Evaluation of congenital anomalies of craniovertebral junction by computed tomography and its embryological basis

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Abstract
Introduction: Craniovertebral junction (CVJ) is the most complex part of the cervical region. Congenital malformations of this region can cause serious neurological deficit and require a surgical intervention. The present study was undertaken to know the embryological basis of the CVJ and to identify commonly observed congenital CVJ abnormalities, their frequency and mode of presentation.
Materials and Methods: Diagnosed cases of CVJ anomalies on computed tomography (CT) head were reviewed. Type of anomaly, clinical presentation, other associated malformations were recorded. Different types of variations were expressed in terms of percentage.
Result: Congenital anomalies were seen in 26 cases. Fifteen types of anomalies were detected. Anomalies were either singly or in combination. Most common anomaly was basilar invagination (23.8%) followed by atlanto-occipital assimilation (19%). In seven cases additional anomalies of other vertebrae were present. Maximum eight cases were detected in age group of 11-20 years. There was male predominance. Commonest symptoms were weakness of extremities, neck pain, paresthesia, torticollis and gait disturbances.
Conclusion: Congenital CVJ anomalies are rare. To prevent long-term neurological problems, early diagnosis and treatment of congenital bony CVJ anomalies is important.

Keywords: Craniovertebral junction, Congenital, Anomaly.

Introduction
Craniovertebral junction (CVJ) consists of basilar part of occipital bone, atlas and axis vertebra. Being the transit zone between cranium and spine, it is the most complex and dynamic area of the cervical region. It has complex bony anatomy and is related with major neurovascular structures. It shows extensive variability in morphology also. Congenital malformations associated with this region have a potential of causing serious neurological and vascular deficit and may require surgical intervention. The incidence of different types of CVJ anomalies varies with demographic regions & genetic factors. CVJ anomalies are more frequently found in Indian subcontinent than anywhere else in the world.[1] These osseous anomalies can manifest with abnormal cerebrospinal fluid dynamics.[2] Computed Tomography (CT) is the most commonly used modality to assess the CVJ. To identify different anomalies, it is important to understand the embryology and developmental anatomy of the region.

Hence the present study was undertaken to know the embryological basis of the craniovertebral junction and to study commonly observed congenital CVJ abnormalities, their frequency and mode of presentation.

Materials and Methods
A retrospective cross- sectional study was conducted after institutional ethics committee approval at NKP Salve Institute of Medical Sciences and Research Center and Lata Mangeshkar Hospital, Nagpur. CT head reports from January 2008 to December 2015 were analyzed. Diagnosed cases of craniovertebral junction anomalies on CT head were reviewed. Total 26 patients with bony congenital malformations of age eight years and above were included in the study. They were divided into six groups according to the age in decade. Side and type of anomaly, clinical presentation, other associated malformations were recorded. Normal CT reports, CT of patients with history of trauma, tumors, tuberculosis and rheumatoid arthritis were excluded. Craniometric measurements on CT included Chamberlain's line, Mc Rae's line, Mc Gregor's line, Wackenheim's Clivus canal line and Welcher's Basal angle. Magnetic Resonance Imaging (MRI) was done in suspected cases of neurological involvement. Different types of variations were expressed in terms of percentage.

Result
Congenital CVJ anomalies were seen in 26 cases. Fifteen types of anomalies were detected (Table 1). Anomalies seen were either singly or in combination. Most common anomaly was basilar invagination (BI) seen in 23.8% cases (Fig. 1) BI was seen in combination with Atlanto-occipital assimilation (Fig. 2), occipital condylar hypoplasia, ponticulus posticus, atlanto-axial assimilation (Table 2). In seven cases additional anomalies of other vertebrae were present (Table 3). Maximum eight cases were detected in age group of 11-20 years (Table 4). There was male predominance. Anomalies were recorded in 22 males and four females. Commonest symptoms were weakness of extremities, neck pain, paresthesia, torticollis and gait disturbances (Table 5).

Table 1: Different types of CVJ anomalies

S. No	CVJ Anomaly	Number of cases	Percentage
1	Basilar invagination (BI) (Fig. 1)	15	23.8
2	Atlanto-occipital assimilation (AOA) (Fig 2)	12	19.04
3	Incomplete posterior arch of atlas (Fig. 3)	6	9.5
4	C2-C3 Fusion	5	7.9
5	Proatlas/ condylus tertius	4	6.34
6	Os terminale	4	6.34
7	Occipital condyle hypoplasia (OCH)	3	4.76
8	Ponticulus posticus (PP)	3	4.76
9	Hypertrophy of anterior arch of atlas	2	3.1
10	Complete atlantoaxial assimilation (CAAA) (Fig. 4)	2	3.1
11	Platybasia (Fig. 5)	2	3.1
12	Hypoplasia of posterior arch of atlas	2	3.1
13	Os odontoideum	1	1.58
14	Absent lateral mass of atlas	1	1.58
15	C1-C2 dislocation	1	1.58

Table 2: Anomalies in combination with CVJ

Combination	Cases	Percentage
BI +AOA	4	26.6
BI+AOA+OCH	2	13.3
BI+AOA+PP	2	13.3
BI+CAAA+PP	2	13.3

BI= Basilar invagination, AOA= Atlanto-occipital assimilation, OCH= Occipital condyle hypoplasia, PP= Ponticulus posticus, CAAA= Complete atlantoaxial assimilation

Table 3: Associated anomalies with CVJ

Associated anomaly	Number	Percentage
C6-C7 Fusion	2	28.5
Bilateral cervical rib	1	14.2
T2-T3 Fusion	1	14.2
Multiple vertebral anomalies	2	28.5
C3 hemivertebra	1	14.5

Table 4: Number of cases in different age groups

Age group in years	Number of cases	Percentage
8-10	5	19.2
11-20	8	30.7
21-30	3	11.5
31-40	2	7.69
41-50	5	19.2
51-60	3	11.5
Total	26	100

Table 5: Types of symptoms encountered in number of cases

Symptoms	Number of cases	Percentage
Weakness of extremities	12	46.1
Neck pain	9	34.6
Paresthesia	3	11.5
Torticollis	1	3.8
Gait disturbances	1	3.8
Total	26	100

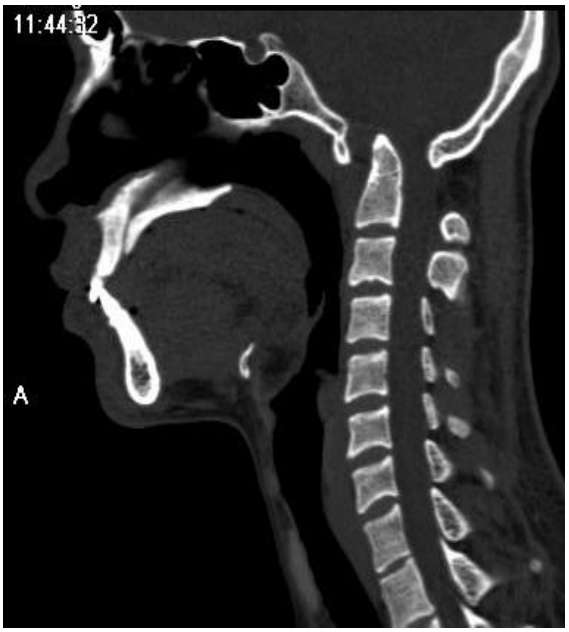

Fig. 1: CT scan showing basilar invagination

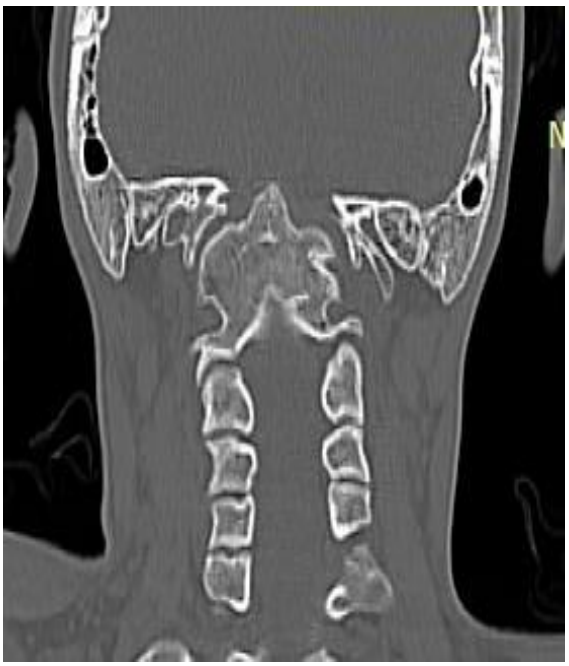

Fig. 2: CT scan showing atlanto occipital assimilation

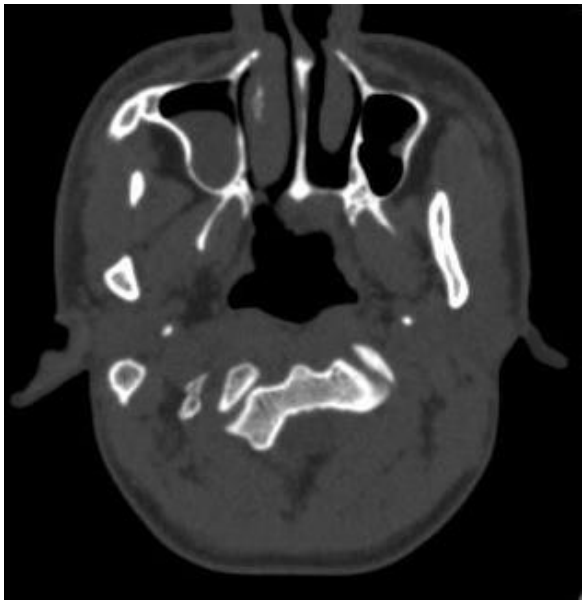

Fig. 3: CT scan showing incomplete posterior arch of atlas

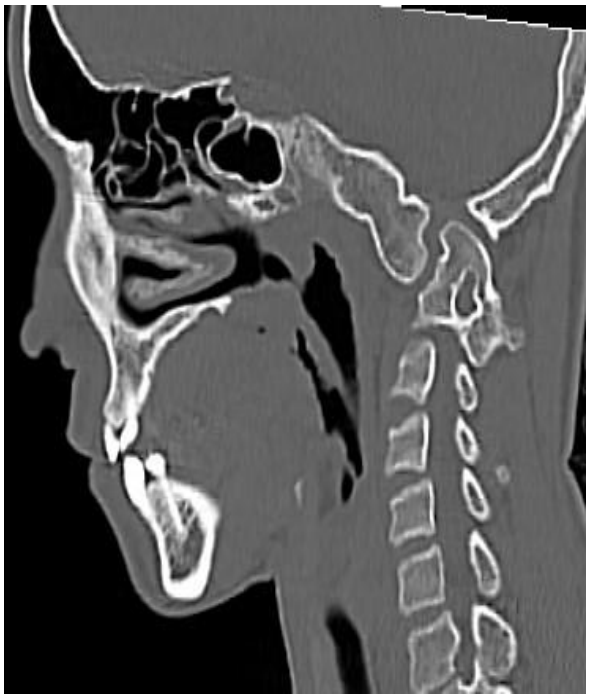

Fig. 4: CT scan showing atlanto axial fusion

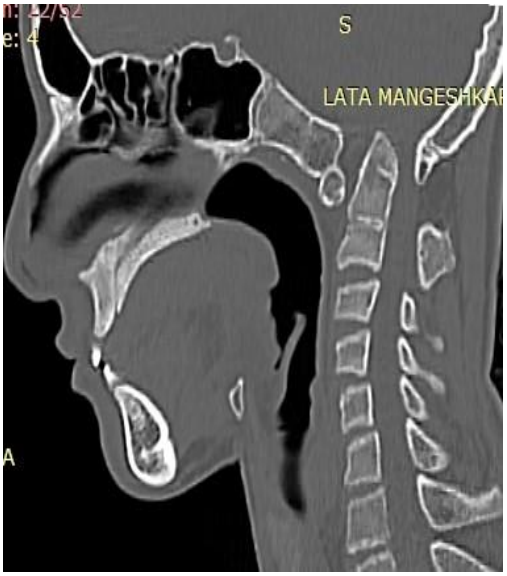

Fig. 5: CT scan showing platybasia with basilar invagination

Discussion

Embryology of CVJ-The vertebral column develops in six separate but overlapping phases. The first phase is gastrulation and the formation of the mesoderm and notochord. In the second phase somites are formed. During third phase somites are reorganized to form dermomyotome and sclerotome. There is resegmentation of the somites to form the definitive vertebrae in fourth phase. This is followed by vertebral chondrification in fifth and vertebral ossification in sixth phase.[3]

Intra-embryonic mesoderm develops in the 3rd week of intrauterine life. It differentiates to form paraxial mesoderm, intermediate cell mass and lateral plate mesoderm. Paraxial mesoderm lies on each side of notochord. The paraxial mesoderm is divided by transverse clefts into cubical blocks, known as somites. There are about 42 pairs of somites in 4th week of development.[4] There are 4 occipital somites, 8 cervical, 12 thoracic, 5 lumbar, 5 sacral, and 8 to 10 coccygeal pairs of somites.[5] Each somite differentiates into ventromedial sclerotome and dorsolateral dermomyotome. The cells of sclerotome migrate ventromedially around notochord to form primitive vertebral bodies.

Each sclerotome is divided by fissure of Ebner into cranial loose and caudal dense cellular area. Fissure of Ebner forms the intervertebral disc.[6] The caudal part of one segment fuses with the cranial part of succeeding segment to form definitive centrum or body of vertebra in the process of resegmentation. The cranial most 4 pairs of somites known as occipital somites are situated by the side of hindbrain. These occipital somites help in the formation of skull. The first and second occipital sclerotomes form the basilar part of occipital bone. The third sclerotome forms exoccipital bone, which develops in the jugular tubercles. Caudal part of 4th occipital somite fuses with cranial half of 5th somite or first cervical to form proatlas sclerotome. The craniovertebral junction abnormalities are caused by abnormalities of resegmentation of the proatlas. The proatlas forms the

anterior tubercle of the clivus, tip of the dens and the apical ligament.[7] The neural arch of the proatlas forms the anterior margin of the foramen magnum, occipital condyle, the lateral atlantal masses and the superior portion of the posterior arch of the atlas. The cruciate ligament and the alar ligaments are derived from the condensations of the lateral part of the proatlas. The caudal half of 5th and cranial part of 6th somite fuse to form C1 resegmented sclerotome, atlas vertebra. Its centrum is fused with the axis body forming the odontoid process. The neural arch of this first cervical sclerotome forms the posterior and inferior portion of the arch of atlas.[8] The caudal half of 6th and cranial half of 7th somites form C2 resegmented sclerotome. The axis body is formed by the centrum and the neural arch forms the facets and the posterior arch of the axis vertebra.[9] The tip of the odontoid process is derived from the proatlas. At birth, the odontoid process is separated from the body of the axis vertebra by a cartilage forming synchondrosis.[8] This synchondrosis is present up to 3 to 4 years of age and is completely ossified by 8 years of age.[10] A separate ossification center appears for the tip of the odontoid at 3 years of age, and fuses with the rest of the dens by 12 years of age.

Resegmentation of sclerotome is under the control of regulatory genes such as Hox and Pax.[11] Variations in vertebral organization are due to imbalance in their genetic expression. Anomalies in the morphology of vertebra can occur due to mutations or teratogenic disturbances in genes. Inactivation of the hox-d3 gene in mutant mice results in atlanto-occipital assimilation.[12] Pax genes are involved in vertebrae formation and contribute to the development of the early nervous system.[13]

Congenital craniovertebral junctional anomaly is a rare condition all over the world and most studies have reported few cases seen over a long period.[14,15] We observed anomalies in 26 patients over a period of eight years. A study at the Kenyatta National Hospital reported 27 patients with same anomalies seen in seven years.[16] In another study 38 patients were seen in the same hospital in next seven years.[17]

The most common congenital anomaly observed in the present study was BI in15 cases. Other study reported the commonest anomaly as BI (48%).[17] BI is due to basioccipital dysgenesis[18] in which the vertebral column remains high and is seen above the margins of foramen magnum.[19] As the basilar part of occipital bone and margins of foramen magnum are less developed, the odontoid process and arch of atlas invaginate resulting in basilar invagination. In four cases (26.6%) BI was associated with atlanto-occipital assimilation. Another study also reported the similar combination in 14.5% cases.[20]

Second most common anomaly observed in the present study was atlanto-occipital assimilation in 12 cases. Mwang'ombe and Kirongo reported occipitalization of the atlas (28%).[17] Congenital fusion of the atlas with the occiput is one of the most common anomalies of the CVJ, with a prevalence rate from 0.08% to 2.8% in the general population.[21] Assimilation of atlas develops due to non-resegmentation of the proatlas sclerotome. It ranges from complete incorporation of the atlas into the occiput to discrete osseous bridges between the two. There is restriction of movements at atlanto-occipital joint. It may be associated with C2- C3 vertebra fusion.[18] Sometimes two or more vertebrae may fuse to giving rise to Klippel-Feil syndrome and occipitalization of atlas.[22] We observed such fusion in five cases.

Other atlas anomalies included two cases each of hypertrophied anterior arch, hypoplastic posterior arch, atlanto-axial fusion, six cases of incomplete posterior arch, absence of lateral mass in one and ponticulus posticus in three. Defects in posterior arch of atlas are ten times more common than defects of anterior arch.[23] Incomplete posterior arch are commonly seen. The gaps never close with age.

We observed platybasia in two cases. Platybasia is the abnormal flattening of skull base due to dysplasia of the occipital segments.[20] Hypoplasia of occipital condyles was seen in three cases in the present study. Hypoplastic condyles results in flattening of skull base which may lead to BI.[24]

According to Menezes and VanGilder condylus tertius or median occipital condyle is observed due to failure of proatlas integration. It is seen as a midline projection in the lower part of clivus along the anterior margin of foramen magnum.[25] Os odontoideum is frequently associated with condylus tertius. We observed condylus tertius or proatlas in four cases.

Os odontoideum was seen in one case. In this odontoid process may remain separate from the body of the axis partially or completely.[22] In four cases Os terminale was seen. The ossiculum is the separated apical portion of dens, which is derived from the proatlas centrum.[26] The detachment is due to failure of upper dental synchondrosis.

In the present study age distribution was from eight to 60 years and most of the patients were diagnosed in second decade with male predominance. In a study of 70 patients by Menezes, 85 to 90% age of presentation was between the first and second decade of life.[2] Other studies reported the same age distribution with male predominance and third decade presentation.[17,20,27]

In our study the complaints were weakness of extremities (46%), neck pain (35%), paresthesia (12%) torticollis (4%) and gait disturbances (4%). Menezes observed spastic quadriparesis as a presenting symptom in 80% of the patients and lower cranial nerve palsies in 33% of the patients. In children with unilateral atlas assimilation torticollis was a presenting symptom.[28] Other studies reported progressive weakness of the extremities as a commonest mode of presentation.[17,27] Few cases were presented with speech disturbance also.[17]

Conclusion

Congenital craniovertebral junctional anomalies are rare. Early diagnosis and treatment form the mainstay in preventing long term neurological complications. CT is the investigation of choice for diagnosis and planning the management. CT complemented with MRI is recommended for associated neurological involvement.

Conflict of Interest: None.

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