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Traumatic spondylolisthesis of the axis: treatment rationale based on the stability of the different fracture types

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Abstract Thirty-nine consecutive patients, 22 male and 17 female with an average age of 37.6 years, with traumatic spondylolisthesis of the axis were reviewed. The cause of injury in 75% of the patients was a road traffic accident. The fractures were classified according to Effendi et al., the type II fractures were further divided into three subgroups: flexion, extension and listhesis injuries. There were 10 type I (25.7%) and 29 type II fractures (74.4%); of these, 12 (30.8%) were classified as flexion-type, 2 (5.1%) as extension-type and 15 (38.5%) as listhesis-type. We did not identify any case of type III injury. Overall, 43.5% of the patients had sustained a significant head or chest trauma, with the highest incidence for type II listhesis injuries. Significant neurological deficits occurred in four patients (10.3%); in all four,the fracture was classified as a type II listhesis. All ten type I injuries were successfully treated with a cervical orthosis. Ten of the 12 type II flexion injuries demonstrated significant angulation. Two were treated with internal stabilisation, in seven with a halo device and one with a minerva plaster of Paris (PoP). Healing was uneventful in all ten patients. For the remaining two stable type II flexion injuries, application of a hard collar was adequate, as was the case for the two stable type II extension injuries. Six of the 15 type II spondylolisthesis injuries underwent primary internal stabilisation, and healing was uneventful in all cases. In four (44.4%) of the nine injuries that were primarily treated with a halo device/minerva PoP, secondary operative stabilisation had to be performed. The classification of Effendi et al. provides a complete description of the different fractures. However, further distinction of the type II injuries regarding their stability is mandatory. Type II spondylolisthesis injuries are unstable, with a high number of associated injuries, a great potential for neurological compromise and significant complications associated with non-operative treatment. The majority of type II extension and type II flexion injuries can be successfully treated with non-rigid external immobilisation.

Key words Spine · Axis · Fracture · Traumatic spondylolisthesis · Classification · Treatment

Introduction

Traumatic spondylolisthesis of the axis usually involves bilateral fractures through the neural arch of the axis, which may result in anterior displacement of the second cervical vertebra on the third. It was first described as a result of judicial hanging with the knot in a submental position [22]. Nowadays the injury is most commonly caused by road traffic accidents or a fall. The important features of this fracture are a high incidence of concomitant injuries to the head, cervical spine and thorax, and a low incidence of neurological damage and of non-union.

Although the radiological appearances are similar, the mechanism causing traumatic spondylolisthesis of the axis is different from that described for judicial hanging. Because of the forward displacement of the axis body, some authors have considered this fracture to be a flexion injury, while others consider the injury to be due to hyperextension-axial loading [8, 11, 15, 19, 21].

Various classification schemes for traumatic spondylolisthesis of the axis have been published. Frances et al. [9] defined two categories based on the stability limits of White and Panjabi (3.5 mm translation, 11° angulation). Effendi et al. [7] described three different types according to radiological displacement of the fragments. Levine and Edwards [15] modified the Effendi classification based on the mechanism of injury.

While all three groups proposed that treatment could be based on their classifications, the question of inherent stability of the fractures has not yet been solved. Cornish [5] considered the fractures to be highly unstable and recommended internal fixation, whereas others thought traction and halo-immobilisation to be the appropriate treatment [2, 8, 9, 11, 15, 20]. Recently, Coric et al. [4] reported successful nonrigid immobilisation for fractures with displacement of less than 6 mm and movement of less than 2 mm on lateral flexion/extension views.

This report describes a consecutive series of 39 patients treated at one institution. The fractures were classified according to Effendi et al., and our results were analysed with respect to the different types of injury. Based on our experience we propose a stability scale for the different type II fractures and recommend a treatment rationale for each type.

Materials and methods

Thirty-nine patients with traumatic spondylolisthesis of the axis were admitted to our institution between 1988 and 1994. There were 22 male and 17 female patients with an average age of 37.6 years (range 14–70 years). The cause of injury was a road traffic accident in 29 patients (74.3%), a fall in three patients (7.7%), and a minor fall in six patients (15.4%). In the remaining patient, the exact mechanism of injury could not be established.

The injuries were classified on the basis of standard anteroposterior (AP) and lateral radiographs taken on admission. To confirm the diagnosis and to assess the stability of the fracture, plain tomographic images, lateral flexion/extension views and computed tomographic (CT) scans were obtained if necessary. (Because of the retrospective character of this analysis, the treatment protocol changed during the observation period, and therefore flexion/extension views were not obtained routinely.) Healing was recorded when there was trabeculation across the fracture or when spontaneous interbody fusion C2/3 had occurred, and when there was no displacement on lateral flexion/extension views. Treatment was based on the stability criteria as explained in the following paragraph. For stable injuries application of a cervical orthosis was chosen, for unstable injuries internal fixation or rigid external stabilisation with a halo device was the treatment of choice. The choice between the two treatment options for unstable injuries was solely based on the experience and preference of the surgeon in charge.

Based on the radiographic appearance, the fractures were classified according to Effendi et al. [7] into three types; the type II fractures were then further divided into three subtypes – flexion, extension and listhesis – as proposed by the aforementioned authors. However, in contrast to them, we distinguished the different types for stability, associated complications, treatment modalities and outcome. The fractures were considered to be unstable when anterior displacement was greater than 4 mm or angulation was greater than 11° on initial radiographs (White/Panjabi), or when there was more than 2 mm translation and/or 11° angulation on lateral flexion/extension views. There were ten type I injuries (25.7%) and 29 type II injuries (74.4%), of which 12 (30.8%) were classified as flexion-type, 2 (5.1%) as extension-type and 15 (38.5%) as spondylolisthesis-type. We did not identify any case of type III injury.

Associated injuries were seen in 28 patients (71.8%). A fracture of the ring of the atlas was documented in two patients (5.1%); in both cases the fracture of the ring of the axis was classified as a type II spondylolisthesis. A fracture in the lower cervical spine was identified in five patients (12.8%), another five patients had sustained fractures in the thoraco-lumbar spine. Ten patients (25.6%) had experienced loss of consciousness, four patients (10.3%) had sustained an additional fracture of the skull, in three of whom the axis fracture was classified as a type II spondylolisthesis. Seven patients (17.9%) had presented with a significant chest trauma, and in 12 patients (30.8%) associated extremity fractures were diagnosed. Five patients (12.8%) were severely injured, with an injury severity score (ISS) [1] of 26.2 (range 19–34), three of these patients had sustained a type II spondylolisthesis fracture and the remaining two a type I injury.

Significant neurological deficits occurred in four patients (10.3%); in two the deficit was graded as Frankel A – complete sensomotoric deficit below the level C1 with respiratory insufficiency – in one as Frankel C and in the remaining patient as Frankel D. In all patients the fracture was classified as a type II spondylolisthesis.

Results

Type I injuries

For all ten type I injuries, healing was uneventful with application of a cervical orthosis, and trabecular bridging of the fracture gap was observed between 6 and 12 weeks. Spontaneous fusion of the C2/3 interspace was not observed. There were no complications in this group.

Type II flexion injuries

In 10 of the 12 type II flexion injuries, at least one of the instability criteria was documented on initial radiographs. In two of these, primary internal stabilisation was performed because of significant angulation (> 11 °), with anterior instrumented fusion of the C2/3 segment in one case, and transarticular screw fixation in the other case. One of these patients had to be reoperated because of an instability in the lower cervical spine, which had not been identified initially. Loosening of a screw was observed in the other case without radiological instability, and solid interbody fusion was achieved without secondary displacement.

In the remaining eight type II flexion injuries with significant angulation, a halo device was applied in seven patients and a minerva PoP in one patient. Solid fusion of the fracture was observed in all eight patients. The halo was maintained for 9 weeks on average (range 6–11 weeks), and subsequently a Philadelphia collar was applied for another 4 weeks (range 2–6 weeks). Anterior bridging of the C2/3 segment occurred in two cases. A pin-track infection in one patient necessitated replacement of the pin. The infection resolved after pin removal under local measurements.

The minerva PoP was removed after 16 weeks, when fracture healing was confirmed on radiographs.

In the remaining two patients with stable injuries a hard collar was applied. Fracture consolidation was documented after 8 weeks in both cases, bony bridging of the C2/3 disc space was observed in one case. While wearing the hard collar one patient developed pressure sores, which healed under local measurements.

Type II extension injuries

A hard collar was applied in the two type II extension injuries for 8 and 10 weeks respectively, until radiographic fracture healing. Anterior fusion with bony bridging of the C2/3 segment was observed in both cases.

Type II spondylolisthesis injuries

All 15 injuries demonstrated at least one of the instability criteria on initial radiographs. Primary internal stabilisation was performed in six cases, including all four patients with neurological deficits. Preoperatively, a halo was applied in five cases; in one patient axial traction with 2.5 kg was applied to maintain stability. Direct posterior screw fixation according to Judet was the method of choice in five cases; in one patient hook-plate fixation of the C2/3 segment was added. In the remaining fracture, anterior and posterior stabilisation of the C2/3 segment was performed. Excessive bleeding due to a lesion of the venous plexus occurred in one patient treated with direct screw fixation without late sequelae. Postoperatively, a hard collar was applied for 5–8 weeks until fracture healing was confirmed in all patients.

For eight fractures, non-operative treatment with a halo device was chosen; in two of these, axial traction with low loads was applied for repositioning and initial stabilisation of the fracture for 1 week, and in one a minerva PoP was applied. Because of persistent instability, secondary internal fixation had to be performed in four cases. In all four cases healing was uneventful after internal fixation. In the remaining five patients, fracture healing was documented after 8–12 weeks. One patient developed an intracranial abscess after a pin-track infection, which resolved after drainage of the abscess without any late sequelae.

The minerva PoP was removed after 6 weeks. Because of only minimal trabecular bridging of the fracture, a halo device was applied for another 6 weeks until fracture healing was completed.

In three of the remaining five cases, fusion of the C/3 disc space was observed.

Twenty-six patients (66.7%) were followed up for 44.2 months on average (range 12–150 months). Nine patients were lost to follow-up, two patients refused to attend, and one patient died 2 years after the trauma. Of the 26 who were followed up, 7 patients had sustained a type I fracture and 19 a type II fracture – nine flexion-, two extension- and eight spondylolisthesis-type injuries.

In six of the seven patients with a type I injury, solid fusion of the fracture in an anatomic position and in one patient with slight anterior angulation (< 11°) of the axis body fragment was documented. Three patients (42.9%) were pain free, two complained of intermittent neck pain, and another two of motion-related neck pain – in one of these (14.3%), range of motion (ROM) was limited in all three planes.

Fracture healing was documented in all nine patients – one was treated with anterior C2/3 interbody fusion, six with a halo device and two were treated with a cervical orthosis, who had suffered a flexion type II injury – in one case with slight anterior angulation (< 11°) of the axis body fragment. In 3 patients (33.3%) spontaneous fusion of the C2/3 interspace was seen. Two of the nine patients (22.2%) were free of pain, four complained of intermittent pain and three complained of motion-related neck pain. Significant restriction of ROM was seen in three patients (33.3%); in two of these, pre-existing multilevel degenerative changes were present.

Both extension type II injuries were consolidated in an anatomic position, with anterior bridging and/or fusion of the C2/3 interspace. One patient was pain free, the remaining complained of intermittent neck pain. ROM was normal in both cases.

Solid fusion of the fracture in an anatomic position was seen in three patients, with a spondylolisthesis type II injury after internal fixation. Two of the three complained of intermittent, and one of motion-related, neck pain. In one patient, neurological deficits were graded as Frankel D (Frankel C initially after the trauma). In all patients but one with non-operative treatment, solid healing of the fracture in an anatomic position was documented. Anterior fusion of the C2/3 interspace was seen in three cases. Two of the five patients (40%) were free of pain, three complained of intermittent and one of motion-related neck pain. There was no significant restriction of ROM in any patient. In one patient, a neurological deficit that was initially graded as Frankel D completely resolved.

Discussion

Although many authors hypothesize that traumatic spondylolisthesis of the axis has a relatively benign prognosis, there has been some controversy over the classification and the appropriate treatment of these injuries [2, 3, 4, 7, 9, 10, 12, 15, 20]. Effendi et al. [7] differentiated three types of injury, based on the radiographic appearance. The type II injuries were further divided into three subtypes; however, they did not differentiate these three subtypes on the basis of stability. Based on our clinical experience, we felt that this classification adequately describes the different fracture types, but that in addition they have to be carefully distinguished regarding their inherent stability and the appropriate treatment.

In contrast to Effendi et al., in our series nearly three-quarters of all injuries were classified as type II fractures. A similar distribution has also been reported by others [15, 20]. We did not identify a type III fracture – a rare injury with a reported incidence of between 5.3 and 9.6% [7, 15, 20].

Regarding associated head injuries and severe chest trauma – 43.5% (17/39) of the patients had sustained at least one of these injuries – our results are consistent with previous studies [4, 7, 13, 14, 16], and support the theory of an extension mechanism due to a direct anterior blow as the primary cause of these injuries [3, 5, 9, 11, 17, 21]. This seems to be especially true for motor vehicle passengers, where the incidence is 50% as compared to 30.8% in the remaining patients. The incidence of a head injury varied between the different types of injury. The lowest incidence, at 16.7%, was found for type II flexion injuries, in contrast to incidences of 50 and 46.7%, respectively, for type II extension and type II spondylolisthesis fractures. For type I fractures the incidence was 30%. This finding may indicate that the mechanism of type II flexion injuries is substantially different, with a predominantly flexion distraction force causing subsequent rupture of the posterior disco-ligamentous complex, as described by Levine and Edwards [15] for their type IIa injuries.

The incidence of neurological deficits is low, at 10.3% (4/39), and correlates well with the already published data [2, 5, 7, 8, 15, 18]. In all four patients, the fracture was classified as a type II spondylolisthesis with anterior translation of the axis body fragment of 4 mm or more. This represents an incidence of 26.7% for this fracture type. Starr and Eismont [20] described an atypical type II fracture with an increased incidence of neurologic injury (see Fig. 1). Our results highlight the increased incidence of neurologic injury for type II spondylolisthesis injuries.

Effendi et al. [7] documented associated injuries in the lower cervical spine in 14% of their patients, which is similar to our findings (12.8%). The importance of an appropriate radiological evaluation of the lower cervical spine is highlighted in the case of one patient with an associated disco-ligamentous lesion of the C3/4 segment, which was not diagnosed initially and became evident 6 weeks later.

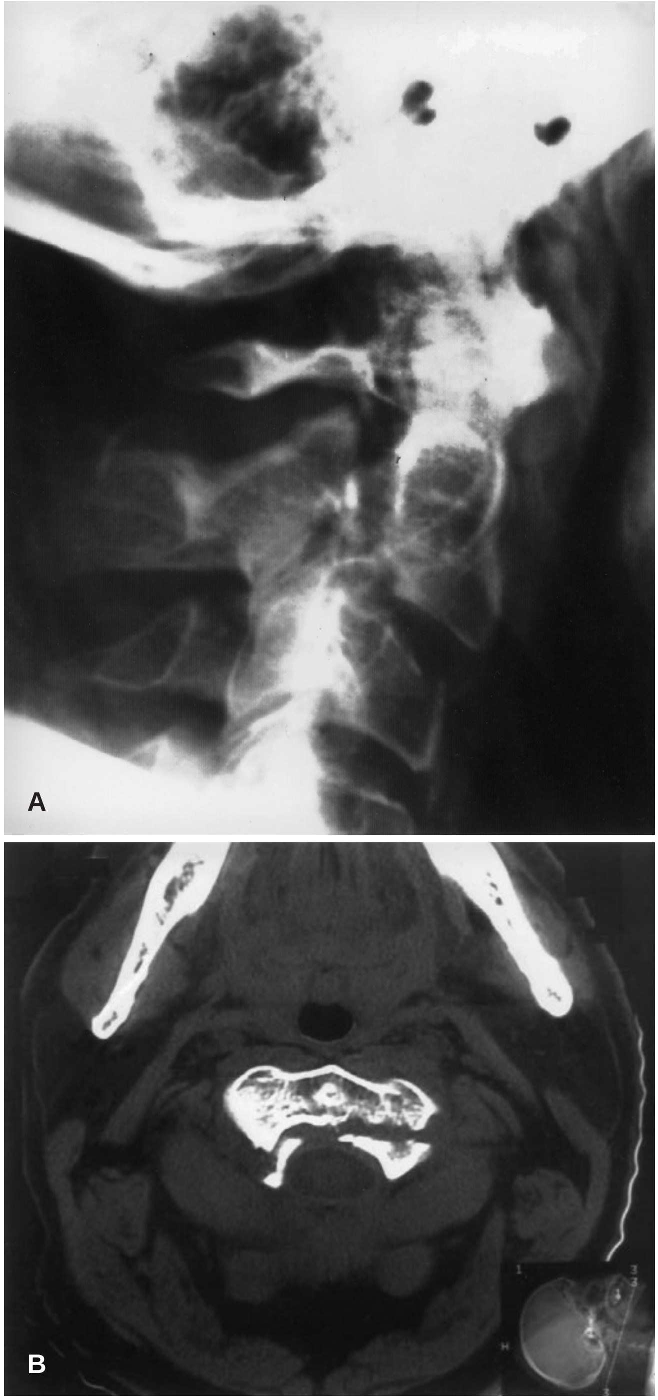

Fig. 1 **A** Type II flexion injury associated with an impaction of the C3 superior end plate. **B** Computed tomographic scan of the injury, demonstrating the atypical configuration of the pedicle fracture

Type I fractures are stable and treatment of these injuries has been associated with few complications. As has been

Fig. 2 **A** Lateral flexion/extension views of a type II extension injury with an avulsion fracture of the anterior longitudinal ligament. No radiological signs of instability are apparent. **B** NMR scan demonstrating the involvement of the intervertebral disc C2/3 and showing the posterior longitudinal ligament to be intact. Also note the haematoma posterior to the axis body

reported by others, application of a cervical orthosis is appropriate. In none of the fractures had the position changed until fusion of the fracture was obvious; the C2/3 interspace also remained unchanged until fusion.

In contrast to Effendi et al., who did not differentiate the type II lesions regarding stability and treatment, we found the various type II fractures to be of different character.

In type II flexion fractures, which are identical to the type IIa injuries as defined by Levine and Edwards [15], the axis body fragment hinges around the intact anterior longitudinal ligament (ALL), and radiological evaluation reveals moderate to severe angulation of the body fragment with no or minimal anterior displacement. Treatment with rigid external fixation is appropriate for the majority of the injuries. According to Levine and Edwards, some fractures that are more widely displaced may become stabilised by anterior ankylosis between C2 and C3 rather than union of the posterior elements. In this series, non-rigid immobilisation was sufficient in two cases with only moderate angulation. Although flexion/extension views were not obtained, this finding may indicate that some of these injuries are stable, and non-rigid immobilisation alone is appropriate even in more displaced fractures. Internal fixation, as performed in two cases, is rarely indicated, and from a retrospective point of view operative intervention was not necessary.

Apart from Effendi et al., type II extension injuries, where the axis body fragment hinges around the intact posterior longitudinal ligament (PLL) while the ALL and the anterior disc are ruptured (see Fig. 2), have not been evaluated in detail. Both cases in our series only demonstrated moderate posterior angulation without translation. We found these fractures to be stable and non-rigid immobilisation is appropriate. Because of the anteriorly located disco-ligamentous lesion, anterior bridging of the C2/3 interspace can be expected.

Type II spondylolisthesis injuries have to be carefully differentiated from the other type II fractures. These lesions are highly unstable because of a rupture of the C2/3 disc as well as of the ALL and PLL, and usually significant anterior displacement of the axis body fragment is seen. There is also a greater potential for neurological compromise. As has been already emphasised by others, overdistraction with cervical traction has to be avoided. Non-operative treatment of these injuries was associated with a significant rate of failure of stabilisation (33.3%) and delayed union (11.1%), whereas with primary internal fixation of these fractures, solid fusion was achieved in all cases. In contrast to Levine and Edwards, we do not recommend placement of the patient in cervical traction for a prolonged period of time. Although Coric et al. [4] found that as much as 6 mm of anterior displacement can be tolerated as long as the fragments are stable in that position, in our experience primary internal stabilisation is the method of choice.

Conclusions

For classification of traumatic spondylolisthesis of the axis, the scheme of Effendi and co-workers provides a complete description of the different fractures. However, further differentiation of the type-II injuries regarding their patho-anatomy and stability is mandatory. The stability assessment should be based on lateral flexion/extension views (see Fig. 3). The important features of unstable type-II spondylolisthesis injuries are a high number of associated injuries, a great potential for neurological compromise and significant complications associated with non-operative treatment. The majority of type II extension and type II flexion injuries can be successfully treated non-operatively.

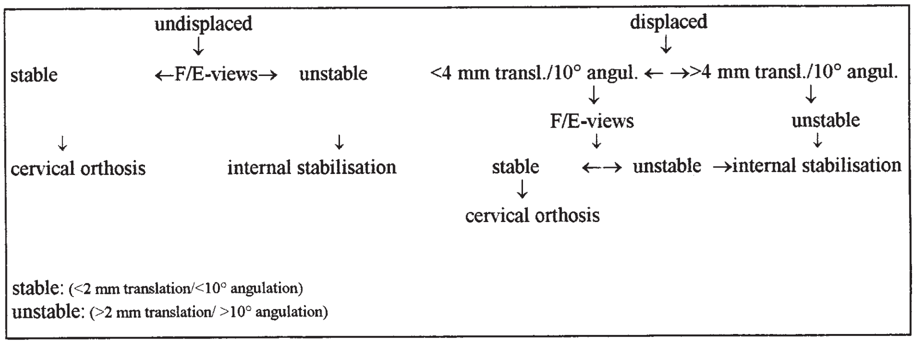

Fig. 3 Treatment algorithm for traumatic spondylolisthesis of the axis based on the stability of the fracture

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