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Original Research Article

A Prospective Study to Assess the Functional Outcome Following Surgical Fixation for Subaxial Cervical Spine Injuries: An Institutional-Based Study

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Abstract

Background: Subaxial cervical spine injuries (C3–C7) are among the most disabling traumatic lesions, frequently complicated by neurological deficit, pain, and long-term disability. Surgical fixation aims to restore stability, decompress neural elements, correct alignment, and enable early rehabilitation.

Aim: To evaluate functional and neurological outcomes following surgical fixation for subaxial cervical spine injuries in a tertiary trauma institution.

Methods: A prospective observational study was conducted at Nalanda Medical College & Hospital, Patna, Bihar, India from 15th February 2025 to 20th November 2025. Thirty consecutive adults with surgically managed subaxial cervical spine injuries were enrolled. Injury characterization used contemporary trauma principles (morphology and neurological status). Functional outcomes were assessed using Neck Disability Index (NDI), modified Japanese Orthopaedic Association (mJOA) score, pain VAS, and neurological status using AIS grade at admission and follow-up (3 and 6 months). Paired comparisons evaluated change over time; multivariable logistic regression explored predictors of a favorable outcome.

Results: Mean age was 31.6±10.2 years; 80% were male. Road-traffic injury was the commonest mechanism (76.7%). At 6 months, mean NDI improved from 65.5±10.5 to 27.4±13.6 ($p<0.001$), mean mJOA improved from 8.8±2.7 to 11.7±3.4 ($p<0.001$), and mean VAS decreased from 6.78±1.34 to 2.13±1.42 ($p<0.001$). AIS grade improved by ≥1 grade in 46.7% overall; complications were mostly minor (overall any complication 23.3%, with no perioperative mortality). Early surgery (≤48 h) showed higher odds of favorable outcome (adjusted OR 4.43, 95% CI 0.62–31.89), though not statistically significant in this small cohort.

Conclusion: Surgical fixation for subaxial cervical spine injuries in our institution resulted in clinically meaningful improvement in disability, pain, and neurological function by 6 months, with an acceptable complication profile. Larger multicenter studies with longer follow-up are warranted.

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Introduction

Subaxial cervical spine injuries (C3–C7) constitute a major share of cervical trauma and are strongly associated with neurological deficit, prolonged disability, and socioeconomic loss, especially in young working-age populations.[1] These injuries typically result from high-energy mechanisms such as road-traffic accidents and falls, producing complex osseo-ligamentous disruption, instability, and varying degrees of spinal cord and root compromise.[2] In low- and middle-income settings, delayed presentation, limited prehospital immobilization, and inconsistent access to advanced imaging and definitive spine care can further worsen outcomes, emphasizing the importance of timely stabilization pathways. The primary goals in managing subaxial cervical injuries are (i) prevention of secondary neurological insult, (ii) restoration of spinal alignment and stability, (iii) decompression of neural elements when indicated, and (iv) early mobilization and rehabilitation.[3] Treatment selection is guided by injury morphology, integrity of the disco-ligamentous complex, and neurological status. The Subaxial Injury Classification and

Severity Scale (SLIC) was developed to systematize these considerations and support decision-making for operative versus non-operative care.[4,5] In parallel, the AO Spine Subaxial Cervical Spine Injury Classification System improved communication by incorporating morphology (A/B/C), facet injury qualifiers, neurological status, and modifiers, and has demonstrated substantial reliability in validation work.[6,7] Together, these frameworks help standardize reporting, stratify injury severity, and inform surgical strategy selection.

While nonoperative management remains appropriate for stable injuries without progressive deficit, operative treatment is favored for unstable patterns, deformity, failure of closed reduction, progressive neurological compromise, or injuries where early mobilization is essential.[3,8] The choice of surgical approach (anterior, posterior, or combined) is typically individualized to address the dominant pathology—anterior column disruption and disc herniation favor anterior decompression and fusion, while posterior tension band failure and facet dislocation may favor posterior fixation, and highly unstable injuries may require combined constructs.[9] Contemporary synthesis suggests that although clinical improvement and complication rates can be similar across approaches, anterior strategies may offer advantages in operative time, blood loss, and hospitalization length in selected contexts.[10] These findings reinforce that "approach selection" should be anatomy-driven and patient-specific rather than preference-driven.

Neurological recovery and disability improvement after cervical trauma are influenced by multiple variables including severity at presentation, adequacy and timing of decompression, and rehabilitation access. Early decompression has been associated with improved neurological outcomes in traumatic cervical spinal cord injury, supporting time-sensitive surgical pathways when medically feasible.[11] Broader evidence in spinal cord injury care similarly emphasizes the benefits of timely surgery, though patient selection and safety remain critical.[12] Additionally, measuring outcome purely by radiographs or fusion rates does not capture patient-centered recovery; therefore, integrating validated functional instruments is essential. The Neck Disability Index (NDI) is widely used to quantify neck-related disability, and clinically meaningful thresholds such as minimal clinically important difference (MCID) improve interpretation of outcome magnitude.[13] Similarly, the mJOA score is commonly used to quantify neurological function in cervical pathology, and MCID thresholds have been proposed to contextualize change.[14]

Evidence from prospective institutional experiences demonstrates that surgically treated subaxial injuries can yield substantial neurological recovery and pain relief, with high fusion rates and acceptable complication profiles.15 However, outcomes vary by injury pattern, baseline neurological grade, timing, and surgical strategy, and there remains a need for context-specific prospective data from Indian tertiary institutions where trauma epidemiology, referral pathways, and rehabilitation access differ from high-income settings. Moreover, standardized reporting using contemporary classification and disability metrics supports benchmarking and quality improvement at the institutional level.

Against this background, we conducted a prospective institutional study at Nalanda Medical College & Hospital, Patna to assess functional and neurological outcomes following surgical fixation for subaxial cervical spine injuries over early follow-up. We hypothesized that operative stabilization would be associated with clinically meaningful improvement in disability (NDI), pain, and neurological status (AIS/mJOA), and we explored perioperative factors associated with favorable recovery.

Materials and Methods

This prospective observational institutional-based study was conducted in the Department of Orthopaedics and Spine Surgery at Nalanda Medical College & Hospital, Patna, Bihar, India, over a period extending from 15th February 2025 to 20th November 2025. The study aimed to evaluate functional and neurological outcomes following surgical fixation in patients presenting with traumatic subaxial cervical spine injuries. Ethical approval was obtained from the Institutional Ethics Committee prior to commencement of the study, and written informed consent was obtained from all participants or their legally authorized representatives.

A total of 30 consecutive patients diagnosed with traumatic subaxial cervical spine injuries involving vertebral levels C3 to C7 and requiring operative stabilization were prospectively enrolled. Adult patients aged ≥18 years with radiologically confirmed unstable cervical spine injury who underwent surgical fixation and were willing to comply with follow-up assessment were included. Patients with upper cervical spine injuries (C0–C2), pathological fractures, penetrating cervical trauma, polytrauma patients with severe head injury precluding neurological assessment, previous cervical spine surgery, or those unwilling to participate were excluded from the study.

All patients underwent standardized trauma evaluation according to Advanced Trauma Life Support (ATLS) principles at presentation. Detailed

clinical assessment included demographic data, mechanism of injury, neurological examination, and associated injuries. Neurological status was graded using the American Spinal Injury Association (ASIA Impairment Scale – AIS). Radiological evaluation consisted of cervical spine radiographs and computed tomography scans for assessment of fracture morphology, alignment, and instability. Magnetic resonance imaging was performed when spinal cord compression, disc prolapse, ligamentous injury, or neural element compromise was suspected. Injury severity and stability were interpreted using accepted contemporary classification concepts for subaxial cervical trauma. The decision regarding surgical intervention, timing of surgery, and operative approach (anterior, posterior, or combined approach) was individualized based on injury morphology, neurological deficit, spinal stability, reducibility of dislocation, and surgeon expertise. Surgical procedures included anterior cervical discectomy and fusion or corpectomy with plating, posterior lateral mass fixation, or combined stabilization techniques when required. Intraoperative parameters such as operative duration, blood loss, fixation method, and perioperative complications were documented.

Standard postoperative protocols including cervical immobilization, early mobilization, physiotherapy, and neurological rehabilitation were uniformly followed. Functional and neurological outcomes were evaluated using validated assessment tools. Neck-related disability was assessed using the Neck Disability Index (NDI), neurological functional status was evaluated using the modified Japanese Orthopaedic Association (mJOA) score, and pain severity was measured using the Visual Analogue Scale (VAS). Assessments were performed at admission (preoperative baseline), and subsequently during follow-up at 3 months and 6 months postoperatively. Neurological recovery was additionally evaluated through changes in AIS grading. A favorable functional outcome was defined as improvement of at least one AIS grade in patients with preoperative neurological deficit or clinically significant reduction in NDI score during follow-up.

All collected data were entered into a structured case record form and analyzed using appropriate statistical methods. Continuous variables were expressed as mean with standard deviation, whereas categorical variables were presented as frequency and percentage. Changes in functional and neurological parameters between baseline and follow-up periods were analyzed using paired sample statistical testing. Multivariable logistic regression analysis was performed to identify predictors associated with favorable functional recovery. A p-value of <0.05 was considered statistically significant for all analyses.

Results

Table 1 presents the baseline demographic characteristics and injury profile of the 30 patients included in the study with subaxial cervical spine injuries. The majority of patients were young adult males, reflecting the higher exposure of this population to high-energy trauma. Road traffic accidents constituted the predominant mechanism of injury, followed by falls from height. The most frequently involved vertebral levels were C5–C6 and C6–C7, consistent with the biomechanical vulnerability of the lower cervical spine. Based on injury morphology, Type B injuries were most common, indicating significant ligamentous disruption and instability requiring surgical fixation. Neurological assessment at admission demonstrated a wide spectrum of deficits ranging from complete injury (AIS A) to neurologically intact patients (AIS E), highlighting the heterogeneity of clinical presentation in subaxial cervical trauma. Overall, the table establishes that the study cohort predominantly consisted of unstable traumatic cervical injuries requiring operative management.

Table 1: Baseline demographic and injury profile (n=30)

Variable	Category / Summary	Value
Age (years)	Mean ± SD	31.6 ± 10.2
Sex	Male	24 (80.0%)
Sex	Female	6 (20.0%)
Mechanism of Injury	Road traffic accident	23 (76.7%)
Mechanism of Injury	Fall from height	5 (16.7%)
Mechanism of Injury	Assault/Other	2 (6.7%)
Time to surgery (hours)	Median (IQR)	44.4 (28.1–67.1)
Common injured level	C5–6	13 (43.3%)
Common injured level	C6–7	8 (26.7%)
Common injured level	C4–5	6 (20.0%)
Common injured level	C7–T1	3 (10.0%)
AO morphology	Type A	10 (33.3%)
AO morphology	Type B	13 (43.3%)

AO morphology	Type C	7 (23.3%)
AIS at admission	A	5 (16.7%)
AIS at admission	B	4 (13.3%)
AIS at admission	C	6 (20.0%)
AIS at admission	D	7 (23.3%)
AIS at admission	E	8 (26.7%)

Table 2 summarizes the operative characteristics and perioperative complication profile among patients undergoing surgical fixation for subaxial cervical spine injuries according to the surgical approach employed. The anterior approach was the most commonly performed procedure, followed by posterior and combined stabilization techniques.

Operative duration, intraoperative blood loss, and length of hospital stay were comparatively lower in patients managed through the anterior approach, whereas combined procedures were associated with longer operative time and hospitalization due to greater injury complexity. The overall complication rate was low and predominantly consisted of minor and manageable postoperative events, including cerebrospinal fluid leak, transient dysphagia, C5 nerve root palsy, and superficial surgical site infection. Importantly, no perioperative mortality was observed.

These findings indicate that surgical fixation for subaxial cervical spine injuries can be performed safely with acceptable morbidity when appropriate surgical approach selection and perioperative care are ensured.

Table 2: Operative profile and complications

Parameter	Anterior Approach (n=14)	Posterior Approach (n=10)	Combined Approach (n=6)
Operative time (min), mean ± SD	129.5 ± 21.1	171.8 ± 30.2	250.5 ± 21.6
Blood loss (mL), mean ± SD	185.9 ± 101.2	367.8 ± 148.2	384.2 ± 143.8
Hospital stay (days), mean ± SD	9.4 ± 3.7	10.7 ± 4.2	14.2 ± 3.2

Complications (overall):

- None: 23 (76.7%)
- CSF leak: 3 (10.0%)
- Transient dysphagia: 2 (6.7%)
- C5 palsy: 1 (3.3%)
- Superficial SSI: 1 (3.3%)
- Perioperative mortality: 0

Table 3 demonstrates the functional and neurological outcomes of patients following surgical fixation for subaxial cervical spine injuries by comparing baseline (admission) parameters with findings at 6-month follow-up. A statistically significant improvement was observed across all evaluated outcome measures. The Neck Disability Index (NDI) showed marked reduction, indicating substantial improvement in neck-related functional disability. Similarly, the modified Japanese Orthopaedic Association (mJOA) score improved significantly, reflecting meaningful neurological recovery following surgical stabilization.

Pain severity assessed using the Visual Analogue Scale (VAS) also demonstrated considerable reduction during follow-up, suggesting effective pain relief and restoration of functional mobility. Furthermore, the majority of patients achieved clinically meaningful improvement, with significant proportions showing substantial disability reduction and neurological gain.

Overall, the table highlights the effectiveness of surgical fixation in achieving favourable functional recovery and improved quality of life in patients with subaxial cervical spine injuries.

Table 3: Functional and neurological outcomes (admission vs 6 months)

Outcome Parameter	Admission Mean ± SD	6 Months Mean ± SD	Mean Change	p-value
Neck Disability Index (NDI, 0–100)	65.5 ± 10.5	27.4 ± 13.6	-38.0	<0.001
mJOA Score (0–17)	8.8 ± 2.7	11.7 ± 3.4	+2.84	<0.001
VAS Pain Score (0–10)	6.78 ± 1.34	2.13 ± 1.42	-4.65	<0.001

Clinically meaningful improvement (distribution-based thresholds)

- NDI improvement ≥7 points: 29/30 (96.7%)
- mJOA improvement ≥1.8 points: 21/30 (70.0%)

Table 4 presents the multivariable logistic regression analysis identifying factors associated with favorable functional outcome following surgical fixation for subaxial cervical spine injuries at 6-month follow-up.

Early surgical intervention performed within 48 hours demonstrated a higher likelihood of favorable

recovery compared to delayed surgery, suggesting the potential benefit of timely decompression and stabilization. Patients presenting with severe neurological deficits showed comparatively lower odds of achieving favorable outcomes, indicating the strong influence of baseline neurological status on postoperative recovery. Injury instability based on morphological classification and increasing age showed no statistically significant independent association with outcome in this cohort. Overall, the analysis indicates that although trends favor early surgical management, functional recovery following subaxial cervical spine fixation is multifactorial and influenced primarily by initial neurological severity and injury characteristics.

Table 4:Predictors of favorable outcome at 6 months (multivariable logistic regression)

Predictor Variable	Adjusted Odds Ratio (OR)	95% Confidence Interval	p-value
Early surgery (≤48 hours)	4.43	0.62–31.89	0.139
Severe neurological deficit (AIS A–C vs D/E)	0.48	0.06–4.15	0.507
Unstable morphology (AO B/C vs A)	1.64	0.05–56.85	0.785
Age (per year increase)	1.02	0.89–1.16	0.772

Discussion

This prospective institutional study evaluated early functional and neurological recovery after surgical fixation for subaxial cervical spine injuries in a tertiary care trauma setting in Bihar, India. We observed substantial improvement in disability and pain by 6 months, with a favorable safety profile. Mean NDI improved by ~38 points and pain VAS decreased by ~4.7 points, while neurological function (mJOA) improved by ~2.8 points. These changes represent not only statistical significance but also clinically meaningful recovery when interpreted against commonly used thresholds for disability and neurological outcome interpretation.[14]

The epidemiological pattern in our cohort—predominance of young males and road-traffic injury—reflects the high-energy trauma burden typically reported in cervical spine trauma literature.[1,2] The peak injury levels around C5–C7 in our series are consistent with biomechanical vulnerability of the lower cervical spine to flexion-extension and translational forces.[3] Standardized classification is essential for communication and reproducible research; therefore, framing subaxial injury assessment within established classification concepts remains important. The SLIC framework emphasizes morphology, neurological status, and disco-ligamentous integrity, and was designed specifically to guide treatment selection in subaxial trauma.[4,5] The AO Spine subaxial system further improves granularity by incorporating facet injury descriptors, neurologic status, and modifiers and has demonstrated substantial reliability—an important property for multicenter benchmarking.[6,7] These structures support consistent reporting across institutions and should be adopted widely to strengthen comparability.

Our functional results align with prospective surgical series reporting meaningful recovery following definitive stabilization. Jain et al. reported high rates of neurological recovery and pain relief with anterior corpectomy-based strategies in a prospective cohort, emphasizing the role of appropriate approach selection and stable reconstruction.[15] Although our study included a mix of anterior, posterior, and combined approaches reflecting injury heterogeneity, overall functional improvement remained robust. This is consistent with contemporary evidence synthesis indicating that while clinical improvement and complication rates may not differ substantially between anterior and posterior strategies, perioperative metrics (operative time, blood loss, length of stay) may favor anterior approaches in selected injuries.[10] Our operative profile similarly suggested lower mean blood loss and operative time in anterior cases compared with posterior/combined constructs, though our study was not powered for formal between-approach comparative inference.

Neurological recovery in traumatic cervical injury is influenced by baseline deficit severity and timing of decompression. The STASCIS prospective cohort demonstrated that decompression performed within 24 hours was associated with improved neurological outcomes compared with later surgery in traumatic cervical SCI.[11] Broader WFNS recommendations similarly emphasize structured early management, appropriate reduction, stabilization, and decompression strategies tailored to injury morphology and neurological status.[3,8] In our cohort, early surgery (≤48 hours) showed higher odds of favorable outcome (adjusted OR ~4.4), though statistical significance was not reached due to small sample size and wide confidence intervals. This directionality is nevertheless consistent with the biological plausibility and published evidence supporting time-sensitive decompression when feasible and safe.[11,12]Complications in our series were predominantly minor and manageable, with no perioperative mortality. Reported complications in subaxial trauma surgery vary by approach and injury complexity; dysphagia is typically associated

with anterior exposure, while posterior approaches can be associated with wound complications and C5 palsy in some contexts.[10] Our observed rates (overall any complication 23.3%) are broadly comparable to published operative series and emphasize that careful approach selection, meticulous technique, and standardized postoperative care pathways are central to minimizing morbidity.[10,15]

A strength of this study is its prospective design with use of validated functional measures (NDI, mJOA, VAS) and neurological grading (AIS). Interpreting magnitude of improvement using clinically meaningful thresholds improves translational relevance; for example, MCID-anchored values for NDI and mJOA have been proposed to contextualize outcome changes in cervical surgery research.[14] Nevertheless, there are limitations. First, the sample size (n=30) limits power for predictor analyses and between-approach comparisons. Second, follow-up was limited to 6 months, whereas fusion outcomes, late kyphosis, and adjacent segment issues require longer follow-up for definitive assessment. Third, as a single-center study, findings may reflect local injury patterns, referral pathways, and rehabilitation resources. Finally, while our study focuses on surgical fixation outcomes, comparative inference versus nonoperative management is outside its scope.

Future work should prioritize multicenter prospective registries using standardized classification (SLIC/AO Spine), uniform outcome sets (NDI, mJOA, AIS, and quality-of-life metrics), and longer follow-up. Such efforts would enable robust modeling of outcome predictors, improve approach selection algorithms, and strengthen evidence for regional trauma system improvements.

Conclusion

In this prospective institutional study, surgical fixation for subaxial cervical spine injuries produced significant and clinically meaningful improvement in disability, pain, and neurological function by 6 months, with an acceptable complication profile and no mortality. Early surgery showed a favorable trend toward better outcomes, supporting time-sensitive definitive stabilization pathways when clinically appropriate.

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