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# *Clinical Case of the Month*

# Traumatic spondylolisthesis of the axis: analysis of management

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## Introduction

We present a case of traumatic spondylolisthesis of the axis, also known as hangman's fracture, to be discussed by a panel of specialists.

Although most of the largest series of traumatic spondylolisthesis of the axis suggest that conservative management[1,2,3] is successful, this case presents unique aspects, related to the unusual distraction[4] and the associated spinal cord injury, with high neurologic deficit and respiratory insufficiency, causing difficulty in non-surgical treatment.

## Case presentation

See display on the right.

The initial X-ray (lateral view) is presented in Figure 1.

## How should the patient be treated?

### First opinion

*HH Bohlman*

This case presentation represents a very unstable type 2 Levine C2 pedicle fracture[5,6] and based on my own experience of post-mortem studies of high level cervical spine injuries this patient has a very unstable cervical spine with total disruption of the longitudinal ligaments and disc, as well as posterior elements. This patient is an incomplete spinal cord injury, as she has motor sparing down to the C8 level and sensory sparing all of the way down to include the perianal dermatomes, which is a somewhat optimistic sign for potential recovery of neurological function.

The treatment of this should avoid over-distraction with skeletal traction, but immobilization with a halo vest. If the patient can be reduced in a more anatomic

**Case presentation**

| MOTOR INDEX | | | | SENSITIVE INDEX | | | |
|---|---|---|---|---|---|---|---|
| | | | | Light Touch | | Needle | |
| | Right | Left | | Right | Left | Right | Left |
| C2 | | | C2 | 2 | 2 | 2 | 2 |
| C3 | | | C3 | 2 | 2 | 2 | 2 |
| C4 | | | C4 | 2 | 2 | 2 | 2 |
| C5 | 3 | 3 | C5 | 1 | 1 | 2 | 2 |
| C6 | 3 | 3 | C6 | 1 | 1 | 2 | 2 |
| C7 | 3 | 3 | C7 | 1 | 1 | 2 | 2 |
| C8 | 3 | 3 | C8 | 1 | 1 | 2 | 2 |
| T1 | 0 | 0 | T1 | 1 | 1 | 1 | 1 |
| T2 | | | T2 | 1 | 1 | 1 | 1 |
| T3 | | | T3 | 1 | 1 | 1 | 1 |
| T4 | | | T4 | 1 | 1 | 1 | 1 |
| T5 | | | T5 | 1 | 1 | 1 | 1 |
| T6 | | | T6 | 1 | 1 | 1 | 1 |
| T7 | | | T7 | 1 | 1 | 1 | 1 |
| T8 | | | T8 | 1 | 1 | 1 | 1 |
| T9 | | | T9 | 1 | 1 | 1 | 1 |
| T10 | | | T10 | 1 | 1 | 1 | 1 |
| T11 | | | T11 | 1 | 1 | 1 | 1 |
| T12 | | | T12 | 1 | 1 | 1 | 1 |
| L1 | | | L1 | 1 | 1 | 1 | 1 |
| L2 | 0 | 0 | L2 | 0 | 0 | 0 | 1 |
| L3 | 0 | 0 | L3 | 0 | 0 | 0 | 1 |
| L4 | 0 | 0 | L4 | 0 | 0 | 0 | 1 |
| L5 | 0 | 0 | L5 | 0 | 0 | 0 | 1 |
| S1 | 0 | 0 | S1 | 1 | 1 | 0 | 1 |
| S2 | | | S2 | 1 | 1 | 0 | 1 |
| S3 | | | S3 | 1 | 1 | 0 | 1 |
| S4-5 | | | S4-5 | 1 | 1 | 0 | 1 |
| Total | 12 | 12 | Total | 27 | 27 | 27 | 35 |

Motor Index 24 Sensitive Index 54 62

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**Figure 1** Initial X-ray in the lateral view

position then an anterior fusion could be carried out with plate fixation. Otherwise, one would have to do a posterior cervical fixation from C1-3 by wiring in an iliac bone graft.

## Second opinion

*DA Capen*

This 27-year-old auto accident victim has a type 2 traumatic spondylolisthesis of the axis. The radiographs reveal a distractive flexion type trauma with some displacement, but not dislocation of the facet joints. By the Levine-Edwards Classification, the injury is one of C2-3 instability. There is the potential for kyphotic angulation with the utilization of traction.[6]

The neurologic injury appears to be an anterior cord syndrome lesion. There is some sensory sparing below the level of trauma, but marked weakness in the C4 and below innervated musculature followed by complete tetraplegia.[15]

On the plain radiographs the spinal canal size does not appear to be congenitally compromised and the fracture deformity does not appear to have any areas of complete translation through the cord. The fracture deformity itself is amenable to reduction and serial neurologic examinations followed by immediate placement in a halo vest immobilizer with the C2-3 injury as reduced as possible. Maintenance of reduction would contraindicate surgery. The only early indication for surgery would be the inability to maintain a reduced position once the patient is upright. Due to the pulmonary compromise it would be necessary to provide respiratory support, but the respiratory status would be helped by the immediate ability to become upright.

Most series of C2-3 injuries and axis injuries suggest that halo vest management will be successful.[1,2] If late instability occurs or if significant neurologic deterioration occurs early to mandate surgery or if the attempt to mobilize the patient in the halo vest leads to loss of reduction, the surgical treatment would be a posterior C1-3 arthrodesis either by wiring or short segment plate and screw fixation. The vast majority of the lesions, however, are stable in a halo. In the rare instance of documentation by MRI scan demonstrating soft tissue compression it may be necessary to consider an anterior arthrodesis with soft tissue removal and plate fixation from the front.

## Third opinion

*J Cotler*

The case presentation of a 27-year-old female admitted 7 h after a motor vehicle accident with high tetraparesia and respiratory insufficiency requiring intubation is obviously a very interesting and potentially lethal injury, but with significant potential to regain function if treated expectantly and very carefully. The reason for the cautious optimism is the presence of sensory findings in the lower extremities,[7] a fact that should make the definitive care an absolute emergency. The injury described is most unusual with a hangman's fracture demonstrating both a bilateral pedicle fracture as well as bilateral facet dislocation.

Our approach to this would be extremely careful, being cognizant of the potential for disc herniation at C2-3, which is frequently seen with this injury. Depending upon the facilities available I would immediately obtain either a CT scan or an MRI for the potential of a disc herniation, and my own preference is MRI. Hopefully the intubation was done with fiberoptic means to protect the skull and proximal vertebral hypermobility, particularly forced flexion or extension. Ideally, this would be managed with neurosensory and perhaps even motor evoked potentials, but at least neurosensory monitoring, and hopefully would be pulling through the body of C2 and have no effect upon the dislocated facets. If the CT scan or MRI show a disc herniation embarrassing the canal, in the neighbourhood of 50% or more, Gardner Wells tongs would be applied and the patient treated on a Stryker frame with the minimal amount of traction for immobilization, only 5–10 pounds. This should be monitored by lateral radiographs for angulation, displacement or distraction. The initial approach for a disc herniation is anteriorly performing a discectomy at C2-3 and nothing more. A loose closure would be applied to the musculature and skin

of the neck, and then the patient would be rotated 180 degrees in order to approach the neck posteriorly. This obviously must be carried out very carefully preventing little in the way of transmitted forces to the floating C1-2 vertebrae. Approach the neck posteriorly, obtain an open reduction of the lamina, facets and pedicles and apply an axis plate and screw into what is remaining of the pedicle of C2 and then into the body of C2 as well as through the facets at C2-3 in order to secure the fixation of C2 and 3. Should that dislocated facet have a fracture and be a floating facet, one may very well have to do the fusion from C1-3, either with posterior spinous or sublaminar wiring to limit the shear forces on the pedicle screw. Since the patient is only 27 years of age and has good bone stock, apply local autogenous bone in the vicinity of the pedicles of C2 as well as in the articular surfaces of 2, 3 prior to application of the plates and the onlay corticocancellous grafts from 2 and 3. Adequate lavage of the wound should be carried out and then proceed with primary closure of the posterior incision. The fracture position would be substantiated by lateral X-ray prior to leaving this operative area. At this point the anterior neck would again be approached. The subchondral bone should be perforated some way in order to allow neoangiogenesis through to nourish the graft. The graft between the bodies of C2-3 would be an autogenous graft, preferably iliac crest, of the Smith-Robinson type.

In the best possible circumstances, the patient would be slim with a small jaw, and perhaps a swivel-type screw driver would be available in order to apply a single level plate to C2-3 to help secure further immobilization of the fracture site, disrupted disc space, and the interbody graft that had been inserted between the bodies of C2-3. In addition, the patient would be immobilized in a halo until healing appeared to be secure. Incidentally, I feel very strongly that this should be carried out on an emergency basis, as soon as the patient is seen and adequately evaluated for assurance this is an isolated lesion, and hopefully to prevent continued ongoing neural compression. The reasoning for acute care in this circumstance is that sensation is present in areas distal to the pathologic lesion. One would be cautiously optimistic that improved motor function as well as sensory function would be forthcoming. In our institution this triple patient rotation treatment approach would be called a 540 degree. Considering the hazards associated with the presence of an untreated disc herniation and fracture dislocation, stabilization of the patient in a prone position and attempting a reduction and stabilization of the posterior elements first can be very dangerous. The process of reflecting the musculature from the posterior lamina allowing pressure to be transmitted to the neural elements without proper decompression of neural canal may predispose to added trauma and damage to the cervical cord. Our treatment protocol is an attempt to give maximum protection to the spinal cord, while trying to stabilize only one motion segment, if possible, thus hopefully not losing more than about 10% of cervical rotation. Of course, it would still predispose the C3-4 interspace to junctional disease long term in perhaps a 15–35 or 40 year window, but would save the possibility of including C1 into C3 or 4 that would be a much more aggressive procedure to rob the patient of a much greater range of motion. In addition we would still be cautiously optimistic that some neural function could return below the current areas of motor deficit.

## Fourth opinion

*K Dons and F Biering-Sorensen*

The initial neurological examination revealed an incomplete C4 tetraplegia with sacral sparing. Due to respiratory insufficiency she had been intubated and presumed ventilated. She was admitted 7 h post-injury. Because she arrived within the time frame of 8 h post-injury we would, according to the study by Bracken *et al*[8] administer high doses of methylprednisolone, ie 30 mg per kg bodyweight iv within 15 min, followed by 5.4 mg per kg bodyweight per hour for the next 48 h. We would further secure drainage of the urinary bladder, preferably by intermittent catheterisation as soon as possible after acute operation, as described below.

The initial lateral X-ray showed a severe C2-3 fracture of the Hangman type with severe axial displacement of the C1-2–body complex relative to the C2 lamina/pedicle–C3 with some kyphotic angulation at the fracture site. The fracture is certainly unstable, with disc rupture and complete ligament rupture. Our treatment goals are to:

- Maximize possibility for neurological improvement
- Ensure spinal stability
- Prevent secondary complications by early mobilization

We would go through the following steps:

(1) Cervical fixation by light traction (Gardner–type or similar, MRI–compatible).
(2) MRI–scan of cervical spine to determine type and extent of spinal canal pathology (intraspinal fragments, spinal cord lesion, epidural hematoma, traumatic disc herniation).
(3) Patient positioned in Stryker frame for easy turning for a combined anterior and posterior procedure.
(4) Surgical procedure: First an anterior procedure with complete discectomy followed by intercorporal iliac crest grafting and fixation by anterior plating. Posterior procedure with removal of the C2 spinous process and lamina to expose the spinal cord, remove possible fragments and hematomas and repair of possible dural tear. Depending on stability obtained from the

anterior procedure, probable additional stabilization by C2 pedicle screws supplemented by C3 and 4 lateral mass screws with plating.[9]

(5) Follow up on the surgery by X-ray control with lateral flexion–extension films after 3, 6 and 12 months.

In addition, an antidecubitus regime, and anticoagulation therapy with low molecular heparin will be initiated immediately. Due to the risk of paralytic ileus, continuous enteral nutrition should be given, to preserve the integrity of the intestinal mucosa and hereby decrease the risk of septicaemia. After surgery the patient will be weaned off the ventilator as soon as possible.

## Fifth opinion

*DG Marchesi*

With this case we are confronted with a severe injury of the C2-3 segment in a plegic young patient. The mechanism of this injury was a severe cervical spine elongation probably combined with hyperextension resulting in a dislocated spondylolysis of C2 associated with distractive injury of the C2-3 disc. These types of injury are extremely rare because mostly they are not compatible with the survival of the patient.

Conservative management can be performed on stable injuries showing the classical fracture in the interarticular portion of C2 and no or minimal dislocation.[10] In our case, because of the important segmental instability in a tetraparetic patient requiring intensive care in a special unit and early rehabilitation I would highly recommend a surgical management with segmental stabilization.

The reduction of the interarticular dislocation will be possible only using a posterior approach and progressive dissection of the C2 lamina. After fracture repositioning both the lytic fracture and the C2-3 segmental instability will need to be addressed.

Suggested is a posterior plate fixation using in C2 a direct inter fragmentary screw through the pars interarticularis as described by Judet (Figure 2) and a conventional articular mass screw in C3.[11–14] The entry point for the screw fixation of the lysis (Judet screw) is located in the center of the articular mass. The previously described dissection of the lamina until the lysis will help to individualize the lateral border of the spinal canal. The screw will be directed slightly convergent towards the midline to avoid the vertebral artery and the C1-2 joint.

As mentioned in the literature, in these extremely unstable injuries the posterior C2-3 plate instrumentation might be insufficiently solid.[15] The stability can be assessed intra-operatively on fluoroscopy by doing flexion/extension movements. In the case of persistent instability no additional anterior C2-3 discectomy and plate fixation will be necessary.

## Sixth opinion

*JE Zigler*

This 27-year-old female is admitted 7 h after trauma, requires intubation for respiratory support, and has incomplete anterior cord tetraparesis with sacral sparing. She has sacral sparing, so she is not in spinal shock. The X-rays demonstrate a flexion–distraction

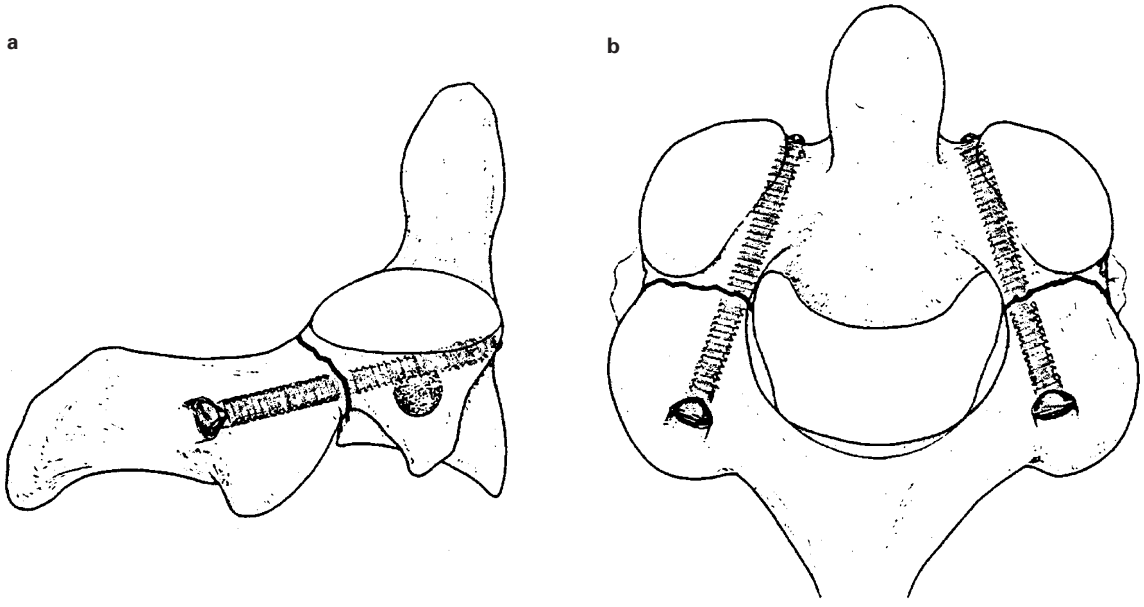


**Figure 2** Schematic representation of the screw through the pars Interarticularis

mechanism of injury, axial distraction at the C2-3 level, and a bilateral pedicle fracture of C2 (Hangman's type). Distraction is maintained, and spontaneous reduction is blocked, by impingement of the fractured posterior arch of C2 on the inferior aspect of the C2 endplate.

As in most acute spinal injuries, it is useful to think of this as two injuries: a neurologic injury and a mechanical injury. Therapeutic intervention should be directed along parallel lines, addressing both components of the injury.

The fracture is probably not causing direct compression. The C2 spinal canal diameter is generally so spacious that cord compression at that level is rare. Also, hangman's fractures are self-decompressing injuries, by their nature. Although we do not have an AP view, so it is possible that one of the pedicles has impaled the cord, this is unlikely since we do not see evidence of rotation of the free posterior element, or of the vertebral body. What is present here that is potentially a source of ongoing injury to the cord, is distraction. The unusual ocurrence of the pedicle stumps impaled to the underside of the C2 body has prevented spontaneous reduction, allowing wide distraction of the C2-3 disc space, and stretching of the cervical cord.

To address the neurologic portion of the injury, the cervical spine should be stabilized to prevent motion of this unstable spine and irritation to this cord-at-risk. In the field, a hard collar or taping to a backboard would be appropriate for transport, but in the hospital setting, this patient should be placed in traction. Gardner-Wells tongs would be easy to apply and adequate for stabilization (and ultimately reduction), but I would recommend application of a halo ring. The ring could be used for initial traction, and would be connected ultimately to a vest, so it would save one step for this patient if a halo could be applied initially. Tongs are fine if adequate assistance or equipment is not available at admission.

This patient should be started immediately on methylprednisolone according to the recommended dosages,[8] with a large initial bolus followed by an hourly dose. Insertion of an urinary catheter, orders for a turning program every 2 h, and a thorough medical assessment need to be set in place. An MRI scan would be a desirable study to have for evaluation of the cord for extrinsic pathology, but should not interfere with a timely reduction.

Considering the mechanical component of this injury, the injury mechanism (flexion and distraction) means that posterior element damage must be suspected. Widening of the interspinous space between the C1 ring and the C2 lamina confirms this portion of the mechanical injury, as does the flexion-rotation of the C2 laminar ring with respect to the C2-3 facet joint. This joint is distracted, so there is soft tissue capsular injury at the C2-3 level, and interspinous ligament disruption at C1-2. But there is also anterior disruption. Distraction of the C2 and 3 vertebral bodies means that there is disruption of the disc annulus and anterior longitudinal ligament. This is an example of circumferential instability, and infers an extraordinarily unstable mechanical situation.

Treatment should consist of attempted closed reduction by axial traction. Given the circumferential nature of the injury, I would start with only 5 pounds of traction and obtain a lateral X-ray. Although classic teaching suggests using 10 pounds of traction for the skull and 5 pounds for each additional level, it has been my experience that in cases of circumferential instability, a relatively small traction force should be used initially.

It is likely that this will reduce with a small amount of traction, starting with 5 pounds, and increasing in 2.5 or 5 pounds increments every 30 min while checking lateral radiographs. A small flexion moment may be helpful in positioning the traction pulley. Once the fracture is 'unlocked', traction should be slowly decreased and the angle of traction placed back into neutral or slight extension (since the injury occurred in flexion). A halo vest should be applied and the patient's neurologic progress followed. Once she is medically stable, she should have surgical stabilization, since the majority of this injury is ligamentous and has a marginal likelihood of stable healing.

If the fracture will not reduce by traction (I would stop at 20–30 pounds in this case due to the potential of increasing the cord injury), this patient should have an emergency open reduction and internal fixation. I would operate through a posterior approach, exposing the ring of C1 and the posterior elements of C2 and 3. The surgeon must be extremely careful in stripping soft tissue from the C2 spinous process and lamina, since the segment is unstable and could rotate in the spinal canal, further damaging the spinal cord. The lamina of C2 should be disimpacted from the inferior end plate of C2, a posterior wire placed under the ring of C1, and a second wire placed through the base of the spinous process of C3. Cortico–cancellous outer table bone plates from the iliac crest should be harvested, and wired onto both sides of the spine, in the method of the Bohlman technique, accomplishing a C1-3 stabilization and fusion. Although this procedure could be done under local anesthesia, a general anesthetic would be appropriate in this case since the patient is already intubated. Spinal cord monitoring should be used intra-operatively, if available.

Following surgical stabilization, I would mobilize the patient in a halo vest on post-operative day 1. As long as the over-distraction was reduced intra-operatively, anterior surgery would not be necessary unless a post-operative MRI-demonstrated anterior cord compression from a herniated disc. In that case, an anterior discectomy and fusion at C2-3 would be indicated. Total halo time could be decreased in an anterior fusion when fixed with a plate (6 weeks halo + 6 weeks collar, *versus* 12 weeks halo).

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