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Posterior Surgical Approach for The Management of Atlanto-Axial instability

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Abstract
Background: Atlanto-axial instability (AAI) is a critical condition requiring surgical intervention. This study aimed to assess the outcomes of the posterior surgical approach for managing AAI across various etiologies.
Methods: A prospective and retrospective multi-center observational study was conducted on 20 patients. Preoperative assessments included full history taking, clinical evaluations, pain scales, and radiological imaging. Surgical techniques involved transarticular screws, pedicle screws, and lateral mass screws with titanium reconstruction plates. Postoperative evaluations were conducted at 1 and 6 months, focusing on clinical and radiological outcomes.
Results: The study included 20 patients with a mean age of 36.3 years. The primary causes of AAI were post-traumatic (55%), inflammatory (10%), and neoplastic (10%). Preoperative severe pain was reported by 95% of patients, which significantly decreased postoperatively (VAS score reduced from 7.06 to 3.2 at six months, $p<0.0001$). Neurological improvements were significant, with 45% of patients achieving an ASIA E classification postoperatively ($p<0.05$). Radiological assessments showed significant improvements in AADI and PADI scores ($p<0.001$). Motor power, bladder, and bowel control also improved significantly post-surgery. Postoperative complications were minimal, with a 5% wound infection rate and a 5% vascular injury rate.
Conclusion: The posterior surgical approach for AAI is effective, providing rigid and short-segment fixation, safety, simplicity, and a high fusion rate, making it a valuable clinical method.
Keywords: Atlanto-Axial Instability (AAI)**,** Posterior Surgical Approach**,** Spinal Surgery**,** Transarticular Screws

Introduction

Atlanto-axial instability (AAI) refers to the excessive movement between the first and second cervical vertebrae, the atlas (C1) and the axis (C2), which can lead to serious neurological deficits due to spinal cord compression. This condition can be caused by various factors, including congenital anomalies, trauma, inflammatory diseases, and degenerative changes [1].

Management of AAI often requires surgical intervention, particularly when conservative treatments fail to provide stability or when neurological symptoms are present.

The posterior surgical approach for managing AAI has evolved significantly over the past decades. This technique primarily involves the use of posterior fusion methods, which aim to stabilize the C1-C2 junction and prevent further neurological damage. The posterior approach is favored due to its direct access to the atlanto-axial complex and its efficacy in achieving solid fusion [2].

Recent studies have highlighted various posterior fusion techniques, such as the use of screws and rods, which have shown high success rates in stabilizing the C1-C2 complex. One such technique involves posterior screw-rod fixation, which has demonstrated effective outcomes in terms of stability and patient recovery [3]. Additionally, a new surgical augmentation technique for ventral fixation has been developed, showing promising results in enhancing surgical stabilization of AAI [4].

Despite the advancements in surgical techniques, the management of AAI remains complex and requires careful consideration of the individual patient's condition. Factors such as the underlying cause of instability, the presence of comorbidities, and the specific anatomical challenges must be taken into account to ensure optimal surgical outcomes [5].

We aimed in this study to evaluate the posterior surgical approach for the management of atlanto–axial instability of different pathologies clinical and surgical outcome.

Patients and methods

This prospective and retrospective multi-center observational study was conducted on 20 cases at Al-Azhar University Hospitals in Cairo, Egypt. The study aimed to assess the clinical and surgical outcomes of the posterior surgical approach for managing atlanto-axial instability (AAI) across various pathologies.

Inclusion Criteria

Patients considered for the study were those with AAI scheduled for posterior surgical correction, aged over 15 years, of either sex, and who provided informed consent to participate.

Exclusion Criteria

Patients were excluded if they underwent other surgical approaches, were younger than 15 years, or had osteoporotic conditions.

Preoperative Clinical Assessment

Patients exhibited a range of symptoms including neck pain, neurological deficits, vascular insufficiency, and signs of myelopathy. Clinical assessment involved taking a detailed history, conducting laboratory investigations, and performing comprehensive general and neurological examinations (including evaluations of tone, power, and reflexes). Pain levels were measured using a numerical Visual Analog Scale (VAS) from 0 to 10, with a modified color pain scale for children. Pain assessments were recorded preoperatively, postoperatively, and during follow-up visits.

Neurological status was assessed using the American Spinal Injury Association (ASIA) Impairment Scale (AIS), which classifies the severity of spinal cord injuries into the following categories:

- **A: Complete** – No sensory or motor function is preserved in the sacral segments S4–S5.
- **B: Sensory Incomplete** – Sensory function is preserved below the neurological level, including S4–S5, but there is no motor function.

- **C: Motor Incomplete** – Some motor function is preserved below the neurological level, with muscle strength grades less than 3.
- **D: Motor Incomplete** – At least half of the key muscles below the injury level have muscle strength grades of 3 or greater.
- **E: Normal** – Normal sensory and motor function are present.

Preoperative Radiological Assessment

Patients underwent a comprehensive radiological evaluation that included plain X-rays (anteroposterior and lateral views), CT scans for detailed assessment of bony structures, MRI for evaluating neurological tissues, and MR or CT angiography for vascular assessment. Key parameters measured were the Anterior Atlanto-Dental Interval (AADI) and the Posterior Atlanto-Dental Interval (PADI).

Indications for Surgery

Patients were categorized based on clinical, laboratory, and imaging findings into the following groups: inflammatory, traumatic, degenerative, congenital, infectious, neoplastic, and those requiring revision surgery.

Surgical Technique

After fiber-optic endotracheal intubation, patients were positioned prone with their faces supported on a specialized Mayfield device and arms placed alongside their bodies. A midline posterior incision was made extending from the external occipital protuberance to the necessary caudal level, followed by subperiosteal dissection of the paravertebral muscles. The surgical techniques employed included transarticular C1/C2 screws or pedicle/pars screws at C2, along with lateral mass screws at the appropriate subaxial levels. Titanium reconstruction plates were secured with bicortical screws. C-arms were utilized to ensure accurate reduction and fixation. A high-speed drill was used to decorticate the posterolateral spinal elements, and a closed system negative suction drain was placed for 48 hours.

Postoperatively, patients were fitted with a cervical collar for 6-12 weeks. Intraoperative metrics recorded included operative time, blood loss, and complications.

Follow-Up

Patients were evaluated clinically and radiologically at 1 and 6 months post-surgery. Assessments included general and neurological examinations (using the ASIA score), pain evaluation (VAS), and cervical spine imaging (X-ray and CT). Any patient presenting with symptoms received further assessment and management based on clinical and radiological findings.

Statistical Analysis

The data analysis was performed using IBM SPSS software version 25.0 (IBM Corp. Released 2017. IBM SPSS Statistics for Windows, Version 25.0. Armonk, NY: IBM Corp). Qualitative data were summarized with frequencies and percentages, while quantitative data were expressed as means and standard deviations. Statistical significance was determined at the 5% level.

Results

This study included 20 patients with AAI who underwent a posterior surgical approach for correction. The mean age of the patients was 36.3 years (± 13.8), with 80% being male and 20% female. Among the participants, 20% had no comorbidities, 30% had hypertension (HTN), 25% had diabetes mellitus (DM), 15% had ischemic heart disease (IHD), and 10% had rheumatoid arthritis (RA). The causes of AAI included post-traumatic (55%), inflammatory (10%), neoplastic (10%), and other causes (15%) (Table 1).

Preoperatively, 95% of patients experienced severe pain. Postoperatively, 70% reported improvement in pain severity. Pain levels assessed by the VAS showed a significant reduction from a preoperative mean of 7.06 (± 1.45) to 3.54 (± 1.19) postoperatively, and further to 3.2 (± 1.3) at six months follow-up (p<0.0001) (Table 2).
Neurological status was evaluated using the ASIA Impairment Scale (AIS). Preoperatively, 10% of patients were classified as ASIA B, 40% as ASIA C, 35% as ASIA D, and 15% as ASIA E. Postoperatively, 45% of patients achieved an ASIA E classification, indicating normal sensory and motor function, showing a significant improvement (p<0.05) (Table 3).
Radiological assessments showed significant improvements in both AADI and PADI scores. The AADI decreased from a preoperative mean of 4.91 (± 2.68) to 2.84 (± 0.89) postoperatively (p<0.001). The PADI increased from a preoperative mean of 11.35 (± 3.96) to 15.62 (± 2.4) postoperatively (p<0.001) (Table 4).
Significant improvements were observed in motor power of upper and lower limb muscles post-surgery (p<0.001). Bladder control improved from 25% to 75% normal function (p=0.002), and bowel control improved from 30% to 70% normal function (p=0.004). Pathological reflexes were reduced, with 90% of patients showing no pathological reflexes postoperatively (Table 5).
Postoperative complications were minimal, with 90% of patients experiencing no complications. There were two cases of complications: one wound infection (5%) and one vascular injury (5%).
A regression analysis indicated that a higher AADI score significantly increased the odds of severe impairment (ASIA B or C) (OR: 2.253, 95% CI: 1.347-3.768, p=0.001), while a higher PADI score was associated with decreased odds of severe impairment (OR: 0.581, 95% CI: 0.395-0.854, p=0.004). No significant correlation was found between the ASIA score and age, sex, or comorbidities.

Table 1:Demographic data and comorbidity of studied patients

Variable		**Cases (n=20)**	
		No	**%**
Age	**Mean ±SD**	36.3	13.8
Sex	**Males**	16	80%
	Female	4	20%
Comorbidities	**Non**	4	20%
	DM	5	25%
	HTN	6	30%
	IHD	3	15%
	RA	2	10%
Causes	**Post traumatic**	11	55%
	inflammatory	2	10%
	Neoplastic	2	10%
	Others	3	15%

Table 2:Pain assessment before and after the operation

Variable		**Cases (n=20)**	
		No	**No**
Pain severity	**Mild**	1	5%
	Sever	19	95%
Postoperative Pain	**Improved**	14	70%
	Not Improved	6	30%

Table 3:Neurological outcome (ASIA scoring system) before and after operation

ASIA score	**Pre operative**		**Post operative**		**P value**
	N	**%**	**N**	**%**	
A	0	0%	0	0%	0.001
B	2	10%	0	0%	
C	8	40%	4	20%	
D	7	35%	7	35%	
E	3	15%	9	45%	

ASIA:(American Spinal Injury Association) score

Table 4:Radiological outcome (AADI score and PADI score) before, after the operation and 6 months follow up.

Radiological outcome		**Cases (n=20)**		**P-value**
		Mean	**SD**	
AADI	**Preoperative**	4.91	2.68	< 0.001.
	Postoperative	2.84	0.89	
PADI	**Preoperative**	11.35	3.96	< 0.001
	Postoperative	15.62	2.4	

AADI: Anterior Atlantodental interval, PADI: posterior atlantodental interval

Table 5:Motor and sphincter function before, after the operation and 6 months follow up.

Outcome	**Pre-operative**	**Post-operative**	**p-value**
	Mean ±SD / No (%)	**Mean ±SD / No (%)**	

Motor Power of Muscles	**Upper Limb Muscles**	2.8 ± 0.6	4.0 ± 0.5	< 0.001
	Lower Limb Muscles	2.4 ± 0.7	3.8 ± 0.6	< 0.001
Sphincter Reflexes	**Bladder Control**	5 (25%)	15 (75%)	0.002
	Bowel Control	6 (30%)	14 (70%)	0.004
Pathological Reflexes	**Presence**	8 (40%)	6 (30%)	0.291
	Absence	14 (70%)	18 (90%)	0.064

Case (1): A 27-year-old male patient with a history of rheumatoid arthritis (RA) and trauma one year prior presented with severe neck pain (VAS = 3) and signs of myelopathy, with muscle strength rated at G5. The patient underwent posterior occipito-cervical fixation using screws, rods, and a plate. At follow-up, the patient reported mild neck pain (VAS = 3), exhibited full muscle power, and maintained intact sphincter function (figure 1-3).

Figure (1): MRI cranio-cervical sagittal view Pre operative

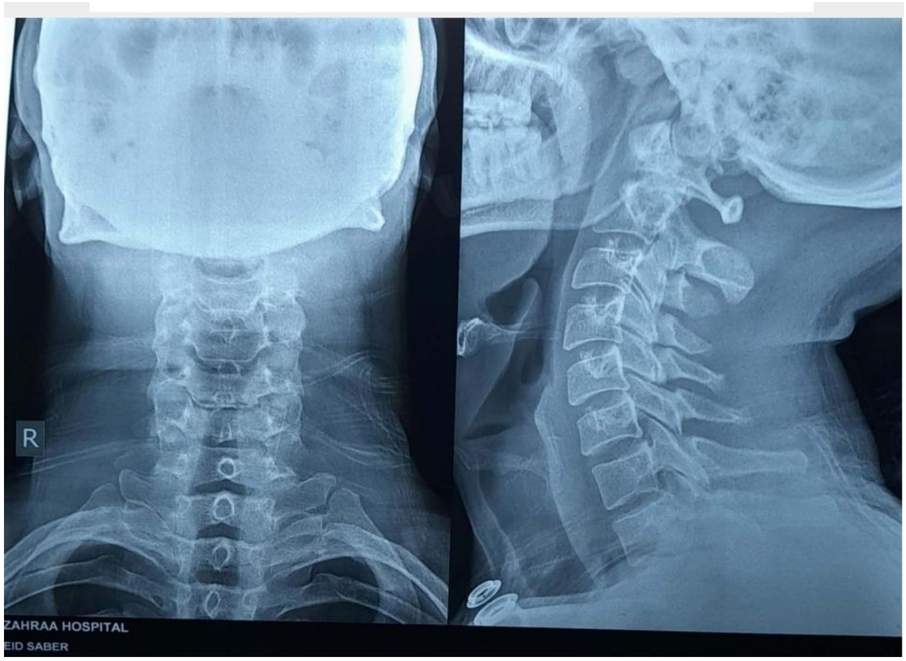

Figure (2**):** plain x-ray cranio-cervical Pre operative.

Figure (2**):** plain x-ray cranio-cervical sagittal view post operative.

Case (2): A 27-year-old male with a history of rheumatoid arthritis and trauma one year ago presented with severe neck pain (VAS = 3) and signs of myelopathy, with muscle power rated at

G5. He underwent posterior occipito-cervical fixation using screws, rods, and a plate. At follow-up, the patient reported mild neck pain (VAS = 3), demonstrated full muscle power, and had intact sphincter function (figure 4-6).

Figure (4): MRI cranio-cervical sagittal view Pre operative

Figure (5): plain x-ray cranio-cervical Pre operative.

Figure (6**):** plain x-ray cranio-cervical post operative.

Discussion

The posterior surgical approach is a critical technique for addressing atlantoaxial instability (AAI), primarily through the fixation of the atlantoaxial joint using screws. This method is particularly advantageous for patients with rheumatoid arthritis (RA), where the atlantoaxial joint is frequently compromised. A study assessing surgical treatments for AAI in RA patients demonstrated positive outcomes in neurological function and screw placement accuracy. Preoperative imaging and navigation systems play a significant role in surgical planning and intraoperative guidance, contributing to optimal results. Nonetheless, RA patients may face a higher risk of surgical complications [6].

Our study, conducted prospectively and retrospectively, involved 20 patients with AAI who underwent posterior surgical correction. The average age of participants was 36.3 years (± SD 13.8), with 80% being male. Regarding comorbidities, 20% of the cases reported no additional health issues, while 30% had hypertension (HTN), 25% had diabetes mellitus (DM), 15% had ischemic heart disease (IHD), and 10% had RA.

The most common cause of AAI in our study was post-traumatic (55%), followed by idiopathic (15%), neoplastic (10%), and RA and ankylosing spondylitis (AS) each accounting for 10%. These findings align with **Bhatia et al.** [7], who identified RA (41%), tumors (16%), trauma (15%), congenital (14%), metabolic (6%), inflammatory (6%), and infection (2%) as underlying etiologies.

Before the operation, 5% of patients experienced mild pain. Postoperatively, 70% of patients reported pain improvement. There was a statistically significant improvement in VAS and NDI scores after surgery ($p<0.0001$). This aligns with Bhatia et al. (2013), who observed significant improvements in VAS scores for neck pain in RA patients (mean VAS 7.5/10 preoperatively vs. 3.7/10 postoperatively, $p < 0.001$). Similarly, **Upadhyaya et al.** [8]reported VAS improvements from 6.65 ± 1.1 to 2.42 ± 0.49 at follow-up.

The duration of surgery ranged from 80 to 190 minutes, with blood loss between 90 to 500 mL (mean, 170 ± 35 mL). There were significant improvements in BI and ADI scores postoperatively. **Bhatia et al.** [7] also noted improvements in myelopathic disability index and outcome measures across trauma and tumor categories. ASIA, AADI, and PADI scores all showed statistically significant improvements post-surgery ($p<0.05$ and $p<0.0001$, respectively). **Upadhyaya et al.** [8]documented AADI improvement from 4.2 ± 1.7 mm to 2.5 ± 1.9 mm.

In our study, 90% of cases had no complications; however, 5% experienced wound infections, and 5% had vascular injuries. Post-surgical complications can include pseudarthrosis, postoperative re-dislocation, neurological injury, and cervical spine malalignment, particularly with posterior wiring techniques [9]. **Guo et al.** [10] reported satisfactory postoperative outcomes for 81 patients, with complications such as pedicle misplacement, pedicle screw fracture, infection, and one death. Despite these, significant neurologic improvement was observed.

Fischgrund and Yang [11] highlighted the risk of neurological dysfunction due to spinal cord compression from atlas-axis displacement. **Gautschi et al.** [12] observed complications in 24.4% of patients, necessitating surgical re-interventions in some cases. **Bhatia et al.** [7] reported 4 cases of instrumentation failure and 5 wound infections, with complications also including vertebral artery injuries.

Conclusion

The posterior approach for atlantoaxial fixation has proven to be an effective method for treating atlantoaxial instability arising from various pathologies. This technique offers several advantages, including providing rigid and short-segment fixation, being safe and straightforward, and achieving a high fusion rate. Its clinical application is highly valuable.

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