Section: Radiology

Original Research Article

PROSPECTIVE STUDY OF RADIOLOGICAL EVALUATION AND EMBRYOLOGY-BASED CLASSIFICATION OF CRANIOVERTEBRAL JUNCTION (CVJ) ANOMALIES AT A TERTIARY CARE CENTRE

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ABSTRACT

Background: The craniovertebral junction (CVJ) represents a complex anatomical region forming the transition between the skull base and cervical spine. It is prone to a spectrum of congenital, developmental, and acquired abnormalities that may result in significant neurological compromise. The aim is to evaluate and classify cranio-vertebral junction (CVJ) anomalies using radiological imaging modalities and to assess their anatomical variations, embryological basis, and potential clinical implications.

Materials and Methods: This prospective study was conducted over a period of 12 months (September 2024 to August 2025) with a sample size of 30 patients. Imaging was performed using 16-slice GE & 80 slice united CT 520 and 1.5 T GE MRI. Both symptomatic patients and incidental findings were included.

Results: Out of 30 cases, 16 were traumatic and 14 were non-traumatic. Among traumatic cases, 10 were symptomatic and 6 asymptomatic. Among non-traumatic cases, 4 were symptomatic and 10 asymptomatic. The most common anomaly was platybasia (26%), followed by dens fractures (23%), basilar invagination (20%), odontoid dysgenesis (16%), hypochordal bow anomalies (8%), and basilar impression (7%).

Conclusion: Embryology-based classification of CVJ anomalies enhances diagnostic accuracy and guides appropriate management strategies.

Keywords: Craniovertebral junction (CVJ) anomalies, Basilar invagination, Atlanto-occipital assimilation, Atlanto-axial instability, Os odontoideum, Cranio-vertebral junction embryology, Cervico-medullary compression.

INTRODUCTION

The craniovertebral junction (CVJ) is a highly specialized anatomical region comprising the occipital bone, atlas (C1), and axis (C2), along with associated neural and ligamentous structures. It serves as a transition zone between the mobile cranium and relatively rigid cervical spine.[1-7]

Due to its complex embryological development and biomechanical significance, the CVJ is vulnerable to a wide range of abnormalities. These include congenital malformations, developmental anomalies, and acquired conditions such as trauma. Accurate diagnosis of these conditions is crucial, as they may lead to instability, neural compression and significant morbidity.[1,2,5]

Advances in imaging modalities, particularly CT and MRI, have significantly improved the detection and characterization of CVJ anomalies. An embryological understanding allows better classification of these anomalies into central pillar and surrounding ring abnormalities, aiding in precise diagnosis and management.[2,4,8,9]

Aim and Objectives

Aim

To evaluate and classify cranio-vertebral junction (CVJ) anomalies using radiological imaging modalities and to assess their anatomical variations, embryological basis, and potential clinical implications.

Objectives

1. To identify and document various CVJ anomalies using radiological techniques including CT, and MRI.
2. To classify CVJ anomalies based on embryological origin, anatomical structures involved (bony, neural, ligamentous), and clinical significance (stable vs unstable).
3. To correlate radiological findings with clinical presentations such as neurological deficits, signs of brainstem or spinal cord compression, or craniofacial deformities in symptomatic patients.

MATERIALS AND METHODS

Study Design: Prospective observational study of CVJ anomalies in patients referred for head & neck and spine imaging to department of Radiodiagnosis

Study Period: 12 months (September 2024 – August 2025)

Sample Size: 30 patients

Imaging Modalities

- 16 slice GE & 80 slice united CT 520 and 1.5 T GE MRI
- CT IMAGING: Axial sections of the required part acquired and post processed using MPR reconstruction.
- MRI IMAGING: Sagittal, Coronal and Axial sections of T1, T2, STIR & FLAIR sequences studied.

Inclusion Criteria

- Patients with clinical suspicion of CVJ pathology
- Patients undergoing CT/MRI cervical spine including CVJ
- Incidental detection of CVJ anomalies

Exclusion Criteria

- Patients with incomplete imaging data
- Post-operative cases (if not evaluable)
- Contraindications for both CT & MRI imaging.

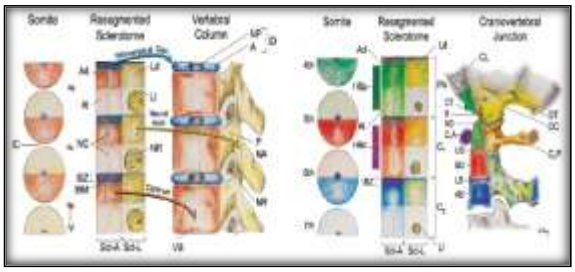
Embryological Basis

The CVJ develops through a complex process of segmentation and resegmentation of occipital and cervical somites. The proatlas, derived from the fourth occipital and fifth somite, contributes to structures such as the basiocciput, apical dens, and occipital condyles.[2,3,7]

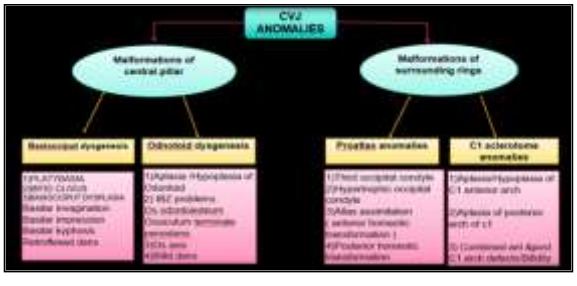
The atlas (C1) and axis (C2) arise from subsequent somites. Disruptions in these processes lead to anomalies categorized into:[2,3]

- Central pillar abnormalities (basiocciput, dens)
- Surrounding ring abnormalities (occipital condyles, atlas ring)

Primordia and their vertebral phenotypes are colour-matched



- Intersomiticcleft (IC). axial sclerotome (Scl-A) , lateral sclerotome (Scl-L) dense zone of the lateral sclerotome (Ld),neural arch (NA) pedicle (P), vertebral body (VB), the loose (Al) ,dense zones (Ad) of the axial sclerotome,Intervertebral boundary zone (IBZ) ,intervertebral boundary mesenchyme (IBM), annulus (A),notochord (NC),nucleus pulposus (NP) , intervertebral disc (ID), loose zone of the lateral sclerotome (Ll),nerve roots (NR).
- Axial sclerotome dense zone (Ad), axial sclerotome loose zone (AI) lateral sclerotome dense zone (Ld), Hypochordal boe of Proatlas (HBp), Hypochordal bow of C1 (HBc), Proatlas (PA), clivus (CL), Clivus tubercle (CT), opisthion (OT) Occipital condyle (OC), Anterior arch of atlas (C1A) posterior arch of atlas (C1P), upper synchondrosis (US),lower synchondrosis (LS) apical segment of dense (AD),basal segment of dense (BD) C2 vertebral body (AB).



RESULTS

Table 1: A total of 30 cases were evaluated:

Category	Symptomatic	Asymptomatic	Total
Traumatic	10	6	16
Non-traumatic	4	10	14

Table 2: Prevalence of CVJ Anomalies

Anomaly	Percentage
Platybasia	26%
Dens fractures	23%

Basilar invagination	20%
Odontoid dysgenesis	16%
Hypochordal bow anomalies	8%
Basilar impression	7%

DISCUSSION

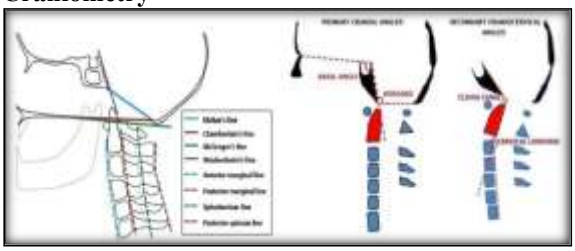
The CVJ is structurally and functionally divided into a central pillar and surrounding ring system. These components arise from distinct embryological origins, which explains the diversity of anomalies encountered.[2,3]

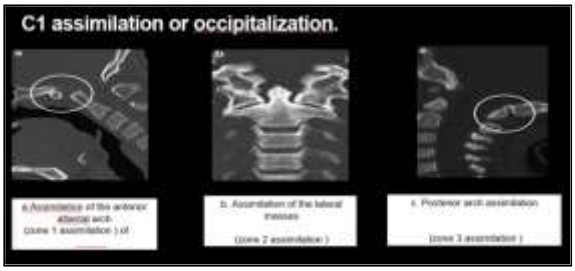
In this study, both congenital and acquired abnormalities were identified. Developmental anomalies such as platybasia, basilar invagination, and odontoid dysgenesis were common. Acquired conditions, particularly traumatic dens fractures, also constituted a significant proportion.[1,5]

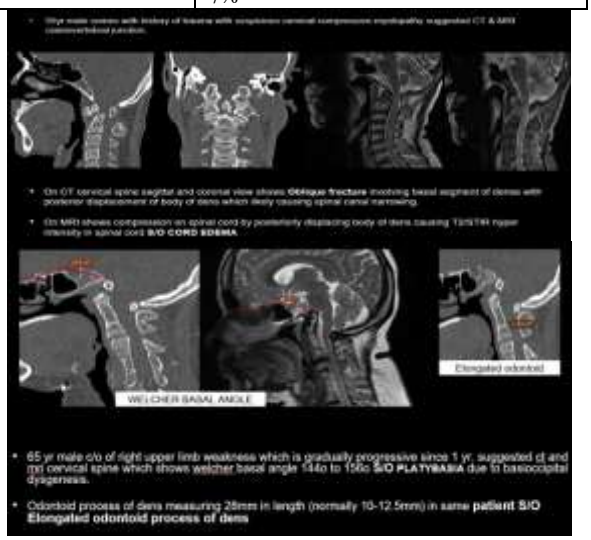
Embryology-based classification provides a logical framework for understanding these anomalies. Disturbances in axial components result in central pillar malformations such as basioccipital dysgenesis, whereas abnormalities in lateral components and hypochordal bows lead to ring anomalies such as atlas assimilation and arch defects.[2,3]

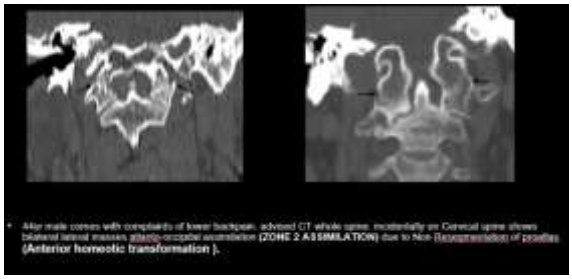
Radiological evaluation using CT and MRI plays a crucial role in diagnosis. CT provides excellent bony detail, while MRI is essential for assessing neural compression and cord signal changes.[4,8,9]

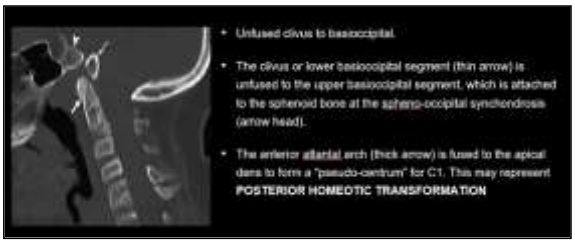
Craniometry

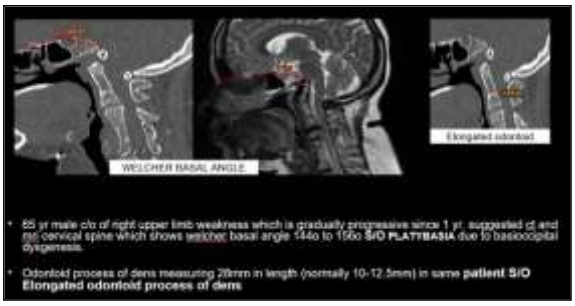








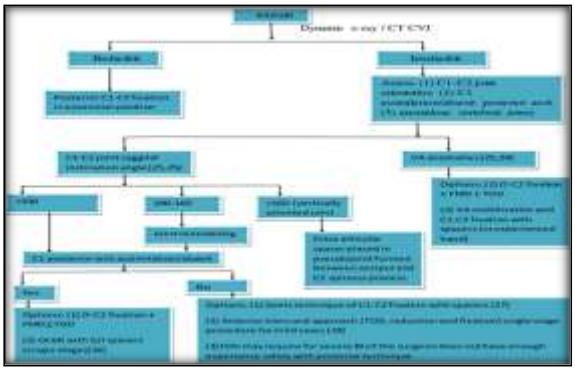




Management

Management of CVJ anomalies depends on the type and severity of the condition:

- Conservative management for asymptomatic or stable anomalies
- Surgical intervention in cases of instability or neural compression
- Multidisciplinary approach involving radiologists, neurosurgeons, and orthopedic specialists



CONCLUSION

Embryology-based classification of craniovertebral junction anomalies is essential for accurate diagnosis and effective management. Developmental anomalies constitute a significant proportion of CVJ abnormalities.

Radiological imaging, particularly CT and MRI, plays a pivotal role in identifying these conditions and guiding treatment strategies. Early and precise diagnosis can prevent serious neurological complications.

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