ORIGINAL RESEARCH PAPER
Volume - 14 | Issue - 01 | January - 2025 | PRINT ISSN No. 2277 - 8179 | DOI : 10.36106/ijsr
INTERNATIONAL JOURNAL OF SCIENTIFIC RESEARCH

A RETROSPECTIVE SINGLE-CENTER STUDY CONDUCTED IN INDIA EXAMINING THE CLINICAL AND RADIOLOGICAL OUTCOMES OF A POSTERIOR SURGICAL APPROACH FOR CRANIOVERTEBRAL JUNCTION ANOMALIES.

Neurosurgery

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ABSTRACT

Introduction: The craniovertebral junction (CVJ) comprises the basilar portion of the occipital bone, along with the atlas and axis vertebrae. The instability of the craniovertebral junction (CVJ) and the atlantoaxial complex presents significant diagnostic and therapeutic challenges, primarily due to their intricate anatomical configurations and biomechanical properties. Such injuries can lead to immediate fatal outcomes or a gradual decline in neurological function. **Objective:** Craniovertebral junction disorders, while regarded as uncommon, are frequently observed in the northern regions of India. This retrospective study aims to examine the clinical and radiological characteristics of these patients and evaluate the fusion rates associated with various techniques used in posterior fusion for CVJ disorders. **Material and Method:** This study conducted on 30 cases of craniovertebral junction (CVJ) anomalies at RNT Medical College Udaipur, Rajasthan, India, during the period from May 2022 to August 2024. Patients were assessed based on their age, sex, clinical features, radiological diagnoses, and the treatments they received. Both preoperative and Postoperative radiological evaluations included measurements of the atlanto-dens interval (ADI), atlanto-axial heights (in mm), and the clivus canal angle. The clinical condition of the patients was evaluated both before and after surgery at six and twelve months using the Visual Analog Scale (VAS) and the Modified Japanese Orthopedic Association (mJOA) score. **Result:** The study included participants aged between 10 and 80 years, with a mean age of 38.8 ± 5.9 years. Among the subjects, there were 22 males and 8 females, resulting in a male-to-female ratio of 2.75:1. The cohort comprised 17 cases of congenital atlantoaxial dislocation (AAD) and 14 cases of traumatic AAD. A significant proportion of the patients (n = 25; 83.33%) presented with myelopathy, followed by neck pain (n = 22; 73.33%) and restricted neck movement (n = 19; 63.33%), with lower cranial nerve involvement noted in 17 patients (56.6%). Surgical interventions included C1 lateral mass with C2 pedicle screw placement in 12 patients (40%) and C1 lateral mass with C2 pars screw placement in 6 patients (20%), tailored to individual anatomical considerations and safety. Postoperatively, the atlanto-dental interval (ADI) increased from 6.55 ± 1.50 mm to 3.11 ± 0.82 mm. Additionally, improvements in the craniovertebral angle were observed in all patients after surgery. The mean A-A height increased from 36.54 ± 7.02 mm to 39.66 ± 6.55 mm postoperatively, while the clivus canal dimensions improved from 134.32 ± 6.54 mm to 145.38 ± 3.76 mm. Clinically, the modified Japanese Orthopaedic Association (mJOA) score showed an enhancement from 9.2 ± 2.2 to 14.9 ± 3.6, and the Visual Analog Scale (VAS) score decreased from 6.3 ± 1.78 to 1.8 ± 1.27 at the most recent follow-up at 12 months. In a review of 30 cases, 24 demonstrated positive outcomes, 4 were stabilized, and neurological deterioration was observed in 2 cases after 12 months. **Conclusion:** Thorough preoperative assessment and the selection of tailored surgical techniques were crucial for achieving outstanding clinical and radiological outcomes.

KEYWORDS

Atlanto-axial dislocation, clivus angle, craniovertebral junction, Lateral mass

INTRODUCTION

The craniovertebral junction (CVJ) comprises the basilar portion of the occipital bone, along with the atlas and axis vertebrae. Serving as the transitional area between the skull and the spine, it represents the most intricate and dynamic segment of the cervical region. This area features a complex bony structure and is closely associated with significant neurovascular components, exhibiting considerable variability in its morphology. The instability of the craniovertebral junction (CVJ) and the atlantoaxial complex presents significant diagnostic and therapeutic challenges, primarily due to their intricate anatomical configurations and biomechanical properties. Such injuries can lead to immediate fatal outcomes or a gradual decline in neurological function[4,5]. CVJ disorders are prevalent in the Indian subcontinent, especially in northern India, where our centre frequently treats such cases[8]. This retrospective study aims to examine the clinical and radiological characteristics of these patients and evaluate the fusion rates associated with various techniques used in posterior fusion for CVJ disorders.

MATERIAL AND METHODS

A retrospective analysis was conducted on 30 cases of craniovertebral junction (CVJ) anomalies. All patient underwent preoperative skull traction with help of Gardner and Well tong with posterior fixation technique. Among them 22 cases were males and 8 cases were female, that were surgically treated at RNT Medical College Udaipur, Rajasthan, India, during the period from May 2022 to August 2024. The study included all CVJ anomaly cases that underwent surgery within this timeframe, provided they had a minimum follow-up of 12 months. Inclusion criteria in our study are: 1) Informed consent; 2) Age is between 10-80 years; 3) Reducible/partially reducible joints; 4) Complaint of neck pain and associated neurological characteristics(defects); 5) Radiological examination verifies the existence of a CVJ anomaly; 6) Atleast one year follow-up. Patients were excluded if they lacked complete follow-up data, had a follow-up duration of less than one year, Irreducible joints and presented with an atlantoaxial infection and tumor. Patient were evaluated for age, sex, clinical characteristics, radiological diagnosis, and the treatments administered. Preoperative radiological assessments included atlanto-dens interval (ADI) and Atlanto-Axial heights (mm) and clivus canal angle. All parameters were defined according to standard definitions. At the 6 and 12 month postoperative follow-up, computerized tomography (CT) scans of the CVJ region were performed for each case, allowing for a reassessment of the bone fusion between C1 and C2, ADI, A-A height and craniobasal angles. Solid fusion was characterized by the presence of continuous bony trabecular structures observed in CT scans or by less than 2 mm of movement between segments in the flexion-extension view. Non-union was identified by the presence of a visible gap, graft collapse evident in CT scans, or more than 2 mm of movement on flexion-extension radiographs. The clinical status of patients was assessed both preoperatively and postoperatively at,six and twelve months using the Visual Analog

Scale (VAS) and Modified Japanese Orthopedic Association (Mjoa) score.

Statistical Analysis

The statistical analysis was conducted using the trial version 20 of the SPSS software package for Windows (SPSS Inc., Chicago, Illinois, United States). Demographic data were examined at two levels: descriptive and analytical. The characteristics of the study participants were described using frequency, percentage, range, and means. Categorical data were reported as numbers along with their corresponding percentages.

Surgical Technique

Among the 30 cases analyzed, all cases underwent posterior reduction, internal fixation, fusion and decompression procedures. In posterior fixation techniques, the C1-C2 joint was accessed, distracted with help of Gardner Well tong preoperatively, and the articular cartilage was drilled, followed by the placement of bone grafts. In the cohort of 30 cases receiving posterior fixation, different surgical approaches done as per patient's anatomy, etiology and safety. In our research, we primarily employed pedicle screws for internal fixation but few patients were also treated with C1 lateral mass and C2 pars screw fixation to address reducible atlantoaxial dislocation (AAD) especially in elderly patients, due to the abnormal and fragile vertebral bone caused by osteoporosis, the use of pedicle screws will have a high risk of VA injury, while short pars screws are usually used when the VA is abnormal or pedicle screw fixation is used when the risk is too high, which indicates that it has become the screw of choice for patients with challenging VA anatomy. Other different posterior fixation approaches like C1 lateral mass and C2 translaminar fixation, C1 lateral mass and right C2 pedicle screw fixation and left C2 pars screw fixation while, C1 lateral mass and right C2 pars screw fixation and left C2 pedicle screw fixation.O-C2 fixation was performed where C1-C2 subluxation was accompanied by C1 anomalies (such as assimilation or absent posterior arch) and atypical C1-C2 joint anatomies (including vertically oriented or deformed joints). This approach was also applied in cases where an abnormal vertebral artery course was identified through preoperative angiography.

RESULT

A total of 30 cases were analysed in this investigation, out of them 22 are male and 8 are female with ratio 2.75:1 and most of patient were in age group between 20-40 years(46.6%)with mean age 38.86±5.9(Table1) Regarding the underlying causes and associated anamolies, the cohort included 17(56.6%) individuals with congenital AAD,13(43.3 %) with traumatic AAD, 14(46.6%) with basilar invagination (BI), 12(40%) with C1 assimilation traumatic odontoid fracture in 8(26.6%) individuals, 4(13.3%) with C2-C3 fusion(Table-2). Myelopathy emerged as the predominant symptom in our investigation(n=25;83.3%) followed by neck pain(n=22;73.3%), restricted neck movement (n=19;63.3%), lower cranial nerve involvement(n=17;56.6%), cerebellar sign (n=14;46.6%)(Table-3).Table-4 illustrated different posterior reduction and internal fixation and fusion technique in our patients as per patients etiology, surgical anatomy and safety. The average duration of surgery was 288.13± 30.36 minutes (ranging from 240 to 355 minutes). A satisfactory postoperative outcome was achieved in 28 patients, with notable neurological improvements observed. Bone fusion was confirmed on midline sagittal reconstructed CT images during the latest follow-up in all but one patient. The average follow-up period for all patients was 12.84 ± 1.86 months. Table 5 illustrates the radiological alterations observed in both the preoperative and postoperative phases. The mean atlanto-dental interval (ADI) was 6.55 ± 1.50 mm preoperatively, which improved to 3.02 ± 1.21 mm postoperatively, and further to 3.11 ± 0.82mm at the latest follow-up. The mean A-A height was 36.54 ± 7.02 mm preoperatively, rising to 41.03 ± 8.3 mm postoperatively, and then to 39.66 ± 6.55 mm at the latest follow-up. Prior to surgery, the angle of the clivus canal was measured to be more acute, with a mean of 134.32 ± 6.5433, in contrast to the postoperative period, where it was recorded at 145.2897 ± 4.2804, and then to 145.3829± 3.7631. A reduction in the anterior-posterior diameter of the atlas-dens interval (ADI) alongside an elevation in the A-A height and the angle of the clivus canal indicates a postoperative decrease in the ventral compression of the spinal cord. Table 6 illustrates the clinical alterations observed during the preoperative and postoperative phases. Assessment done with Modified Japanese Orthopaedic Association(Mjoa)score. The recovery rate in cervical cases is calculated using the formula: [(postoperative score – preoperative score) / (17 – preoperative score)] × 100%. Surgical outcomes were categorized into two distinct groups: those with favourable outcomes, defined as patients achieving a recovery rate of the Mjoa score exceeding 40%, and those with unfavourable outcomes, characterized by a recovery rate below 40%.C-JOA score significantly improved after intervention from 9.2±2.2 to 14.5±3.1 post operatively with recovery rate 50.1±20.4 %, further to 14.9 ± 3.6 with recovery rate 52.2±21.8% at the latest follow-up. Clinically, there was a notable reduction in neck pain postoperatively, as assessed by the Visual Analog Scale (VAS) in our research, significantly improved after intervention from 6.3 ±1.78 to 2.1±1.42 post operatively, further to 1.8 ± 1.27 at the latest follow-up.

In our study, we observed several complications, pain at the bone harvest site (n=2; 6.6%), cerebrospinal fluid (CSF) leak (n=3; 10%), neurological deterioration (n=2; 6.6%), and wound infection (n=2; 6.6%) (Table-7).

DISCUSSION

In our investigation, we conducted a retrospective analysis of clinical and radiological outcomes associated with CVJ anomalies utilizing various fixation techniques, supported by intraoperative skull traction. Wang et al. demonstrated the effectiveness of employing skull traction while the patient is under general anaesthesia for the purpose of reduction[26]. The primary objectives of surgical intervention for patients with craniovertebral junction (CVJ) anomalies are to alleviate compression and to ensure stabilization of the CVJ. In many instances, both objectives can be accomplished through a single posterior midline approach. Traditionally, atlantoaxial instability has been managed through posterior wire stabilization combined with structural bone grafting, employing techniques such as the Gallie or Brooks methods however, recent studies have demonstrated that rigid screw fixation yields superior outcomes[1]. Guoxin Fan et al. also demonstrate the application of pedicle screws in addressing spinal deformities has facilitated a more significant correction of curvature in comparison to systems that utilize hooks, sublaminar wires, or hybrid constructs[6]. In our research, we employ polyaxial screws rather than monoaxial screws. Wan et al. also employ a comparable screw for the correction of the sagittal view[25]. The clinical symptoms frequently emerge later, typically in the second and third decades of life, as they tend to be subtle and can be overlooked in children unless specifically investigated[14].In our study most of patient were also lies in age group between 20-40 years (46.6%) followed by age group between 40-60 years (26.6%). In our research, the male to female ratio is 2.75:1, a finding that aligns with the results reported by Prajapati HP et al. in their study[18]. Martinez-Del-Campo et al. indicated that the average age in their study was 39.9 years[15].

CVJ disease was characterized by various bony anomalies. In our research, the prevalent bony CVJ anomalies included congenital AAD (n = 17; 56.6%), traumatic AAD (n = 13; 43.3%), basilar invagination (BI) (n = 14; 46.6%), assimilation of the atlas (n = 12; 40%), and odontoid fractures (n = 8; 26.6%). So congenital AAD was observed to be more prevalent in our research, with traumatic causes following closely behind[16]. This finding aligns with the results reported by Bhagwati et al. in their investigation[3]. Our findings indicated that congenital AAD was most frequently associated with BI, and C1 assimilation, a conclusion that aligns with the findings of Shankar et al. in their [study7,21]. Ravikanth et al. also identified comparable characteristics in their research[20]. In our research, we found that the majority of traumatic atlantoaxial dislocations (AAD) are linked to odontoid fractures, particularly type 2 fractures, and that their prevalence tends to rise with advancing age[23]. Asemota et al. similar statics for traumatic injuries[2]. In our study, the most frequently observed symptoms included myelopathy (n=25; 83.3%) followed by neck pain (n=22; 73.3%), limited neck mobility (n=19; 63.3%), lower cranial nerve involvement (n=17; 56.3%), cerebellar signs (n=14; 46.6%), and a low hairline (n=8; 26.6%). In our study, the most common symptom observed was weakness in all four limbs accompanied by difficulty in walking. This is likely attributed to patients presenting late at a tertiary care facility for comprehensive treatment within our Indian context. A study conducted by S. Vazquez et al. reported similar findings, with weakness identified as the most prevalent symptom in 84.6% of their patients with paresthesia followed by neck pain in 58.5% of cases[24]. Yang et al. found that 70% of their patients experienced numbness, while 50% reported neck pain, which aligns with our findings[28].

The development of C2 screw internal fixation technology has significantly enhanced the surgical management of upper cervical spine disorders. C2 pedicle screws and pars screws are frequently regarded as the preferred methods for internal fixation during posterior procedures involving the upper cervical spine[10]. Biomechanical research conducted previously indicated that pedicle screws exhibited a higher insertional circulatory strength compared to pars screws, but utilization of pedicle screws notably increases the likelihood of vertebral artery injury in patients with vertebral artery anomalies, particularly when a high-riding vertebral artery is present[13]. Despite their robust anchoring capabilities, pars screws may serve as an alternative in such scenarios[22]. In our study, we utilized C1 lateral mass screws in conjunction with C2 pedicle screws in 12 patients, accounting for 40% of the total. Additionally, C2 pars screws were used in 6 patients, representing 20% where C2 pedicle screw placement is not feasible[17]. In cases where C1-C2 fixation is not possible, such as in C1 assimilation, the absence of the posterior arch of C1, or a fractured posterior arch of C1, we prefer to perform occipito-axial fusion utilizing screws and rods for stabilization. 20% of our patients are treated using this approach. Joaquim et al. provide insights into the specifics of the occipitocervical fixation (OCF) technique, along with important factors to consider when planning the procedure[12].

We evaluated outcomes of the patients through radiological assessments of the Atlanto-Dental Interval (ADI), Atlanto-Axial height, and clivus angle. In our research, we observed a notable enhancement in neurological function following the intervention. Bone fusion was successfully attained in all patients. The average ADI value was recorded at 6.55 ± 1.50 mm preoperatively, which improved to 3.11 ± 0.82 mm during the most recent follow-up. Additionally, the mean A-A height was 36.54 ± 7.02 mm preoperatively, increasing to 39.66 ± 6.55 mm at the latest follow-up. These values can be compared to the research conducted by Guo J et al., where they considered ADI and A-A height as part of the radiological evaluation[9]. The study conducted by Yamada T. et al. demonstrated a significant decrease in the postoperative ADI, which dropped from 8.6 mm to 3.8 mm in the group with favourable outcomes following fixation[27]. A study by Prajapati HP et al. demonstrates an improvement in the clivus angle, increasing from 131.02 ± 7.7 to 146.32 ± 5.3 following intervention, which aligns with the findings of our research[19]. Clinically, we based our evaluation on the C Japanese Orthopaedic Association (JOA) score and the Visual Analogue Scale (VAS) at both preoperative and postoperative stages. C-JOA score significantly improved after intervention from 9.2±2.2 to 14.9 ± 3.6 at the latest follow-up. In the study conducted by Jeon SW et al., the mean Visual Analog Scale (VAS) scores were recorded as 6.5 preoperatively and 2.4 postoperatively[11]. Additionally, the Japanese Orthopaedic Association (JOA) scores were 13.6 before the operation and 14.6 after the operation. Visual Analog Scale (VAS) scores were recorded as 6.3±1.78 preoperatively and 1.8±1.27 at latest follow up period in our study. Positive results were observed in 22 cases, representing 73.3% of the total. Additionally, 6 cases, or 20.00%, exhibited stabilization, while 2 cases accounting for 6.66%, experienced a decline in condition.

In our study, we observed complications such as pain from iliac crest harvesting (n = 2; 6.66%), cerebrospinal fluid (CSF) leaks (n = 3; 10%), wound infections (n = 2; 6.66%), and neurological deficits (n = 2; 6.66%).

This research faced several limitations. Firstly, it was a retrospective study rather than a randomized case-control study, which may weaken the strength of the conclusions drawn. Secondly, the sample size was relatively small, and the study was conducted at a single center. Additionally, the range of etiologies among the patients was restricted, as cases involving irreducible anomalies, infections, and tumors were not considered. The majority of the cases were attributed to odontoid fractures, which could skew the findings and limit their applicability to other conditions. Furthermore, the duration of follow-up was insufficient. Future research should aim for longer follow-up periods, utilize randomized case-control designs, and involve multiple centers.

CONCLUSION

Congenital anomalies of the craniovertebral junction (CVJ) were identified as the predominant lesions affecting this area, with a significant number of cases occurring in individuals aged 20 to 40 years who presented late to medical facilities. The majority of patients exhibited symptoms such as myelopathy, neck pain, and limited neck mobility. Fortunately, most cases resulted in positive clinical and radiological outcomes. It is essential to conduct thorough preoperative assessments and choose tailored surgical techniques to minimize the risk of complications.

Table 1: Distribution of Age & Sex

Age groups (in years)		Numbers (%)
0-20		4(13.3)
20-40		14(46.6)
40-60		8(26.6)
60-80		4(13.3)
SEX	Male	22(73.3)
	Female	8(26.6)

Table 2: Etiology and Diagnosis

Type of CVJ anomaly	Number (%)
1. Congenital AAD	17(56.6)
2. Traumatic ADD	13(43.3)
3. Odontoid fracture	8(26.6)
4. Basilar invagination	14(46.6)
5. C1 Assimilation	12(40)
6. C2-C3 fusion	4(13.3)

Table 3: Clinical Features

Symptoms	Number (%)
1. Myelopathy	25(83.3)
2. Neck pain	22(73.3)
3. Restricted neck movement	19(63.3)
4. Lower cranial nerve involvement	17(56.6)
5. Cerebellar sign	14(46.6)
6. Low hair line	8(26.6)

Table 4: Surgical Procedure

Type	Number (%)
1. C1 lateral mass + C2 pedicle screw fixation	12(40)
2. C1 lateral mass + C2 pars screw fixation	6(20)
3. Occipito axial (0-C2) fusion	6(20)
4. C1 lateral mass + C2 hybrid screw fixation	4(13.3)
5. C1 lateral mass + C2 Laminar screw fixation	2(6.6)

Table 5: Radiological Results

	Preoperative	postoperative	Latest follow-up
ADI	6.55±1.50	3.02±1.21	3.11±0.82
A-A (heights)	36.54±7.02	41.03±8.3	39.66±6.5
Clivus angle	134.32±6.54	145.28±4.2	145.38±3.7

Table 6: Clinical Outcome

	Preoperative	postoperative	Latest follow-up
C-JOA	9.2±2.2	14.5±3.1	14.9±3.6
VAS	6.3±1.78	2.1±1.42	1.8±1.27

Table 7: Complication

Type	Number (%)
Pain at bone harvest site	2(6.6)
CSF leak	3(10)
Neurological deterioration	2(6.6)
Wound infection	2(6.6)

Conflict of Interest

The authors declare no conflict of interest

Informed Consent

Informed consent was obtained from all individual participants included in the study.

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