CASE REPORT

Atlantoaxial Joint Interlocking Following Type II Odontoid Fracture Associated with Posterolateral Atlantoaxial Dislocation: a Case Report and Review of Published Reports

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A rare case of atlantoaxial lateral mass joint interlocking secondary to traumatic posterolateral C_{1,2} complete dislocation associated with type II odontoid fracture is herein reported and the impact of atlantoaxial joint interlocking on fracture reduction discussed. A 72-year-old man presented with traumatic atlantoaxial lateral mass joint interlocking without spinal cord signal change, the diagnosis being confirmed by radiography and 3-D reconstruction digital anatomy. Posterior internal fixation was performed after failure to achieve closed reduction by skull traction. After many surgical attempts at setting had failed because of interlocking of the lateral mass joints, reduction was achieved by compressing the posterior parts of the atlantal and axial screws. Odontoid bone union and C_{1,2} posterior bone graft fusion were eventually obtained by the 12-month follow-up. The patient had a complete neurological recovery with no residual neck pain or radiculopathy.

Key words: Atlantoaxial joint interlocking; Odontoid fracture; Posterior dislocation; Posterior operation

Introduction

Type II odontoid fracture associated with atlas posterolateral dislocation is a rare upper cervical injury, only such nine cases having been reported so far in English. Because so few case reports have been published, no consensus has been reached regarding the extent of the damage and treatment of this type of injury^{1–9}. Reduction was achieved by traction in only three of nine previously reported cases. Fortunately, all those patients who survived had no or mild neurological deficit. Closed reduction was achieved in two cases by applying skull traction or Halo followed by posterior fixation^{1,2}. A failed closed reduction was reportedly successfully set by posterior open reduction and internal fixation^{3,6,8}. One author reported failure of closed reduction followed by transoral reduction and anteroposterior fixation⁴. Many factors can contribute to the difficulty in reduction of this type of

injury. The main reason for failure is likely the bilateral atlantoaxial lateral mass joint interlocking that occurs with this type of injury. The phenomenon of interlocking has not been described clearly in previous published reports. Here, we report a case of atlantoaxial lateral mass joint interlocking resulting from type II odontoid fracture associated with atlas posterolateral dislocation, which led to failure in reduction. This article focuses on the mechanism of lateral mass joint interlocking and its impact on reduction. To our knowledge, this is also the first description of the interlocking phenomenon and analysis of its mechanism.

Case Report

A 72-year-old man gave a history of falling and rolling down an approximately 2 m high hillside. When he

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recovered from a brief episode of loss of consciousness, he experienced neck pain and impaired movement.

On examination on admission, the patient was found to have maxillofacial skin contusions, mild torticollis and a stiff neck. Neurological examination revealed bilateral upper extremity superficial hypoesthesia. Limb muscle strength was graded V. Cervical X-ray films revealed a type II odontoid fracture with posterolateral atlas dislocation (Fig. 1A). Cervical CT scan and 3-D reconstruction digital anatomy confirmed an odontoid fracture associated with a partial cortical avulsion fracture of the anterior tubercle of the atlas. The odontoid process and atlas were dislocated to an extreme posterior and right position (Fig. 2) and the left lateral mass of the atlas compressed into the vertebral canal, causing step-off interlocking (Fig. 2B,D). The right lateral mass of the atlas was located to the right of the right lateral mass of the odontoid vertebra, which also demonstrated step-off interlocking (Fig. 2C,E). MRI showed no atlantoaxial plane spinal canal compression or spinal cord signal change (Fig. 1B).

An attempt to gradually perform a closed reduction was made using Gardner–Wells tongs and weights from 3.0 kg to 10.5 kg in steps of 1.5 kg. Cervical radiographs were obtained to check the alignment of the spine after each traction weight increase. The patient complained of pain when the traction weight had reached 10.5 kg, yet there was no evidence of atlantoaxial joint reduction. A 4.5 kg traction weight was maintained and an open reduction scheduled a week later.

Because the atlas was dislocated both posteriorly and to the right and had lateral instability, the posterior fixation spectrum comprised C₁–C₃. Surgery was performed in the prone position under general anesthesia with skull traction

sustained. A posterior median incision was used to expose the posterior arch of the atlas and spinous processes and laminae of C₂ and C₃, to obtain a view of the right posterolaterally displaced atlas. Setting was attempted with a combination of a towel clip gripping the axis spinous process and a thumb pushing the atlas posterior arch forward; however, reduction was not achieved because of the interlocked lateral atlantoaxial joints. According to Harms¹⁰, C_{1,2} stabilization can be accomplished using multi-axial screws in the C₂ pedicle and C₁ lateral mass and applying the same screws in the C₃ lateral mass. However, repeatedly distracting the C₁ and C₂ screws under C-arm monitoring failed to achieve complete reduction (Fig. 3A). Because of the lateral mass interlocking, a switch to compressing the atlantoaxial screws was made. An unlocking snapping sensation was then clearly felt, indicating that reduction was complete (Fig. 3B). Complete reduction and reliable fixation were confirmed by C-arm. Iliac and particulate bone was then implanted over the posterior arch of the atlas and the axis lamina, the cortex of which had been removed (Fig. 4).

There were no postoperative complications such as neurological damage or wound infection. A neck brace was used continuously for 3 months. At the final 12-month postoperative follow-up, dynamic radiographs revealed no atlantoaxial instability and CT scan confirmed that the odontoid fracture was healing and C_{1,2} posterior fusion was complete (Fig. 4).

Discussion

A search of published reports revealed that type II odontoid fracture combined with atlas posterolateral

Fig. 1 (A) Lateral cervical film showing a type II odontoid fracture combined with posterior dislocation of the atlas (arrow). (B) MRI showing no cord compression or intramedullary cord signal abnormality at the level of the atlantoaxial dislocation (arrow).

Fig. 2 (A) Cervical CT scans and sagittal reconstruction confirming the trans-odontoid luxation fracture with atlas displaced right posterolaterally; (B, D) The whole left lateral mass of the atlas has been compressed into the spinal canal and a step-like interlocking has been formed by the exterior and medial parts of the lateral mass of the axis; (C, E) The same phenomenon has developed between the right posteriorly displaced left lateral atlantal mass and right lateral mass of the axis; (F) Three-D reconstruction CT images showing force lines of ligaments and position of joint interlocking in left (left panel), right (middle panel) and top (right panel) views. a, anterior longitudinal ligament and anterior membrane; b, posterior longitudinal ligament and tectorial membrane; c, intertransverse ligament; d, ligamenta flava and posterior membrane; e, interspinal and nuchal ligaments; f, position of joint interlocking.

dislocation is rare, only nine cases with adequate radiography data having been reported thus far¹⁻⁹; reduction with cervical traction was achieved in only three of eight cases (Table 1). Many factors can make reduction of this type of injury difficult, the central factor likely being bilateral interlocking of the atlantoaxial lateral mass joint. There are few descriptions of interlocking in published reports.

Atlantoaxial lateral mass joint interlocking differs from low cervical lateral mass interlocking. The articular surface of the atlantoaxial lateral mass is almost parallel to the horizontal plane, whereas the lower cervical lateral mass is perpendicular to the horizontal plane and imbricated in the sagittal plane. The upper vertebral lateral mass slides anterior to the lower vertebra, which produces interlocking.

Fig. 3 (A) C-arm image showing that, because of anterior interlocking, distraction between C₁ and C₂ screws failed to achieve reduction. (B) C-arm image showing that compressing the C₁ and C₂ screws released the interlocking, enabling reduction to be achieved.

Fig. 4 (A) Three-D reconstruction CT images: left (left panel), right (middle panel) and top (right panel) views of the patient 1 month after open unlocking, reduction and fixation of C₁₋₃. a, odontoid process and bone fragment; b, atlas; c, axis; d, posterior fixation spectrum; e, bone graft. (B, C) At the 12-month follow-up, flexion/extension and lateral radiographs of the cervical spine demonstrate no instability of the atlantoaxial complex. (D) Thin-slice CT image showing a healed dens fracture and successful posterior C₁₋₂ fusion.

TABLE 1 Summary of recent reported cases of the type II odontoid fracture associated with posterolateral atlas complete dislocation

Case no.	References	Age (years)/sex	Neurological deficit	Reduction		Operation and approach
				Closed	Open	
1	Clarke <i>et al.</i> ¹	80/M	No	Yes (reduced in a halo body jacket)	—	Posterior fixation of C _{1,2}
2	Sullivan <i>et al.</i> ²	82/F	No	Yes	—	Posterior pedicle screw fixation
3	Mackey and Bancroft ⁶	Not mentioned/M	Not mentioned	Yes, but failed	Yes	Posterior fixation with transarticular, lateral mass and pars screw
4	Wang <i>et al.</i> ⁴	57/M	Yes, upper limb numbness and motor weakness	Yes, but failed	Yes	Anterior odontoid screw fixation and posterior lateral mass and pedicle screws fixation
5	Kandziora and Langheinrich ⁵	84/F	Not mentioned	Not mentioned	Yes	Posterior pedicle screw fixation
6	Koç <i>et al.</i> ³	57/M	Not mentioned	Yes, but failed	Yes	Posterior transarticular screw fixation and wiring
7	Riouallon <i>et al.</i> ⁷	25/M	No	Yes	—	Anterolateral odontoid screw fixation and transarticular screw fixation
8	Zhang <i>et al.</i> ⁸	38/M	Yes, numbness of all fingers, motor weakness	Yes, but failed	Yes	Transoral atlantoaxial reduction plate fixation
9	Pedersen <i>et al.</i> ⁹	77/M	Yes, numbness of all fingers, motor weakness	Yes, but failed	Yes	Occipital cervical fusion and wiring

F, female; M, male.

Why does interlocking of the atlantoaxial lateral mass joint occur? From the anatomical point of view, the odontoid tip is attached by the apical odontoid ligament, both sides of which adhere to the inside edge of the occipital condyle alar ligament. These ligaments and the transverse ligament of the atlas maintain the stability and mobility of the atlantoaxial joint. The over-extension of the neck that occurs with cervical hyperextension injury may lead to severe strain of those ligaments and odontoid fracture. Secondary dislocation of the atlas posteriorly could occur as a result of the inertia effect of violence. If the violence is strong enough, complete dislocation can occur. When both lateral masses of the atlas have been dislocated to the posterosuperior aspect of the axis vertebra, the force on the posterior aspect of the atlas increases, mainly because of pressure from the posterior longitudinal ligament. This results in instability of the atlantoaxial joint and makes it prone to sliding. The stretching of ligaments can eventually cause one mass of the atlas to slide into the spinal canal and the contralateral mass to slide to the axial ipsilateral mass posterolaterally, all of which creates a step-off between these masses. This creates a relatively stable interlocking state under the reverse stretch action of the periphery of the ligaments, which mainly comprise the anterior longitudinal ligament (Fig. 2F).

Odontoid fracture-dislocation, a highly unstable traumatic lesion of the atlantoaxial complex, is most often associated with an Anderson type II odontoid fracture⁵. However, sometimes patients with this injury have no or mild neurological deficits because of interlocking of the articular processes, which prevents the atlas from rocking and therefore prevents further spinal injury. Therefore, although odontoid fracture and dislocation may be obvious on imaging, the

symptoms of spinal cord injury are frequently mild. In the present case, as in some of the reported cases^{1,2,4,7-9}, the patient's neurological symptoms did not parallel the significant radiographic fracture-dislocation.

Surgical treatment of odontoid luxation fracture remains controversial^{6,11}. Our review of published reports revealed that different authors performed different surgical procedures for type II odontoid fractures associated with posterolateral atlas complete dislocation¹⁻⁹. In our case, after closed reduction had failed we operated via a posterior approach. When planning the surgical procedure, correction of the atlas dislocation with simultaneous correction of the lateral slide should be considered. We believed that a fixed segment from C₁ to C₃ was required to achieve solid stability. On the basis of our experience of achieving reduction in the present case, we conclude that the interlocking state of the atlantoaxial lateral mass created a block between the two lateral masses and ligament stretching, such that simple distraction reduction could not be achieved. When we applied adequate pressure to the lateral mass of the atlas and used the axial arch as a fulcrum, the tilting of the anterior arch of the atlas rode over the step, relieving the interlocking and enabling complete reduction.

According to our review of published reports and the present case, lateral mass interlocking is a relatively stable state for trans-odontoid fracture with complete posterolateral atlantoaxial dislocation. The upside is that this prevents the secondary spinal cord injury that can be caused by local movement when the position changes. The downside is that, it may affect setting of the dislocation because in some cases severe fixed counter-traction of ligaments makes reduction more difficult. Thus, clinicians must be aware of this "double-edged sword".

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