Traumatic spondylolisthesis of the axis: Surgical indication and outcomes

A van der Horst MBChB(UFS), FCOrth(SA)
Spine Fellow*
S Lippross MD, PD
Visiting Spine Fellow**
RN Dunn MBChB(UCT), MMed(Orth), FCOrth(SA)
Professor and Head of Department*
***Department of Orthopaedic Surgery, University of Cape Town, Cape Town, South Africa**
****University Medical Center of Schleswig-Holstein, Kiel, Germany**

Reprint requests:
Dr A van der Horst
Department of Orthopaedic Surgery
H49 Old Main Building
Groote Schuur Hospital
University of Cape Town
Observatory 7925
South Africa
Tel: +27 (21) 404-5108
Fax: +27 (21) 447-2709
Email: gospine.avdh@gmail.com

Abstract

Study design:
A retrospective review of patient records, images and demographic data.
Objective:
The purpose of this study is to review the indications for surgery in traumatic spondylolisthesis of the axis (TSA).
Summary of background data:
The majority of authors agree that non-operative management with traction reduction, followed by rigid immobilisation, will result in bony union in 95% of all cases. Asymptomatic pseudo-arthrosis or local kyphosis is usually tolerated well. There are very few true indications for surgery in TSA.
Methods:
A retrospective review of all patients admitted to a level one spinal cord injury centre between 2003 and 2012 with a TSA who underwent surgical intervention. Seven cases were identified. Mechanism of injury, associated injuries, fracture type, indication for surgery, surgical procedure employed, clinical and radiological outcomes were reviewed.
Results:
In 80 patients managed as in-patients with TSA over a 10-year period, only 7 (<10%) required surgery. The fracture configuration had no bearing on whether surgery was utilised, but 'patient factors' had the biggest impact on the decision to operate. These factors included poly-traumatised patients, ICU admission, need for ventilation, skull fractures, scalp lacerations and acute psychosis.
Conclusion:
Indications for surgery are based largely on patient factors and ease of nursing rather than a specific fracture displacement or configuration.
Key words: Hangman's fracture, traumatic spondylolisthesis of the axis, surgical management of TSA, axis fractures, Cape Town

Introduction

Haughton[1] first reported on C2 posterior arch fractures following judicial hangings in 1886. He noted bilateral neural arch fractures with an anterior subluxation of C2 on C3. In 1913 Wood-Jones[2] described the fracture-dislocations of the upper cervical spine after judicial hangings. Schneider *et al*[3] in 1965 introduced the term 'Hangman's fracture' after recognising a similarity in the fracture pattern in patients who were involved in motor vehicle accidents and those associated with judicial hangings. This is however a misnomer due to the very different mechanisms, and traumatic spondylolisthesis of the axis (TSA) is preferred.

TSA is a common injury of the upper cervical spine associated with falls from a height, motor vehicle accidents or any other cause of a sudden deceleration. By definition, the classic 'Hangman's fracture' and TSA are both 'ring-type' fractures – i.e. the ring may be broken through the laminae, articular facets, body, pedicles or pars inter-articularis of the axis vertebra. True TSA is however defined as having a disruption of the pars inter-articularis (*Figure 1*). Both these injuries are often associated with an injury to the ligaments or the inter-vertebral disc or both.

The injury mechanism results in the difference in fracture pattern that we see between TSA and 'Hangman's fracture. In the 'Hangman's fracture' there is a sudden distractive force on a hyper-extended neck which can result in cord transection. In TSA an axial load on a hyper-extended (or flexed) neck leads to a pars inter-articularis fracture.

Whitley and Forsyth[4] recognised that in fracture dislocations of the articular facets, due to compressive hyper-extension injury by frontal impact, the vertebral body dislocated anteriorly, contrary to normal backward motion in extension. To account for this reverse motion, they developed the hypothesis of motion of the head through an arc. According to this 'Forsyth Mechanism',[5] an axial load on a hyper-extended neck resulted in an axial-rotational translated force. This caused bilateral pars inter-articularis fractures and the body of C2 to displace anteriorly on C3, and effectively open the canal. Thus despite the significant fracture displacement, neurological damage is rare. This is due to the lack of a distractive force and the enlargement of the spinal canal.

In 1968 Cornish[6] published his experiences with 14 cases of TSA and in the same paper described surgery in selected cases as a management option.

Effendi *et al*[7] introduced a classification system that was later modified by Levine and Edwards.[8] This system describes four subgroups of fractures (type I, II, IIa and III). Most classification systems rely on the degree of fracture displacement and angulation, which indirectly tell us about the degree of injury to the C2–C3 disc, ligaments, and facet joints.

Displacement can be measured as the distance between a line drawn parallel to the posterior margin of the body of C2 and the posterior margin of the body of C3 at the level of the disc space between the two vertebrae. Angulation is measured by the angle subtended from lines drawn parallel to the inferior end-plates of C2 and C3.

White and Panjabi[9] demonstrated with biological models that when there was more than 3.5 mm of displacement of one vertebral body on top of another, there is significant damage to the inter-vertebral disc and it should be considered unstable. Francis *et al*[10] later defined instability as anterior translation of >3.5 mm, with regional angulation of >11°. In another system, instability was defined as >6 mm of displacement and >2 mm of mobility on flexion and extension X-ray views.

TSA is a common injury of the upper cervical spine associated with falls from a height, motor vehicle accidents or any other cause of a sudden deceleration. True TSA is defined as having a disruption of the pars inter-articularis

Figure 1. True traumatic spondylolisthesis of the axis with disruption of the pars inter-articularis

Without disco-ligamentous injury, fractures of the pars on both sides of C2 can be considered stable (e.g. type I). Concomitant injury to the disc and ligaments of a mobile segment can cause instability (e.g. type II, IIa, and III).

In our study we used the classification system by Levine and Edwards.

Type I injuries are caused by an axial load on a hyper-extended neck. They include all undisplaced fractures, those with <3.5 mm of anterior translation, and no angulation. These injuries are stable as there is no disco-ligamentous injury.

Type II injuries are caused by an initial hyper-extension force while axially loaded, followed by a severe rebound flexion force on the neck. The fracture shows anterior translation of >3.5 mm, with significant angulation (>11°). These injuries are unstable due to disco-ligamentous injury.

Type IIa injuries are caused by a distractive force with the neck in a hyper-flexed position. There is no or minimal translation, but severe angulation (>11°). These injuries are unstable as there is damage to the inter-vertebral disc and the posterior longitudinal ligament.

Type III injuries are rare. They are caused by an axial load on a hyper-flexed neck. This results in severe angulation and translation of C2 on C3 with an associated uni- or bi-facet dislocation. Due to the disco-ligamentous damage type III injuries are highly unstable.

Conservative management with skeletal traction (*Figure 2*) will result in osseous healing in most cases. Vaccaro *et al*[11] reported his experience with conservative management of TSA and stated that after 24–48 hours of successful closed reduction, patients who reduced, could be managed successfully in halo jackets. Effendi[7] and Francis[10] *et al*, confirm that most patients can be successfully managed non-operatively with cervical immobilisation. There is however still controversy regarding the optimal duration of traction.

Conservative management entails initial reduction of the fracture/dislocation with the use of skeletal traction, and maintenance of traction until osseous healing has occurred. This can be achieved with the use of cone callipers or halo traction, followed by rigid (e.g. halo-vest) or non-rigid immobilisation (e.g. Philadelphia collar). The decisive factor in determining the therapeutic approach is the initial angulation and the extent of the disco-ligamentous injury (as per the Levine and Edwards classification). Coric *et al*[12] subsequently suggested that the majority of TSA can be treated with non-rigid immobilisation (Philadelphia collar), and not only rigid immobilisation (halo vests) as previously suggested.

The prognosis for healing of TSA is excellent with over 95% of cases uniting by non-operative method.[10] Rigid immobilisation produces a high level of fracture consolidation with only a 5% pseudo-arthrosis rate. Controversially some authors have suggested that collar immobilisation alone without anatomic realignment may suffice. This is because of the perceived lack of long-term complications from facet joint mal-alignment or inter-vertebral disc disruption. Post-mortem studies by Bucholz and Cheung found spontaneous fusion of the C2/C3 anterior longitudinal ligament and disc following conservative treatment.[13]

It is difficult to justify surgical intervention when conservative care is so effective. Traditional indications have been based on the failure of conservative treatment, i.e. symptomatic non-unions, severe kyphosis or chronic instability after an adequate trial of non-operative treatment. Indications in the acute setting may be for patients with head injuries or scalp lacerations that do not allow the use of a halo vest.

Figure 2. Conservative management: Traction with a halo ring

Surgical options include anterior C2–C3 decompression and fusion with anterior bone graft and plating, C2 trans-pedicular lag screw fixation, and posterior C1–C3 or C2–C3 fusion.

When there is a disc herniation with cord compression, a C2 body fracture, or a failed posterior arthrodesis, then the anterior approach may be preferred.

The posterior approach is popular as it is a relatively simple exposure. However, some authors have claimed that the injury rate to critical structures for C2 trans-pedicular screws is high. Another shortcoming of the posterior fixation by rods and screws is the neck pain experienced after surgery. Nevertheless segmental fixation, such as the trans-pedicular screw of C2 has been widely adopted, for it preserves rotation movement of the neck by sparing the atlanto-axial articulation.

Management in our unit

As type I injuries are stable, they are managed as outpatients in a Philadelphia collar (*Figure 3*) for 8–12 weeks.

Type II injuries have some degree of instability, and are initially all managed in skeletal traction (*Figure 4*). If an acceptable reduction can be achieved and maintained on skeletal traction (e.g. cone callipers or halo-type traction), then the patient may be discharged in a halo vest (*Figure 5*) or Philadelphia collar for 12 weeks as their definitive management. If the translation is >6 mm, or an adequate reduction is not achieved, or it is not possible to maintain the reduction, then these patients may require a longer period of skeletal traction (4–6 weeks) prior to rigid collar immobilisation.

Type IIa injuries are caused by a distractive force, which may result in severe circumferential disco-ligamentous instability. Current management guidelines recommend against axial directed traction because of the possibility of catastrophic over-distraction at the fracture site. Uncontrolled skeletal traction is therefore contraindicated, but if it is applied, it must be in a fully alert patient, the traction must be directed to cause hyper-extension, with careful attention being given to the maximum weight applied.

Type III injuries are rare. They are managed in skeletal traction to reduce the fracture-dislocation. If an adequate reduction is achieved and maintained, they may be managed as type IIa.

Our study

From 2003 until 2012, we managed 80 cases of TSA as in-patients, and seven cases required surgical intervention.

This study presents the indications, outcomes and complications of the seven surgically managed cases with lessons learnt.

Methodology

A retrospective review of case notes and imaging was performed looking at demographic data, associated injuries, indications for surgery, surgical approach and fixation method used. The clinical and radiological outcomes were analysed.

The prognosis for healing of TSA is excellent with over 95% of cases uniting by non-operative method

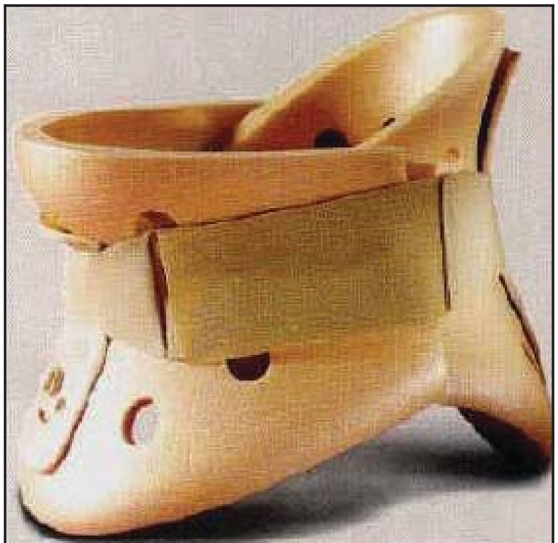

Figure 3. Type I injuries can be managed in a simple Philadelphia collar

Figure 5. Type II and III injuries can be managed in halo vests

Figure 4. Cone callipers are used in the initial management of most cases of TSA

Five patients were males and two were females with a median age of 45 years. Various surgical techniques were used. When the anterior approach was used, a C2/C3 fusion was performed with autogenous bone graft and a cervical locking plate. Multiple posterior techniques were used including isolated pars repairs with lag screws, polyaxial screw and rod constructs from C1–C3, or C2–C3.

Results

Our surgical cohort is briefly described with regard to their unique technicalities and indications for surgery (*Table I*).

Traditional indications for surgery have been based on the failure of conservative treatment

Patient 1

A 62-year-old female, poly trauma, ventilated in ICU with a type II injury. The indication for surgery was that she was a poly-trauma patient requiring prolonged ventilation in an intensive care unit where traction was impeding her care. She was managed with an anterior C2–C3 instrumented fusion (*Figure 6*). There were no complications and bony union had been achieved at the 6-month follow-up.

Patients 2 and 3

These two middle-aged patients both had type IIa injuries. One was a poly trauma and in her third term of pregnancy. The pregnancy made prolonged supine positioning problematic and the ICU wanted her stable to sit. The male was also a poly trauma patient in ICU requiring prolonged ventilation. Once again the ICU staff requested surgical stabilisation to expedite weaning.

Both patients underwent a posterior surgical approach with isolated repair of the C2 pars with a lag-screw technique (*Figure 7*). This allowed improved ICU care and subsequent discharge. At six-week follow-up both patients had radiological signs of some anterolisthesis of C2 on C3 (*Figure 8*). The one necessitated revision to a C2–3 posterior fusion. At the 6-month follow-up both patients were asymptomatic and had achieved bony union.

Patient 4

This 54-year-old male, with poly trauma and a head injury, required ventilation in ICU. He had a type II injury. Again ICU requested surgical stabilisation to obviate the supine position and allow weaning. Based on the previous failures above, a posterior instrumented fusion with C2 pedicle screws and C3 lateral mass screws was performed. He went on to bony union at follow-up.

Table I: A summary of our patient population

Patient	Type	Indication	Approach	Surgery	Complication
62 y.o. F	II	Poly trauma, prolonged ventilation	Anterior	C2/C3 fusion Locked plate Allograft	Nil
30 y.o. F	IIa	Poly trauma, pregnant	Posterior	Isolated C2 pars/lag screw repair	Anterolisthesis C2 on C3
39 y.o. M	IIa	Poly trauma, prolonged ventilation	Posterior	Isolated C2 pars/lag screw repair	Anterolisthesis C2 on C3
54 y.o. M	II	Poly trauma, head injury, ventilated	Posterior	C2/C3 fusion pedicle screws C2 and lateral mass screws C3	Nil
48 y.o. M	IIa	Failed conservative treatment after 6 weeks	Posterior	C2/C3 fusion pedicle screws C2 and lateral mass screws C3	Nil
45 y.o. M	II	Poly trauma, head injury/frontal lobe syndrome	Anterior and posterior	C2/C3 fusion locked plate, C1–C3 fusion rod and screws	Nil
28 y.o. M	II	Non-compliance, loss of reduction, pneumonia, ventilation	Posterior	C2/C3 fusion pedicle screws C2 and lateral mass screws C3	Nil

Patient 5

This 48-year-old male sustained a type IIa injury. After 6 weeks of in-hospital skeletal traction, he showed no signs of union. The surgical indication was thus failure of conservative care. Instrumented fusion from posterior was then performed with C2 pedicle and C3 lateral mass screws.

Patient 6

A 45-year-old male, poly trauma with closed head injury and subsequent frontal lobe syndrome with confusion and poor compliance. He sustained a type II injury. Due to his confusion, he did not tolerate traction and surgery was indicated. His MRI confirmed a disc extrusion and thus the disc was removed via an anterior approach, the patient re-positioned and a posterior C1–C3 instrumented fusion was performed. Finally the patient was re-positioned supine and an anterior interbody fusion with a plate was performed.

Patient 7

This 28-year-old male sustained an isolated type II injury. An acceptable reduction was achieved with skeletal traction. He became confused, and became non-compliant displacing his fracture. In an effort to continue traction, sedation was prescribed. This led to a pneumonia requiring intubation and ventilation. In an effort to wean him, the fracture was stabilised by means of a posterior instrumented fusion with C2 pedicle and C3 lateral mass screws (*Figure 9*).

Discussion

TSA is a continuum from stable to unstable types. Although there are surgical and non-surgical options, the vast majority of patients can be managed conservatively with excellent functional outcomes.

There is however a small group of patients who might benefit from surgical intervention. This is not determined by the fracture configuration but rather by specific 'patient factors'.

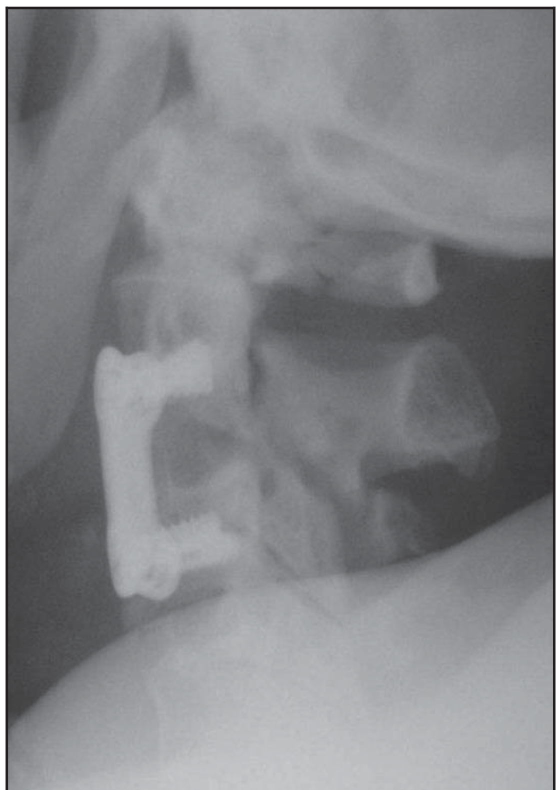

Figure 6. Lateral radiograph demonstrating a C2–C3 anterior instrumented fusion

A small group of patients who might benefit from surgical intervention

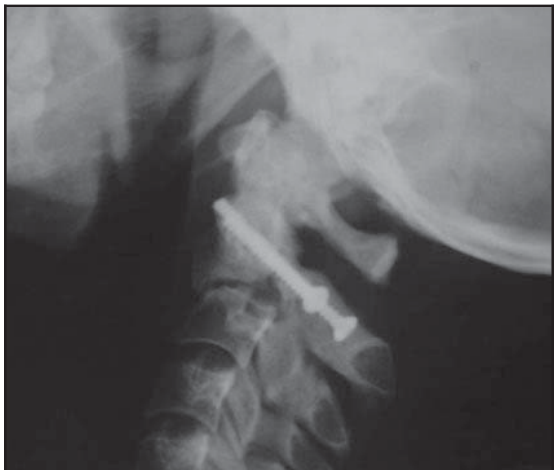

Figure 7. Lateral radiograph demonstrating an isolated repair of the pars of C2 using the lag screw technique

Figure 8. Six-week follow-up radiograph demonstrating anterolisthesis of C2 on C3

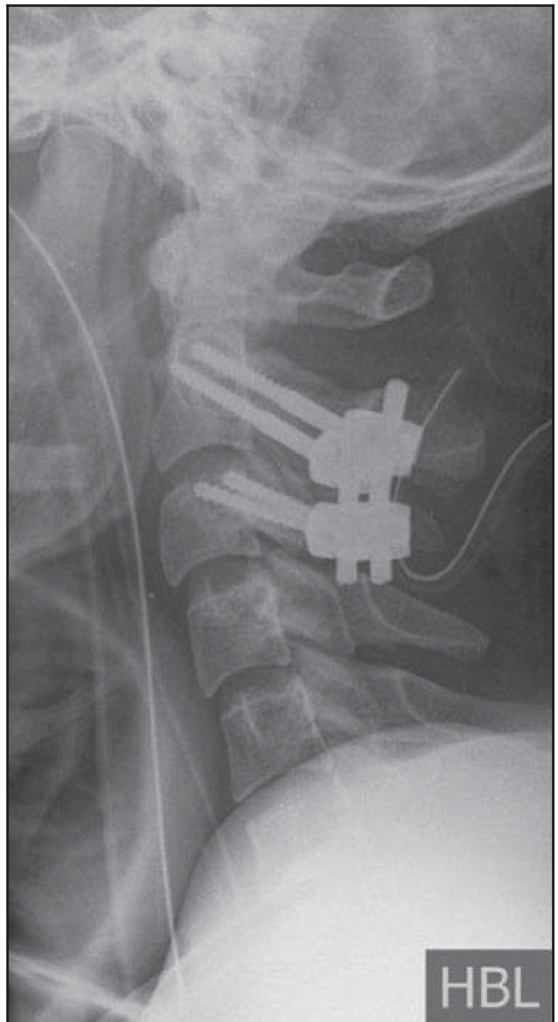

Figure 9. Our preferred technique: C2 poly-axial pedicle screws connected to C3 poly-axial lateral mass screws with hard rods

These 'patient factors' range from poly-traumatised patients particularly with chest injuries necessitating ICU and ventilation to problems with prolonged supine position from advanced pregnancy, psychosis, etc. In addition, patients with skull fractures or open head injuries precluded application of skeletal traction.

In the rare instances where one's hand is forced to operate – there has been success with anterior and posterior procedures – and on a case to case basis, certain approaches may be favoured. From our experience, our preferred technique is now the posterior approach with pedicle screws into C2 (lagging the posterior arch to the body if necessary) with lateral mass screws into C3. These are connected with rods and a fusion with on-lay bone graft is achieved. We have found this technique to be effective and safe as both the C2 arch fracture and disco-ligamentous injury are addressed allowing bony union by 12 weeks' follow-up.

We no longer perform an isolated C2 lag screw repair, due to the associated C2/C3 disc injury which resulted in progressive anterolisthesis. This has been confirmed in biomechanical studies.[14] This study also demonstrated that C2/C3 posterior fusion provided better biomechanical stability than an anterior C2–C3 plate.

Conclusion

The default management of TSA is non-surgical but associated injuries may dictate the need for surgical stabilisation. These include poly-traumatised patients, often with pulmonary compromise requiring ICU/ventilation. Occasionally prolonged supine skeletal traction is not possible such as in advanced pregnancy, skull fractures and non-compliance.

Key points

The literature is very clear that conservative management will be successful in more than 95% of cases of TSA.

Conservative management entails a variable initial period of skeletal traction followed by non-rigid immobilisation for stable injuries and rigid immobilisation for unstable injuries.

Traditional indications for surgery were for failure of conservative management.

Modern indications for surgery have more to do with specific 'patient factors' than with the fracture configuration, displacement, angulation or perceived instability.

Patient factors include: open head injuries, skull fractures/laceration, anticipated prolonged ventilation and then a few unique scenarios like psychosis, advanced pregnancy, and obesity that would make conservative management impractical.

The content of the article is the sole work of the author. No benefits of any form have been or are to be received from a commercial party related directly or indirectly to the subject of the article. The research has been approved by an ethical committee.

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