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Original Research Article

Surgical Outcome Following C1 Lateral Mass and C2 Pedicle Screw and Rod Fixation in Atlanto-Axial Dislocation: A Prospective Study

Dr. Saquib A Ansari[1], Dr. Ashish Mathur[2], Dr. Shubhra Shrivastava[3], Dr. Aditya Shrivastava[4]

Ex Senior Resident, Department of Neurosurgery, G.R. Medical College Gwalior M.P.[1]
Associate Professor, Department of Anaesthesiology, G.R. Medical College Gwalior M.P.[2]
Department of Anaesthesiology, G.R. Medical College Gwalior M.P.[3]
Professor, Department of Neurosurgery, G.R. Medical College Gwalior M.P.[4]

Corresponding Author: Dr. Aditya Shrivastava

Abstract

Background: Atlantoaxial screw and rod fixation is considered to be the "gold standard" for treating atlantoaxial instabilities. This challenging surgical procedure requires high skills and appropriate surgical armamentarium. The evolution of instrumentation methods for C1-C2 fusion from the use of posterior wiring methods to transarticular screws and C1 lateral mass with C2 pedicle screw construct have improved fusion rates to almost 100%.

Methods: This is a prospective study of a series of 24 patients who were planned for C1-C2 fusion using C1 lateral mass and C2 pedicle screw technique between september 2017 and september 2019.

Results: The union rate was 100% with an average union time of 5.3 months (range from 3 to 8 months). Postoperatively, the patients achieved an average of one Frankel grade neurological improvement and JOA SCALE improvement over a period of 6 months to 1 year.

In conclusion, this technique provides an excellent union rate and good neurological recovery.

Key Words: C1 Lateral Mass, C2 Pedicle Screw, C1-C2 Instability,Outcome

1. Introduction

Atlanto-axial dislocation leads to severe neurological impairment with passage of time. AAD is an abnormal movement at junction between Atlas (C1) and Axis (C2). Cervical instability at C1-C2 may be due to pathological alteration in bone, ligaments or both caused by congenital deformity or acquired like trauma, inflammatory diseases, infections or tumor. In symptomatic AAD repair of deformity,stability restoration, and to reduce neurological consequences fixation and fusion of atlanto-axial joint becomes mandatory. Traditionally several reduction and fixation techniques were used to manage atlanto-axial instability. Gallie first reported sublaminar wiring in 1939, since then various modifications had been suggested by Brooks-Jenkings and Sonntag and others. Unfortunately these methods were having high non-union rates upto 80% (range 3%-80%). Poor stability and prolong immobilization were other drawbacks. These unsatisfactory results lead to continued search for alternative better methods of atlanto-axial fixation. Transarticular screw fixation was described by Magerl but it was more technically demanding with medially located vertebral artery a significant limitation. In 2001

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Harms and Melcher popularized C1 lateral mass C2 pedicle screw fixation with superior clinical results and good stability. With safe screw trajectory and posterior reduction and fixation of C1-C2 we describe our clinical experience in 24 cases of AAD that were planned for treatment using C1 lateral mass and C2 pars screw and rod fixation.

2. Material and Methods

A consecutive series of 24 patients with AAD admitted in our institution from November 2017 to October 2019 were surgically treated by C1 lateral mass C2 pars-interarticularis screw-rod. All aspects of our research were assessed and approved by Research Ethics Committee of Gajra Raja Medical College. Radiological assessment of all patients was done with both X-Ray and CT scan.
Following outcome measures were assessed : 1)neurological outcome using Frankel Grade and modified Japanese orthopaedic associaltion score. 2) complications that occurred both intra and post-operatively.

Surgical Technique

Under general anesthesia, the patient was positioned prone using a Mayfield head holder. The neck was kept in 15-30 degree extension with cervical traction using Gardner-well tongs. The arms were tucked by the sides and the shoulders retractedcaudally using adhesive tape. After positioning lateral X-ray of cranio-vertebral junction was taken to confirm reduction. A midline incision was made, extending from the inion to C-4. The incision was extended inferiorly as per requirement. Subperiosteal dissection of the paraspinal muscles was performed bilaterally to expose the facet joints and lateral mass of C1 and C2. Dissection was continued laterally over the posterior arch of C-1 and presumed pathway of vertebral artery was isolated and protected during surgery, however exposing the VA in the vertebral groove on the C-1 arch was never required. Bipolar cautery and hemostatic agents such as gelfoam were used to control bleeding from the perivertebral venous plexus. The C-2 nerve root was identified and preserved by mobilizing inferiorly. The lateral mass of C-1 was exposed. The junction of the lateral mass and inferior aspect of the posterior C-1 arch was the site of screw insertion with direction being anteromedial about 15 degree and 20 degrees cephalad and a 3.5-mm polyaxial screw of an appropriate length was inserted into the lateral mass of C1. For C-2 screw medial border of pars interarticularis was identified and entry point burred and the direction of the screw was approximately 20° to 30° in a convergent and cephalad direction and a 3.5-mm polyaxial screw of an appropriate length was inserted. Further intra-operative reduction was achieved using persuader causing reduction of C1 vertebra over C2. For fusion purposes, the posterior arch of C1 and the lamina of C2 were decorticated with a burr to prepare the raw bed for bone grafting and then packing cancellous iliac crest autograft over these surfaces. A lateral radiograph was taken at the end of procedure to confirm fixation in reduced position. A vacuum suction drain was placed prior to wound closure. Traction was removed at the end.

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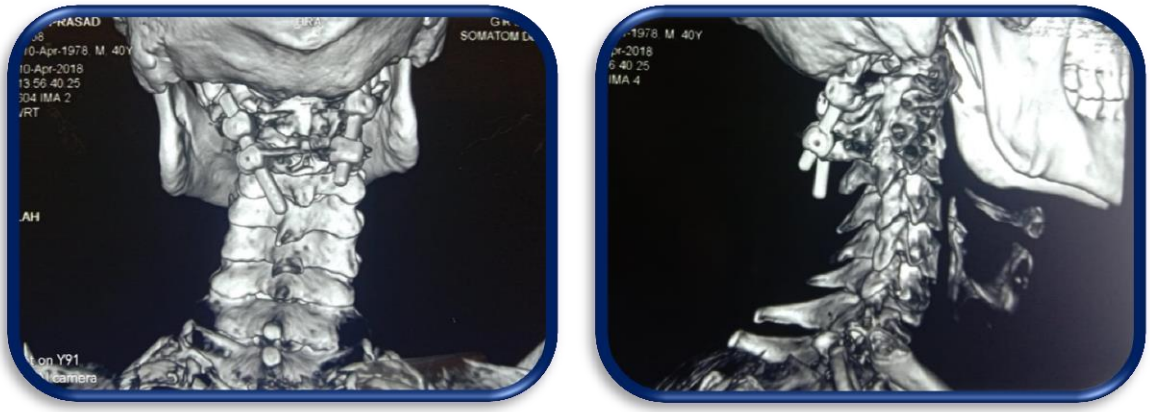

Figure1. Sagittal and coronal view Showing satisfactory polyaxial screw positioning.

3. Results

Surgical correction was performed in 24 patients of congenital AAD. 17 were males (70.8%) and 7 females (29.2%). Mean age of patients was 30.83±16.12 years (range 6-56). Eight (33.4%) patients were smoker. Rest had no addiction. Patients were followed up with clinical examinations and radiological investigations for a period of one year. Neurological deficit was present in all 24 (100%) patients. Frankel grade assessment showed 22 (91.7%) patients out of total 24 showed improvement to grade D from preoperative grade C on 7th postoperative day and all 24 improved to grade D on final follow up.

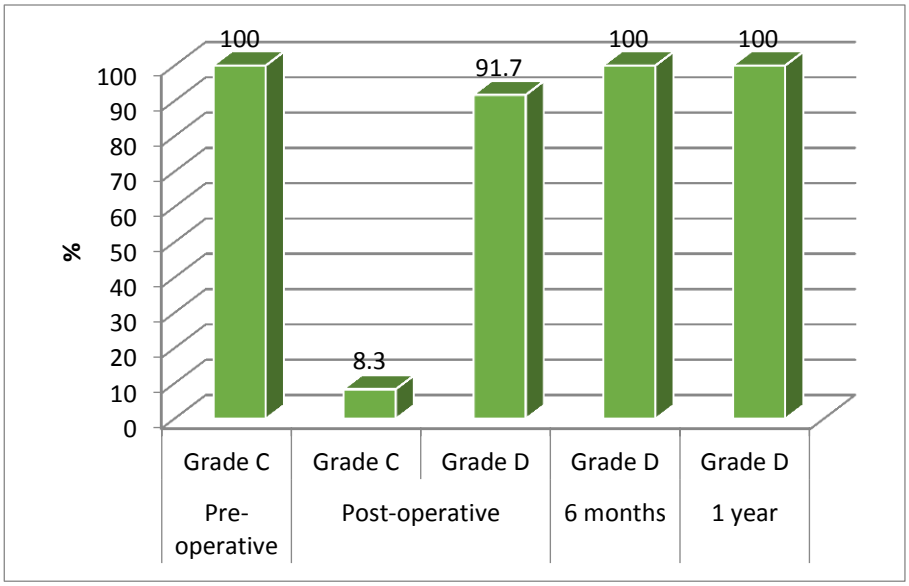

Figure 2.Comparison of Frankel grade from pre-operative to subsequent time periods

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Mean JOA score analysis showed patients improved from preoperative mean JOAS of 9.88±1.87 to 11.25±1.59 on 7th postoperative day (P < .001) and 15.25±0.98 at last follow up (P < .001). None of the patient regained complete neurological recovery at last follow up. One patient with poor neurological status on admission had neurological deterioration after vertebral artery injury complicated by brainstem and cerebellar stroke with VAP and finally death on 10th postoperative day. Preoperative pain related to instability at the atlanto-axial junction had improved in all patients at last follow-up and in most cases had resolved fully.

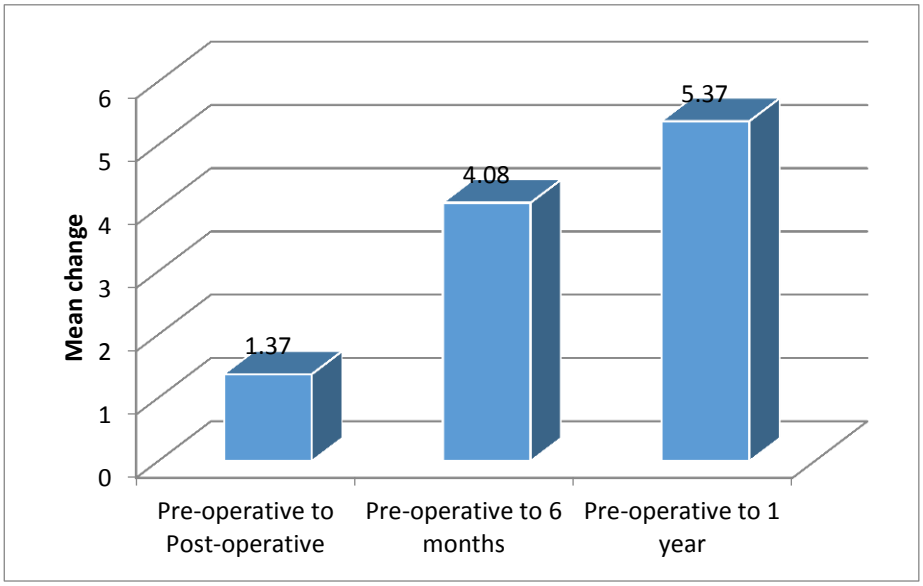

Figure 3. Comparison of mean change in JOA total average score from pre-operative to subsequent time periods

4. Discussion

Various causes can lead to instability of the C1-C2 Joint. Failure to recognize this clinical problem can lead to progressive narrowing of the spinal canal resulting in myelopathy and neurological abnormalities. This can manifest as gait instability, frank weakness in patients who already have physical impairment, regression of motor skills. Historically atlanto-axial instability management consisted of traction and posterior bone wire fusion techniques. Posterior wiring techniques were first described by **Gallie** in 1939. He passed a wire in the cephalad direction around the posterior arch of C1 and then looped it around the spinous process of C2. The wire was then tightened around an onlay graft seated between C1 and C2. **Brooks** used double twisted wires in a similar fashion. Since then several modifications of these techniques have been used to improve fixation strength as well as to enhance the probability of a successful fusion. Although these approaches are reasonably safe and effective, they have drawbacks. There may be further canal compromise after C1/C2 wiring. The rates of nonunion have reportedly exceeded 10%. Moreover, these procedures generally require rigid postoperative bracing.

This led to continued search for development of alternative internal fixation techniques with the desire for increased safety, decreased postsurgical bracing requirements, the achievement

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of C1-C2 fixation without incorporating the occiput in the presence of C1 posterior element incompetence, and the improvement of fusion rates.

Magerl developed a technique of posterior fusion of C1 to C2, using bilateral trans-articular screw fixation with supplemental wiring. The technique involves passage of screws bilaterally, beginning directly above the C2-C3 facet joints, across the C2 isthmus, and through the C1-C2 facet complex into the lateral mass of C1.

Although this technique has a higher union rate and is biomechanically stronger, the transarticular screw technique has several drawbacks. First, it requires a preliminary reduction of the C1-C2 joint before definitive fusion. Secondly, approximately 20% of patient needing C1- C2 fusions are not suitable for transarticular screws due to anatomical variations of the vertebral artery. Next alternative was C1 lateral mass screws with C2 pars screw fixation. The C1 lateral mass screw with C2 pedicle screw construct was initially created with plates and screws by **Goel et al** in the 1980's and then subsequently popularized by **Harms and Melcher**.

Our study indicates that Atlanto-axial dislocation (AAD) is an important issue affecting middle aged and adolescent population.

Demographic profile

Sun Y. Yang et al reported most of their cases in adolescent age Group. Similarly **Martinez-Del-Campo et al** reported mean age in their series to be 39.9 years with range 7months to 88 years. One third of their patients were younger than 40 years. **Liang et a** reported mean age 44. Mean age in our series was 30.28±16.36 range (6-56).

More than half of our patients were males 64.5% and 35.5% were female. **Martinez-Del-Campo et al** reported 64 (53%) male and 56 (47%) female patients in their study. Male predominance is probably due to increased number of male patients being investigated, which is an important social feature in Indian society.

Most of our patients were labourer followed by students and housewife comprising 25.8% and 22.6% respectively. We could not find any study about occupation of patients suffering from AAD.

Sign and symptoms

The presentation of Atlanto-axial dislocation may range from minor axial neck pain to death. All of our patients had weakness of all four limbs with difficulty in walking (100%). **Sun Y. Yang et al** reported 90% of their patients with pyramidal signs. Numbness and tingling in all four limbs were present in 18 (58.0%) followed by neck pain in 16 (51.6%) of patients in our study. **Sun Y. Yang et al** reported 70% of their patients with numbness and 50% with neck pain, similar to our results. 4 (12.9%) of our patient had bladder dysfunction, 3 (9.6%) had sub-occipital headache and 1(3.2%) patient had difficulty in breathing. While **Martinez-Del-Campo et al** in their study reported neck pain to be most common presenting complaint in 83 (69%), followed by numbness and weakness in 52 (43%), bladder bowel incontinence in 20 (17%) and gait ataxia in 13 (11%). They also reported that 37 (31%) of their patients had no neurological deficit preoperatively.

Weakness of all four limbs and walking difficulty was predominant symptom in our series. The probable reason is late presentation at tertiary care centre for definitive management in our Indian society.

Frankel grading

In our study the pre-operative neurological status of all patients who underwent C1 lateral mass C2 pedicle screw fixation fell in Frankel grade C. All of our patients had one Frankel grade improvement at 6 months and 1 year follow up.

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Similar results were seen in study by **M K Kwan** et al who reported one Frankel grade improvement in their 85.7% patients at final follow up.

In this study we assessed patients on basis of Modified Japanese Orthopedic Association (JOA) score along with Frankel grading.

JOA total average score was 9.88±1.87 at pre-operative which increased to 13.96±1.57 at 6 months and 15.25±0.98 at 1 year. There was significant (p=0.0001) mean change in JOA total average score from pre-operative to 6 months and 1 year period. Similarly **Martinez-Del-Campo et al** reported a preoperative mean JOAS score of 12.0±3.5 which increased to 14.8±3.4 postoperatively (P <.001) and 14.9±3.5 at last follow-up (P < .001). Similarly **Liang et al** [2]reported a preoperative mean JOAS score 7.3 ± 1.8 which increased to 13.1 ± 1.4 at last follow-up (P<.001). These results were similar to our study when compared at last follow up.

JOA score can be used to assess improvement in different domains of neurological impairment and can be followed over time with easy reproducibility and without any observer bias.

Atlanto-dental interval

In our study the mean of ADI decrease after operation was statistical significance ($p < 0.01$). The mean and SD of ADI before operation and after operation was 7.88±1.36 and 4.4±1.25. **Werasak Sutipornpalangkul et al** in 2014 did Atlanto-axial transarticular screw fixation and posterior fusion using polyester cable and published mean and SD of ADI before operation and after operation which was 4.86 ± 3.07 and 2.76 ± 1.38 mm, respectively. They also reported it to be statistically significant. Both studies show similar results with reduction in mean ADI after reduction and fixation of C1-C2 joint.

Fusion rates

We observed excellent outcomes in terms of fusion rates which was 100%. All of twenty-four cases achieved union with average union time of 5.5 months. **O. Rezaee** et al reported similar fusion rates in 3.5 months and **Kwan et al** reported 100% fusion rates in 5.3 months. **Yoonet al** have achieved excellent bone fusion using C1 lateral mass screw and C2 pedicle screw compared to results of other methods without any procedure related complication.

It is imperative that good preparation of bed for the bone graft is performed and a good quality morselized cortico-cancellous bone autograft is used. In all our cases the surface of posterior arch of atlas and C-2 lamina was decorticated using drill and good quality cortico-cancellous iliac crest bone graft was harvested and applied to the graft bed to promote fusion.

Use of screw and rod technique led to significant improvement in neurological recovery in all cases that presented with neurological deficit preoperatively. All cases had improvement in Frankel grade at 6 months follow up and modified JOA score improvement at 6 months and 1 year follow up. Kwan[61] et al and O. Rezaee et al also reported significant improvement in neurological status in about 87.5 % of their subjects using screw and rod technique. Modified JOA in comparison to Frankel grade gives better idea about improvement in specific functions and individual limb improvement.

Cervical Collar was discontinued after one week in screw and rod fixation in view of rigid construct.

The main technical difficulty that we encountered was venous bleeding due to the large number of plexuses around the C2 root and the entry point on the C1 lateral mass. During exposure, these plexuses were distracted downward, preventively, using 1 or 2 spatulas and bleeding was controlled using haemostatic agents. In case of persistent bleeding, which is of venous origin, we performed prolonged swabbing which was usually effective. Also, due to

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the proximity of the C2 root, unprotected by any bony structure, bipolar forceps coagulation was preferred to monopolar sectioning.

Smith et al reported dural tear below Axis while performing wiring fixation but in our study we did not encountered this complication. Compared to wiring techniques there are minimal chances of cord injury and reduction of canal diameter is not seen with C1-C2 screw and rod fixation. Comparing Stability between the Magerl techniques and C1 – C2 screw and rod fixation the two are equivalent; C1 – C2 screw and rod technique has the better biomechanical properties reported so far with posterior C1-C2 arthrodesis. Considering potential technical difficulties of Magerl screw fixation, especially when C1-C2 alignment is not conserved and the greater risk of vertebral artery lesion (due to less convergent screw positioning), C1 – C2 screw and rod technique appears preferable.

After screw placement in C1 and C2, a reduction maneuver can be carried out, either by repositioning of the patient's head or by direct manipulation of C1 and C2, using the instrumentation as the reduction device. We monitored the reduction maneuver under C-Arm and then stabilized it by attachment of a small rod to the screws. If necessary, this maneuver can be easily repeated until the result is satisfactory. We recommend anatomical variations of vertebral artery and ossoeus anatomy should be assessed properly before performing this procedure to minimize complications. Technical ability to convert to other methods of fusion is also necessary in event of encountering intra-operative complications.

Harms et al reported as this technique avoids damage to the C1-C2 facet joint, it can be very well used in patients who require an open reduction followed by fixation.

Early Post operative complications included neck pain as the main compliant of all patients after surgery which significantly reduced in due course of time. Graft site pain was also a limiting factor in early mobilization of patients, but we did not encounter its persistence beyond 10 days. **Sawin et al** reported a bone graft donor site morbidity, 4% during rib and 25% during iliac crest harvests. Surgical site infection occurred in 2 cases (6.4%) limited to subcutaneous plane only and subsided with antibiotics. **Martinez-Del-Campo et al** reported 5.8% wound healing complications similar to our series.

We did not encounter implant failure, nonunion, C2 nerve root injury. **Martinez-Del-Campo et al** reported two patients in their series required reoperation for hardware failure. **Martinez-Del-Campo et al** also reported vertebral artery injury in 3 patients (2.5%). Other studies reported rates of 4.3%[70] and 5.9%[71]. In our study we encountered vertebral artery injury in 3 patients (10.6%) which was slightly higher compared to other studies but we were able to manage it with screw placement and bone wax intra-operatively. 2 of them were nondominant while 1 was dominant.

In this study we encountered death of (3.20%) patients. We did encountered Cerebellar infarct in one patient (with dominant vertebral artery injury intraoperatively) in post-operative period which lead to gradual deterioration and finally death of patient on fourth post operative day. In study by **Martinez-Del-Campo et al** no mortality was reported as they had vertebral artery injury in 3 patients but of non dominant side. Similarly **O. Rezaee**, **Kwan et al**, **Harms et al** also did not reported any mortality in their study.

Complications	**Number**
Graft site pain	3
Wound infection	2
Hardware failure	1
Vertebral artery injury	3

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Mortality	2

The limitation of our study was its prospective design and single institutional case series so the results may not be generalizable. Some patients were excluded from this study on account of incomplete medical record and being lost to follow up. Sample size of Group 2 was not comparable with Group 1 either. Furthermore the follow up period was limited to 1 year.

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