Traumatic Atlantoaxial Dislocation

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Indian J Neurotrauma 2019;16:52–57

Introduction

Atlantoaxial dislocation (AAD) refers to the relative motion between C1 and C2 and results from abnormal articulation between the C1 (atlas) and C2 (axis). It occurs across all age groups. C1–C2 instability can be congenital or it can result from traumatic or inflammatory etiologies.[1] Osteoarthritis or degenerative arthritis is a less known cause of C1–C2 instability. We will focus on traumatic AAD in this article.

It is prudent to discuss the anatomy of craniovertebral junction (CVJ), which is quite complex. The C1–C2 joint stabilizes the head in addition to being one of the most mobile joints of the body, allowing a great amount of movement. About half of the total cervical flexion occurs at the occipito-C1 joint, while similar amount of total cervical rotation occurs at the C1–C2 joint.[2,3] Other unique anatomical variation in this region is the dens and the transverse ligament, and the absence of intervertebral disc between C1 and C2.[4] The vertebral bodies of C1 and C2 do not directly bear the weight of head, rather it is transferred from occipital condyles to C1 lateral masses and then to the C2 lateral mass.[5] The lateral masses of the C1 and C2 form a pillar of stability and mobility for the head and neck.

Ligaments play a greater role in the stabilization of these joints as compared with other joints in the body.[5] Transverse ligament runs across the posterior aspect of dens and is attached to the lateral masses of C1 on either side and prevents anterior translation of C1 over C2.[4] Alar ligaments extend from the odontoid in a lateral and cephalad direction to the basilar portion of the occiput and provide additional stability.[4] C1–C2 facets are arranged in axial plane and no bony structure is there to prevent dislocation, in contrast to subaxial spine. Transverse ligament presents dislocation in the sagittal plane.

Traumatic AAD can occur in one of the following settings:

1. Ligament injury.
2. Bony injury.

We will further discuss the following entities in detail:

- Traumatic transverse atlantal ligament (TAL) insufficiency.
- Atlantoaxial rotatory subluxation/dislocation.
- Odontoid fracture.

Traumatic Transverse Atlantal Ligament Insufficiency

The disruption or insufficiency of TAL can occur following a violent hyperflexion force to the neck. It results in significant instability and can lead to significant neurological deficits. A lateral X-ray of cervical spine may show increase in the atlantodental interval (ADI), cutoff being 3 mm in adults and 5 mm in children. This increased ADI is best appreciated in the flexion X-ray films, though one should avoid passive neck movements and only active movements are allowed. An open mouth X-ray may show lateral overhang of C1 lateral masses over C2, which if more than 7 mm (Rule of Spence) also signifies a TAL injury. TAL can be directly viewed on magnetic resonance imaging (MRI) scans and an injury can be made out. TAL typically appears dark on T2-weighted and proton density imaging, and an injury is seen as a bright spot.

TAL injuries are classified as disruptions of the substance of the ligament (type I injuries) or as fractures and avulsions involving the tubercle for insertion of the transverse ligament on the C1 lateral mass (type II injuries).[6] These two types of injuries have distinctly different clinical characteristics that are useful for determining treatment. Type I injuries are incapable of healing satisfactorily without internal fixation; they should be treated with early surgery. Type II injuries, which render the transverse ligament physiologically incompetent even though the ligament substance is not torn, should be treated initially with a rigid cervical orthosis because they have a high success rate nonoperatively. Surgery should be reserved for patients with type II injuries that have nonunion with persistent instability after 3 to 4 months of immobilization. In one study, type II injuries had a 26% rate of failure with just immobilization; therefore, close monitoring is recommended to detect patients who will require delayed operative intervention.[6]

Atlantoaxial Rotatory Subluxation/ Dislocation

The atlantoaxial joint is one of the most mobile joints of the body and is estimated to be moving at approximately 600 times every hour. This extra range and frequency of mobility

DOI https://doi.org/ 10.1055/s-0039-1700620
ISSN 0973-0508.

of atlantoaxial joint comes at the cost of its stability, thereby making this joint prone to injury. The facet joints of C1–C2 are almost horizontal which allows 60% of the entire normal rotation of the cervical spine. The C1–C2 joint is largely stabilized by two sets of ligaments—TAL and alar ligament, of which the latter is primarily responsible for limiting the rotation of C1 over C2.

Atlantoaxial rotatory subluxation/dislocation can occur with or without odontoid fracture. The odontoid fracture is conducive to rotatory subluxation by allowing the C1–C2 facet joints greater rotational freedom.

Atlantoaxial rotatory and horizontal displacement is usually classified by Fielding or White/Panjabi classification systems (►**Table 1**).[7,8] Fielding devised four types of these injuries, rotatory injuries, in which C1 uses the odontoid process as center of rotation with no sliding in the horizontal plane, are described as type I. Injuries are type II if the lateral facet joint C1/2 presents the center of rotation and there is a dislocation of 3 to 5 mm in the anterior–posterior plane. If there is bilateral dislocation and sliding increases up to more than 5 mm in the horizontal plane, the lesion is classified as type III; if a dorsal sliding appears with uni- or bilateral dislocation, Fielding matches type IV. White and Panjabi classified bilateral anterior displacement of C1 against C2 as type A, bilateral posterior dislocation as type B, rotatory dislocation of the atlas around the ipsilateral facet joint C1/C2 as type C, and rotatory displacement around the contralateral facet joint as type D. If there is a bilateral displacement around the center of the odontoid process, the lesion this is typed E.[8] Most frequently in these cases of rotatory or anterior–posterior dislocation, fractures of the atlas and the odontoid process graded as type II or III according to Anderson and D'Alonzo are diagnosed additionally.[9]

As the alar ligaments are known to be the major restrictor of rotation and lateral flexion, traumatic rotatory luxation appears if the alar ligaments and the facet joint capsules are damaged due to flexion and rotation forces. The TAL, however, provides rotatory movement of C1 and C2 and remains intact in these cases.[4,10,11] Present results agree that rotatory displacements mostly result from low-energy trauma as domestic plunges and that unilateral joint dislocation occurs usually. Adams observed in his autopsy series that solitary rotatory dislocations of C1 against C2 were accompanied by ligamentous lesions of the alar ligaments in 14 cases.[12] Additional osseous lesions occurred in some cases. None of the patients showed laceration of the transverse ligament.

Atlantoaxial rotatory subluxation is an anterior displacement of one C1–C2 joint with a concomitant posterior migration of contralateral articulation and presents with the "cock robin position" of the neck, with head tilted to one side and rotated to the contralateral side with slight flexion of the neck. The TAL is preserved in this type of subluxation. The patients may present with occipital pain due to C2 root compression, posterior fossa symptoms, and neurological deficits, which are more common in adults as compared with children.

The differential diagnosis includes benign torticollis, in which the contraction of sternomastoid muscle happens on the contralateral side of head rotation.

Open mouth X-rays may demonstrate asymmetric C1 lateral masses with respect to midline. Computed tomography (CT) is essential in diagnosing these injuries and reveals the rotated position of C1 on C2.

Nonsurgical treatment of patients with traumatic rotatory subluxation has been reported to be successful. Early cranial traction followed by external immobilization for 1.5 to 3 months has been shown to have achieved good long-term rotational stability in several studies. However, surgical reduction and fixation is required for irreducible injuries, recurrent subluxations, and ligament injuries. The most successful method of reduction and instrumentation is C1 lateral mass and C2 pedicle screw rod fixation, among the various methods of posterior fixation of C1–C2 joint.

Fielding recommended C1–C2 arthrodesis for patients with type II or III lesions (anterior displacement) who display neurologic deficits or fail to respond to skeletal traction.[13] Schmidek et al proposed transoral facetectomy followed by traction to allow fracture reduction and then occipitocervical arthrodesis.[14]

Odontoid Fracture

Unstable odontoid fractures can also lead to AAD (►**Fig. 1**). Odontoid fractures comprise 9 to 20% of all cervical spine injuries. Most common symptom is neck pain, and major neurological deficits are infrequent.

Anderson and D'Alonzo have classified odontoid fractures into three types. Based on this universally accepted classification, the type II odontoid fractures often require some form of stabilization as the chances of nonunion are very high with just immobilization. The problem with the conservative management of these fractures is the risk of nonunion and delayed development of myelopathy. Instantaneous fixation is achieved with surgical management, thus permitting an early mobilization and rehabilitation. However, the optimum treatment strategy on whether to perform surgery or to continue the patient on conservative management is still mired in controversy. The surgical approaches prevalent for dealing with acute odontoid fractures include either an anterior odontoid screw placement or posterior C1–C2 fixation. The decision to choose one

Table 1 Classification systems for atlantoaxial rotatory luxation

	Odontoid pivot	Anterior displacement with one lateral articular process pivot		Posterior displacement
Fielding	Type I	Type II (3–5 mm)	Type III (> 5 mm)	Type IV
White/Panjabi	Type A	Type C		Type B

Fig. 1 X-ray and computed tomography (CT) images showing type II odontoid fracture with resultant atlantoaxial dislocation.

approach over the other depends on many factors, out of which integrity of TAL is the most important factor. The anterior fixation can be considered if the TAL is intact and perfect reduction can be achieved, and it has the advantage of preserving C1–C2 motion and head/neck rotation.

A halo brace requires prolonged application before fusion is achieved. It is also very cumbersome to use with a relatively low compliance, especially in the hot and humid environment of the Indian subcontinent. Hence, conservative management is only considered in those patients who have a nondisplaced and stable odontoid fracture; and in those who were unfit for anesthesia due to severe comorbidities or were unwilling for surgery.

Odontoid fractures in elderly is a topic of concern, some studies showing the rate of mortality equal to that following fracture neck of femur. There is a debate regarding which management strategy (surgical vs. nonsurgical, anterior odontoid screw vs. posterior C1/C2 fixation) to be followed in these patients. The recent AO spine study showed that operative intervention in the form of posterior fixation is safe and results in good outcome.

Management of Traumatic Atlantoaxial Dislocation/Subluxation

Nonoperative management of AAD includes the use of a cervical collar or a halo. It is used if reduction of subluxation/dislocation can be achieved and the orthosis is used to maintain the reduction. A halo provides better immobilization but is difficult to tolerate for the patient, especially in countries where the climate is hot and humid.

Operative management is required for many of these patients. There are many surgical options which can be used in these patients. We will briefly discuss each of these. We have divided the various options into anterior and posterior approaches.

Posterior Approaches

Dorsal Wiring/Interlaminar Clamps

Gallie first described posterior C1–C2 sublaminar wire fixation in 1939 with the use of steel wire. Brooks and Jenkins and Sonntag later on modified the wiring technique. Neck immobilization is recommended for up to 3 months after the procedure (►**Fig. 2**). Cables made up of titanium are readily available these days. Gallie's fusion offers good stability in flexion and extension. However, it offers very poor stabilization in rotational movements. High rates of nonunion have been described after Gallie's technique. Sonntag recommended halo immobilization for 3 months followed by a Philadelphia collar for 4 to 6 weeks for all patients in postoperative period to improve the fusion rates. The other shortcoming of these techniques is the requirement of an intact posterior C1 arch and the risk of dural/spinal cord injury while the wires are passed beneath the posterior elements.

Fig. 2 Postoperative image showing C1–C2 wiring.

Another method of C1–C2 arthrodesis using the same principle is the use of posterior interlaminar clamps. Presence of Jefferson's fracture or a Hangman's fracture or significant degenerative changes and osteoporosis of the posterior elements of C1 and C2 precludes this technique.

C1–C2 Transarticular Screw Technique

C1–C2 transarticular screw was described by Magerl for the treatment of odontoid fractures. Since then this technique has been tried in AAD of other etiologies. The greatest advantage of the C1–C2 transarticular screw technique is the complete obliteration of rotational motion of the atlantoaxial joint. However, this technique has a steep learning curve and there is risk of serious complications like spinal cord injury, hypoglossal nerve injury, or vertebral artery injury. Good preoperative planning using CT with angiography is required to avoid these complications and get the desired trajectory. Procedure should not be done in cases of aberrant position of vertebral artery. One very important prerequisite of the procedure is that the C1–C2 should be in reduced position before the screw path is drilled.

C1 Lateral Mass Screw with C2 Pars or Pedicle Screw Fixation (Goel and Harms Technique)

The technique of C1 lateral mass screw and C2 pedicle screw and plates for C1–C2 fusion was pioneered by Goel et al (►**Figs. 3** and **4**). The authors recommended sacrifice of bilateral C2 ganglia to achieve expose and denude the C1–C2 joint and achieve joint arthrodesis. They reported 100% fusion rates. This fixation technique has many advantages over the transarticular screw. C1 and C2 need not to be in reduced position before screw insertion is done. Moreover, this fixation method can be done in patients with an aberrant vertebral artery. The authors described that the plates act as a tension band, providing stability in flexion/extension and hence a dorsal wiring is not necessary.

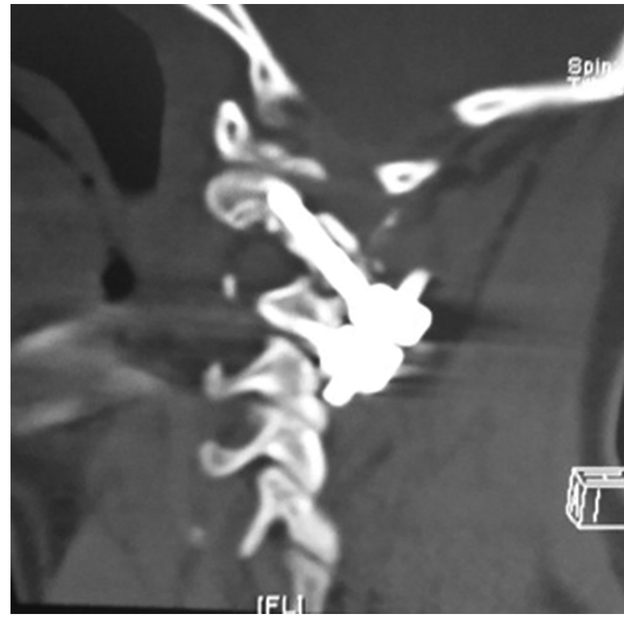

Fig. 3 Postoperative computed tomography (CT) showing C1 lateral mass and C2 pars screw.

C2 Translaminar Constructs

Screws can also be inserted in the C2 laminae which can be connected to C1 screws or screws in subaxial spine. This technique was described by Leonard and Wright and is a safe technique as the screws are away from the vertebral artery and offer rigid fixation. The perquisite for these screws is an intact posterior C2 element.

Occipitocervical Fixation

Occipitocervical fixation is done in certain scenarios when C1–C2 segmental fixation is not possible or when transoral odontoidectomy (TOO) has been done (►**Fig. 5**). It is not a preferred approach as there is significant loss of neck movement. Occipital clamps are inserted and connected with rods with C1 and/or C2 and/or subaxial spine lateral mass screws.

DCER (Distraction, Compression, Extension, and Reduction) Technique

DCER stands for distraction, compression, extension, and reduction. This is a surgical technique to reduce AAD, realign and correct basilar invagination (BI), with a single-staged posterior approach. This involves motion in two-axis using the lever principle. This is a technique which was pioneered by Professor P. S. Chandra. Though it is described for congenital CVJ anomalies, it has some role in the traumatic AAD cases as well. DCER is helpful in old

Fig. 4 Pre- and postoperative X-ray images showing type II odontoid fracture following C1–C2 posterior fixation by Goel–Harms technique.

Fig. 5 Computed tomography (CT) demonstrating occipitocervical fixation.

neglected cases of traumatic AAD where reduction is not possible with the other techniques described above.

C1–C2 joints are opened and the cartilage over the joints is removed. The joints are then drilled with a diamond drill and then spacers (autologous bone graft or polyetheretherketone or titanium) are inserted in the joint space. This step reduces the BI. BI is usually not there in posttraumatic cases. However, this joint manipulation and distraction might help in reducing the AAD which is otherwise nonreducible.

Next step is compression and extension component. A braided no. 20 stainless steel wire tied between the temporary occipital screw and inferior border of the C2 spine is used to achieve compression and extension. Gradual turning of the wire leads first to compression between OC1–2 tightly holding the spacer in place. Following optimal opposition between the spacer and the joint surfaces, it is next followed by extension at the OC1–2 joints. This results in the correction of AAD. Occipital clamps are placed and secured with rods to C1–C2 screws after adequate reduction has been achieved. Additional screws can be placed in subaxial spine.

Anterior Approaches

Odontoid Screw

An anterior odontoid screw placement is preferred over posterior fixation in both type II (including anterior oblique fractures and comminuted types IIA fractures) and type III (high type) odontoid fractures as it preserves C1–C2 mobility. A proper alignment of the fractured fragment following application of traction and the intactness of the transverse ligament (determined on MRI) are the essential prerequisites for an anterior odontoid screw fixation (►**Fig. 6**).

Posterior fixation is recommended for patients in whom anterior odontoid screw fixation is not possible due to coexistent transligamentous tears/inability to attain alignment/reduction.

Fig. 6 Postoperative computed tomography (CT) showing bony fusion following an odontoid screw insertion.

Transoral Odontoidectomy

TOO is an old procedure and is usually used in congenital CVJ anomalies. TOO has a limited role in posttraumatic AAD, especially in patients with old malunited odontoid fractures, where reduction could not be achieved and there is anterior compression over the neural elements. TOO is not a favored approach due to its associated patient morbidity and the requirement of occipitocervical fusion. Nowadays, most of the patients with AAD are first approached from posterior and C1–C2 joint manipulation is tried. If the reduction cannot be achieved, only then TOO procedure is done.

Anterior C1 and C2 Fixation Technique

Goel et al described transoral instrumentation for unstable CVJ in 1994. Later, Harms and colleagues described the transoral technique to fixate the anterior cervical spine in patients undergoing transoral approaches to the odontoid for rotatory dislocations, tumors, or infections. Recently, many other techniques of anterior fixation have been described, including one from retropharyngeal approach. The main advantage of this approach is that transoral decompression with anterior fusion can avoid a subsequent posterior neck incision for fixation. Many special types of implants including "T"-shaped plates are available.

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