incomplete in our study similar to one case of Radhika[5]. Assimilation of atlas is commonly associated with type A posterior arch defect. & it can be associated with clinical symptoms such as weakness and paresthesia of all four limbs, chronic neck pain and headache. [2]. Kwon et al.( 2009) [2] mentioned various types of posterior arch defect of atlas. Various authors also

reported the Incidence of atlanto-occipital fusion per the literature. (Table no. 1) This is a rare congenital malformation at craniovertebral junction. Its incidence ranges from 0.08%–3% in general population. Occipitocervical synostosis is associated with other skeletal malformations such as Spina bifida of atlas, occipital vertebra, basilar invagination, Klippel-Feil syndrome (fusion of the second and third cervical vertebrae), Arnold Chiari I malformation and cervical stenosis.

Based on the etiology, Swjetschnikow classified three types of atlanto-occipital fusion; [4]

**Acquired type** due to Tuberculosis, Syphilis, Arthritis deformans etc.

**Acquired by fetus in utero** by pelvic pressure, known as Basikyphosis of Virchow.

Schniffner put forward theory called as DRUCK theory stating that “during delivery, pushing inwards of parts of occipital bone around foramen magnum results in Basikyphosis”.

**Purely congenital type** occurring at the time of Sclerotome differentiation; Smith (1907).

**Table no. 1 Incidence of Atlanto-occipital fusion by various Authors**

Sno.	Authors Name	Incidence = No. of cases/ Total no. of skulls studied	Percentage (%)
1	Sharma et al. (2008) [6]	2/70	2.85
2	Hussain Saheb et al. (2010) [7]	1/125	0.80
3	Kassim et al. (2010) [8]	2/55	3.63
4	Seema et al. (2011) [9]	2/100	2
5	Surekha et al. (2012) [10]	1/150	0.67
6	Kulkarni et al. (2012) [4]	1/136	0.7
7	Radhika et al (2013) [5]	2/200	1
8	Ajay Net al (2015) [11]	1/147	0.68
9	D.K.Sharma et al (2017) [12]	2/192	1.04
10	Present Study	1/60	1.67

Soni P(2008) [15] found the incidence of C2-C3 fusion to be 0.4- 0.7%. Sharma M (2013)[16] reported fusion of Upper Cervical vertebrae in 6.25% (3 Cases out of 48 vertebral columns). In one case C1, C2 and C3 vertebrae were seen fused as a single functional unit, with forward displacement of atlas, while in other 2 cases there was fusion between C2 & C3. Mohd Nazeer (2014) [17] found 2 cases of C2-C3 fusion among 2400 vertebrae examined. Ajay et al (2015)[11] mentioned an incidence of 0.36% for the fused C2-C3. Mamata Sar(2017) [18] mentioned a case of complete fusion of C2+C3+C4+C5 vertebral bodies with an anterior concavity and 1 case of C2+C3 among 392 Cervical vertebrae. Paraskevas G K (2019)[19] discovered one specimen of block vertebrae which involved the C2, C3, and C4 vertebrae, among the 93 second cervical vertebrae (axis) derived from different individuals, thus an incidence of 1.08%. Three cases of fused vertebrae were identified at the C2-C3 level by Eirini et al(2023) [20].

In the present study we also found a case of Fusion of C2-C3 cervical vertebrae in which there was complete

fusion of vertebral bodies, articular processes & Laminae.

Congenital Cervical vertebral fusion leads to decrease in length of spine, prominent trapezei, webbed neck, lowered hair line, signs of peripheral nerve compression. It has been noted that up to 70% of atlantooccipital fusions have an associated C2-C3 fusion with instability at the atlantoaxial joint; Soni P(2008)[15].

Somanath Deepa [21] noted a single case of Fusion between typical cervical vertebrae among 50 vertebral columns. Mamata Sar[18] also mentioned 2 cases of fused 2 typical cervical vertebrae. Kulkarni V (2012)[4] mentioned a case of Fused cervical vertebrae at 6th and 7th level, Mohd. Nazeer (2014)[17] also found 2 cases of C6-C7 fusion & 1 case of C7-T1 fusion. The incidence of block vertebrae varied in literature, but is most commonly seen in cervical region.

Meera Jacob [22] found three sets of fused vertebrae among 400 dry specimens of assorted vertebrae. One case of cervico thoracic synostosis, in this C6, C7 and T1 were fused as a single unit.

According to Clarke et al.,(1995) Sequence of presentation of vertebral synostosis is: C5-C6, C1-C2, C4-C5 followed by C6-C7fusion[4].According to Masnicova et al., (2003) prevalence of vertebral synostosis in Lithuanian population is 2.6% of cervical vertebral fusion, 1.6% of thoracic vertebral fusion and 0.5% of Lumbar vertebral fusion[4].

The most frequent area of fusion occurs at the level of the 2nd with the 3rd cervical Vertebrae (CV), thus creating the C2-C3 osseous complex, with a prevalence varying between 0.10% and 1.33%, followed by the fusion of the 5th with the 6th CV [20,24, 25]

### Phylogenetic

Case of congenital vertebral fusion and assimilation of atlas to occipital bone is a further stage of evolutionary process. During transition from fish to amniote, many vertebrae become fused and assimilated to occipital bone. An addition of another vertebra to already absorbed cranium is a feature of amniote cranium. [4]

### Embryological Significance

During fourth week of intrauterine life sclerotome part of somites migrate around the notochord and the neural tube and undergo a process of resegmentation. Any defect in resegmentation can lead to vertebral anomalies causing neurological deficits.

Fused vertebrae or block vertebrae are caused by non-segmentation of the primitive Sclerotome. Atlanto-occipital fusion occurs as a result of failure of segmentation of the first cervical somite into its cranial and caudal components. Consequently, the atlas gets fused into the occipital region, because the fourth occipital somite has fused with the entire first cervical somite and also the cranial portion of the second cervical somite. [5]

According to Cone et al., (1981)developmentally, occipital condyles and articular facets of atlas, tip of odontoid process are derived from proatlas, the cranial portion of 4th occipital sclerotomes. Thus failure of segmentation of the vertebral column results in the occurrence of assimilation of atlas.[4].Posterior arch defect of atlas attributed to failure of development of cartilaginous preformation of atlas. The defect is also associated with syndromes such as KlippelFeil, Arnold Chiarimal formation, Turner and Down's syndromes (Kwon *et al.*, 2009).[2]

### Clinical Implications

Congenital fusion of vertebrae is usually asymptomatic and the anomaly sometimes found incidentally on Radiographs taken for unrelated conditions. Awareness of this anomaly is important for correct diagnosis. The atlanto-occipital fusion may reduce the size of the foramen magnum and may lead to neurological complications due to spinal cord compression.

According to Grilliot et al.(1988).Decreased height of atlas at the time of fusion with occiput is the cause of basilar compression resulting in muscular weakness, ataxia, muscular spasticity and hyperreflexia. [4]A narrowed intervertebral foramen may also cause nerve compression, leading to sensory and motor abnormalities. Subjects with C2-C3 fusion often had symptoms associated with dens dysplasia and occipitocervical instability. Reported symptoms include neck, upper extremity, or cervical axial pain, numbness, tickling, bilateral upper extremity weakness, headaches, and muscle atrophy.

### CONCLUSION

Abnormal fusion of vertebrae in cervical regions of vertebral column can lead to a variety of symptoms or may be asymptomatic, depending upon the degree of compression exerted by them on adjoining structures like spinal nerves, blood vessels or spinal cord. It is associated with genitourinary, neurological and musculoskeletal abnormalities.A detailed knowledge of location, incidence and extent of fusion may assist the neurosurgeon, ENT surgeons, anesthesiologist etc. in preventing possible complications during surgeries in the region and also formulate lifestyle modification plans for the patients so as to avoid injuries of this region.

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