Traumatic cervical spine spondyloptosis: A systematic review

ABSTRACT

Background: Spondyloptosis is a rare presentation of cervical spine traumatism where listhesis is more than 100%. Traumatic cervical spine spondyloptosis (TCS) is one of the least discussed forms of cervical spine traumatisms because of its rarity and the gravity of patient’s condition, limiting good management, and the number of reported cases.

Objectives: This study aimed to discuss clinical, radiological, and best management tools of the aforementioned pathology.

Materials and Methods: Scopus, ScienceDirect, PubMed, and Google Scholar databases were searched for English articles about traumatic cervical spondyloptosis. Titles, abstracts, or author‑specified keywords that contain the words “spondyloptosis” AND “cervical” AND “spine” were identified. There were no time limits. In sum, 542 records were identified, 63 records were screened, and 46 records were included in this review, describing 64 clinical cases of traumatic cervical spondyloptosis. The clinical cases of two patients managed at our department are also presented and included. In the end, 66 cases were included in this study. Demographics, clinics, radiology, management tools, and outcome of the reviewed cases were discussed. This study was conducted in agreement with the Preferred Reporting Items for Systematic Reviews and Meta‑Analyses statement 2009. The American Spinal Injury Association Impairment Scale (AIS) score was used to evaluate the clinical presentations.

Results: This review included 66 patients consisting of 46 males (70%) and 20 females (30%), with a mean age of 41 years. The accident was indicated in 62 cases; it was a road traffic accident in 29 cases (46%), a fall in 24 cases (38%), and motor vehicle accident in 15 cases (24%). The lesion was iatrogenic in four patients. Twenty‑one patients were received without motor or sensitive deficit and so scored Grade E on AIS, 10 with Grade D, 11 Grade C, four Grade B, and 20 with Grade A. On imaging, spondyloptosis involved the C1–C2 segment in two cases (3%), C2–C3 in one case (1.5%), C3–C4 in six cases (9%), C4–C5 in nine cases (13%), C5–C6 in 20 cases (30%), and C6–C7 in 20 cases (30%), and C7–T1 in 26 cases (38%). In all cases, there was either fracture or dislocation in posterior elements. Bilateral pedicles or facet joint fractures were noted in 53% of the 56 patients where the associated lesions were described, but it jumps to 89% when a vertebra is projected in front of another. In two cases, there was no mention of closed reduction via transcranial traction; in 13 cases (20%), it was avoided for a reason (child, patient’s refusal, ...). In the 51 cases where the traction was clearly applied, 17 cases (33%) were reduced totally; in 13 cases (25%) the reduction was partial; it failed in 19 cases (37%); and in the remaining cases, the result was not clear. Traction weight varied from 4 kg to 27.2 kg, applied from 6 h to 20 days. Where total reduction was achieved, an average weight of 11.9 kg with proximal average time of 6 days was needed, whereas an average of 11.5 kg was needed for partial reduction with proximal average time of 10 days. 62 patients were operated rather in one or two times. Anterior approach was used in 20 patients (32%), a posterior approach in 14 patients (23%), and combined anterior/posterior approaches in 28 patients (45%). In four patients, the outcome was not available; in the remaining 62 cases, an improvement of an initial deficit was noted in 25 patients (40%), conservation of an initial motor force integrity was noted in 19 patients (30%), and nine patients (14.5%) kept the same initial deficit. Few complications were declared: dura tears with cerebrospinal fluid leaks, meningitis, esophageal laceration, and vocal cord paralysis. There was a mortality of 11% (seven cases).

Conclusion: Traumatic cervical spine spondyloptosis predominates in the lowest levels of the cervical spine, allowed in all cases by a failure in posterior elements. It is a lesion with the worst clinical presentation. Traumatic cervical spine spondyloptosis is highly instable, imposing urgent reduction followed by surgical stabilization. At the limit of the reviewed cases, outcome is in general good, but mortality is still important.

Keywords: Cervical spine, spinal traumatism, spondyloptosis
INTRODUCTION

Traumatic cervical spine spondyloptosis (TCS) is the most severe form of cervical spine injuries.[1] Many classifications have been proposed for cervical spine spondylolisthesis; all these classifications have strength and weakness points; and some descriptions of the lesions although valid and useful such as burst fracture and teardrop fracture, they are still general.[2] Meyerding’s classification of spondylolisthesis defines spondyloptosis or Grade V as more than 100% slippage.[3] Studying TCS will help give more precision to its anatomic description, radiological aspects, and then the best management strategy.

MATERIALS AND METHODS

Cases

Case 1

History and physical examination
The first patient is a 19-year-old man without medical history; he was victim of diving accident in shallow water with head reception 3 days before the evacuation to our center. Initially, he presented tetraplegia. At our level, the clinical examination found a conscious patient; arterial pressure at 150/70 mmHg, 40° fever, and hyperhidrosis. The motor force was estimated at 2/5 in the upper limbs and 0/5 in the lower limbs, with sensitive level at D4 and urinary retention. Reflexes were abolished in both upper and lower limbs, and he presented abdominal breathing. The patient was Grade A on AIS.

Radiographic imaging
Spine CT objectified a posterior C5–C6 spondyloptosis allowed by a bipedicular fracture of C6, with right C6–C7 facet joint distraction; two fragments were detached from C5 body, the first anteriorly and the second jumped behind the body of C6 in the spinal canal; there was also a sagittal line of fracture of C5 body [Figure 1a-f].

Preoperative management
No infection was found and hyperthermia was attached to neurovegetative disorder.

Bladder care was provided. Traction using Gardner–Wells tongs up to 10 kg was applied gradually, resulting in partial reduction of the dislocation (from Grade V to Grade II), so an open reduction was needed [Figure 1g and h].

Operative technique
No facet joint dislocation was present, and at the level of C6, there was a total disconnection between posterior elements (bipedicular fracture); for that, posterior reduction was not evident, so an anterior approach was planned initially. A right Smith–Robinson approach was used to perform C5 corpectomy, C6–C7 discectomy followed by iliac autograft, and C4–C7 plate fixation [Figure 1i].

Postoperative course
The patient was extubated, the clinical examination was unchanged, but temperature decreased to normal levels. Twenty four hours later, the patient presented suddenly breathing difficulties, SpO₂ decreased to 37% for what he was intubated. Three days later, the patient presented hemodynamic instabilities and 40° fever after what he presented as a heart arrest despite hours of resuscitation efforts.

Case 2

History and physical examination
The second patient is a 30-year-old man, without medical history, victim of traffic accident the same day. At our center, the patient is conscious, presenting incomplete tetraplegia, coted 1/5 in the upper limbs and 0/5 in the lower limbs, with sensitive level at D4, and urinary retention. Reflexes were abolished in both upper and lower limbs, and the patient presented abdominal breathing. The patient was Grade A on AIS.

Radiographic imaging
Plain X-rays and spine computed tomography (CT) objectified a posterior C5–C6 spondyloptosis allowed by bilateral C6 bipedicular fracture; two fragments were detached from C5 body; the first anteriorly and the second jumped behind the body of C6 in the spinal canal down to the level of C6–C7 disk and a sagittal line of fracture of the C5 body [Figure 2a-f]. The lesions on these levels were associated with a right fracture of the anterior arch of the atlas. There was also a right acetabulum fracture.

Preoperative management
Bladder care was provided. Traction using Gardner–Wells tongs up to 7 Kg was applied gradually, resulting in partial reduction of the dislocation (from Grade V to Grade III) [Figure 2g and h]. Few hours later, the patient presented breathing difficulties and SpO₂ decreased to 70% for that he was intubated. Giving his evolution, no more time was allowed to traction and the patient was admitted to the operating room.

Operative technique
Same as in Case 1, no facet joint dislocation was present, and there was a total rupture between anterior and posterior elements (bipedicular fracture) at the level of C6; for that, posterior reduction was not attempted, so an anterior approach was planned initially. A right
Smith–Robinson approach was used to perform C5 corpectomy followed by iliac autografting and C4–C6 plate fixation [Figure 2i].

**Postoperative course**

In postoperative course, the patient was always dependent to assisted ventilation, and 3 days later, he presented hemodynamic instabilities followed rapidly by a heart arrest and resuscitation efforts failed.

**Literature review**

Scopus, ScienceDirect, PubMed, and Google Scholar databases were searched for English articles about traumatic cervical spondyloptosis. Titles, abstracts, or author-specifed keywords that contain the words “spondyloptosis” AND “cervical” AND “spine” were identified. There were no date limits. The citations were not included in the search. Fifty-seven records were identified in Scopus, 6 in ScienceDirect, and 34 in PubMed. In Google Scholar, there were initially 703 records identified; then, we added the word “trauma,” so we get 521 records identified. In sum, 618 records were identified. All the records were imported to an online version of Endnote where duplicates were merged. Five hundred and forty-two records were identified after duplicates were removed. Sixty-three records were screened. Ten records were excluded after screening the abstracts, 5 were excluded after reading the full texts, and 2 records were we could not reach the whole paper. In sum, 46 records were included in this review describing 64 clinical cases of traumatic cervical spondyloptosis [Figure 3]. The clinical cases of two patients managed at our department that we believe are directly relevant to this review are also presented and included. At the end, 66 cases were included in this study. The years of reports, countries (geographic distribution), patient’s demographics, nature of traumatism, timing of management, clinical presentation, segments involved, description of the lesions (anterior/posterior, simple grade V spondyloptosis or total projection of vertebrae in front of the other), associated lesions, details about reduction, surgical techniques, and outcome; all these previous parameters were collected, organized, analyzed, and discussed. This study was conducted in agreement with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses statement 2009. The protocol for this systematic review was not registered.
AIS score was used to evaluate the clinical presentation; in some cases, the authors gave directly the score, and in other cases, we gave the score according to the author’s description.

**RESULTS**

This review included 66 patients consisting of 46 males (70%) and 20 females (30%). Ages range between 2 weeks and 73 years, with a mean age of 41 years. Eighty-six percent of cases were reported in the last 10 years [Table 1]. Twenty-three cases (35%) were reported from India, 20 (30%) from the USA, seven from Korea (10%) and four (6%) from Turkey. The accident was indicated in 62 cases; it was a road traffic accident in 29 cases (46%). TCS was caused by a fall in 24 cases (38%), and the altitude varies from only 1.5 m down while hiking to a fall from of over 30 m in a cliff; motor vehicle accident was the cause in 15 cases (24%). It is important to note that the lesion was iatrogenic in four patients: obstetrical maneuvers in two cases, postintubation in one patient, and rehabilitation trauma in one patient. In seven cases, the management timing was not clear; it was urgent in 43 cases and was very late in 16 cases, ranged from few days to 8 years. Remarkably, in the six patients under 15 years old, four were managed lately (8 years, 3 weeks, 4 months, and 2 weeks). Twenty-one patients were received without motor or sensitive deficit and so scored Grade E on AIS, 10 with Grade D, four Grade C, four Grade B, and 20 with Grade A. All patients were explored with cervical CT, spine magnetic resonance image (MRI), or both. In few cases, angiography or angio-CT was used. On imaging, spondyloptosis involved the C1–C2 segment in two cases (3%), C2–C3 in three cases (5.5%), C3–C4 in one case (1.5%), C4–C5 in six cases (9%), C5–C6 in nine cases (13%), C6–C7 in 20 cases (30%), and C7–T1 in 26 cases (38%) (in one case, two levels were involved) [Figure 4]. In 55 cases, there was an anterior transposition, whereas in seven cases (including our two cases), the spondyloptosis was posterior; only one case was reported of lateral transposition; and in three cases, it was not clear. A total projection of a vertebra in front of another
was noted in 34 cases: anterior in 28 cases (51% of anterior TCS) and posterior in six cases (85% of posterior TCS). In all cases, there was either fracture or dislocation in posterior elements. Bilateral pedicles and/or facet joint fractures were noted in 30 patients of the 56 patients where the associated lesions were described (53%), but it jumps to 89% where vertebra is projected in front of another (25 cases of 28 where there is a description). In two cases, there was no mention of closed reduction via transcranial reduction; in 13 (20%) of the remaining 64 cases, it was avoided for a reason (child, patient’s refusal,...). in 51 cases where the traction was clearly applied; 17 cases (33%) were reduced totally; in 13 (25%), the reduction was partial; it failed in 19 cases (37%); and in the remaining cases, the result was not clear. Traction weight varied from 4 kg to 27.2 kg, applied from 6 h to 20 days. Where total reduction was achieved, an average weight of 11.9 kg with proximal average time of 6 days was needed; whereas an average of 11.5 kg was needed for partial reduction with proximal average time of 10 days. Four patients refused surgery and 62 were operated rather on one or two times. Anterior approach was used in 20 patients (32%), a posterior approach in 14 patients (23%), and combined anterior/posterior approaches in 28 patients (45%). Corpectomy was performed in 18 cases (29%); it involved one vertebra in 11 cases (61%), two vertebrae in 5 cases (28%), and three vertebrae in 2 cases (11%). In four patients, the outcome was not available; in the remaining 62 cases, an improvement of an initial deficit was noted in 25 patients (40%), conservation of an initial motor force integrity was noted in 19 patients (30%), and nine patients (14.5%) kept the same initial deficit. Few complications were declared: dura tears with cerebrospinal fluid (CSF) leaks, meningitis, esophageal laceration, and vocal cord paralysis. There was a mortality of 11% (seven cases).

**DISCUSSION**

When 66 patients were reported in this review, the authors think that the incidence of cervical spine spondyloptosis is largely underestimated basing on the fact that most of patients present this severe lesion associated with other fatal lesions limiting the good management and so the presentation of the cases. However, with the development of management tools, more and more cases are appearing in the literature, and so, 86% of the cases from this review were reported in the last 10 years. Although roughly one-third of the patients
Table 1: Summarizing briefly the reviewed cases

| Reports                        | Genders | Ages | Levels |
|-------------------------------|---------|------|--------|
| Acikbas and Gurkanlar 2010    | Male    | 42   | C7-D1  |
| Ahn et al., 2015              | Male    | 32   | C7-D1  |
| Breaks et al., 2019           | Male    | 25   | C1-C2  |
| Bhojra et al., 1992           | Female  | 8    | C6-C7  |
| Chadha et al., 2010           | Female  | 35   | C6-C7  |
| Chang et al., 2016            | Female  | 49   | C5-C6  |
| Choi et al., 2014             | Male    | 51   | C6-C7  |
| Dahdaleh et al., 2013         | Male    | 61   | C7-D1  |
| Dahdaleh et al., 2017         | Female  | 48   | C6-C7  |
| Dahdaleh et al., 2013         | Male    | 51   | C7-C1  |
| Dahdaleh et al., 2017         | Male    | 48   | C6-C7  |
| Dahdaleh et al., 2014         | Male    | 42   | C7-C1  |
| Dhall and Sribnick 2014       | Female  | 28   | C6-C7  |
| Fattahi et al., 2019          | Female  | 18   | C5-C6  |
| Fattahi et al., 2021          | Male    | 34   | C2-C3  |
| Feigenbaum et al., 1997       | Female  | 15   | C5-C6  |
| Gasco et al., 2013            | Male    | 45   | C4-C5  |
| Haimovich et al., 2020        | Male    | 24   | C6-C7  |
| Keskin et al., 2013           | Female  | 51   | C6-C7  |
| Kim et al., 2018              | Male    | 60   | C7-D1  |
| Kim et al., 2018              | Male    | 39   | C7-D1  |
| A Kumar et al., 2017          | Male    | 11   | C1-C2  |
| D Kumar et al., 2020          | Male    | 40   | C7-D1  |
| R Kumar et al., 2019          | Female  | 30   | C6-C7  |
| Lee et al., 2007              | Male    | 65   | C7-D1  |
| Lee et al., 2007              | Male    | 72   | C7-C1  |
| Maminida et al., 2013         | Female  | 46   | C5-C6  |
| Manjila et al., 2014          | Male    | 39   | C2-C3  |
| Mehra et al., 2018            | Female  | 45   | C6-C7  |
| Menku et al., 2004            | Male    | 35   | C6-C7  |
| Modi et al., 2016             | Male    | 35   | C6-C7  |
| Modi et al., 2016             | Male    | 8    | C7-D1  |
| Munakomi et al., 2015         | Female  | 56   | C7-D1  |
| Nguyen et al., 2017           | Female  | 63   | C7-D1  |
| Okoro et al., 2021            | Female  | 18   | C5-C6  |
| Oppenlander et al., 2015      | Male    | 73   | C6-C7  |
| Oraee-Yazdani et al., 2018    | Female  | 35   | C6-C7  |
| Özdoğan et al., 2017         | Female  | 36   | C4-C5  |
| Padwal et al., 2015           | Female  | 50   | C6-C7  |
| Padwal et al., 2015           | Male    | 40   | C7-C1  |
| Padwal et al., 2015           | Male    | 40   | C7-D1  |
| Padwal et al., 2015           | Male    | 45   | C6-C7  |
| Padwal et al., 2015           | Male    | 64   | C7-D1  |
| Padwal et al., 2015           | Male    | 24   | C6-C7  |
| Padwal et al., 2015           | Male    | 45   | C6-C7  |
| Padwal et al., 2015           | Male    | 55   | C6-C7  |
| Payne et al., 2020            | Male    | 63   | C7-D1  |
| Rameri et al., 2014           | Female  | 55   | C6-C7  |
| Rokaya et al., 2021           | Male    | 22   | C4-C5  |
| Sara Saleh et al., 2017       | Male    | 2 weeks | C4-C5 |

Table 1: Contd...

| Reports                        | Genders | Ages | Levels |
|-------------------------------|---------|------|--------|
| Shah et al., 2003             | Male    | 40   | C7-D1  |
| Sharma et al., 2015           | Male    | 15   | C4-C5  |
| Singh et al., 2019            | Male    | 32   | C2-C3  |
| Sribnick et al., 2019         | Male    | 37   | C7-D1  |
| Srivastava et al., 2010       | Male    | 35   | C3-C4  |
| Tsujimoto et al., 2020        | Male    | 69   | D7-D1  |
| Turnia et al., 2012           | Male    | 43   | C4-C5  |
| Turnia et al., 2009           | Male    | 48   | C7-D1  |
| Wong et al., 2017             | Female  | 49   | C5-C6  |
| Zavatsky et al., 2008         | Male    | 29   | C7-D1  |
| Our cases 2021                | Male    | 19   | C5-C6  |
| Our cases 2021                | Male    | 30   | C5-C6  |

were reported from India and one-third from the United States, it seems that no specific geographic distribution exists. Knowing that cervical spine injuries are more frequent in young men, TCS is two times more frequent in men with a mean age of 41 years. TCS is caused in nearly half of the cases by road traffic accidents; in second row, falls are responsible of more than third of reviewed cases, mostly from small altitudes but with bad reception. Other causes of TCS way uncommon include diving accidents and iatrogenic traumatisms; in fact, when the two cases of obstetrical TCS seem to have no particular precaution on childbirth than other spinal traumas,

Contd...
children of this review were managed lately. Clinical presentation varies and does not reflect the severe character of the lesion due probably to the selectivity of cases to report. In fact, one-third of reviewed patients are received initially without any neurologic deficit (AIS Grade E) and one-third with incomplete motor deficit (Grades D and C), whereas only 36% of patients are totally paralytic (Grade B and A). In most cases, CT is sufficient to identify a spondyloptosis with the associated bone lesions and to plan management strategy. MRI is very useful in detecting associated soft tissues lesions, especially spinal cord compression, ligamentous rupture, and disk hernia, which led surgeons to prefer starting with anterior decompression before posterior reduction or stabilization. Exploring arterial posttraumatic lesions with either angiography or angio-CT is justified; in fact, in this review, three patients presented vertebral artery lesions; in one case, it was a sharp angulation of one side vertebral artery and a posttraumatic pseudoaneurysm on the other side,[9] and in two cases, a total occlusion in one side.[10,11] It appears that the incidence of TCS rises the more we go down on cervical spine levels, and so, 68% of the reviewed cases are located in the lowest two levels [Figure 4]; these levels are where the mobility is the least and the load is bigger.[12] TCS is dominated by anterior slippage of the superior vertebrae (anterolisthesis) in more than 83% of cases; whereas posterior form (retrolisthesis) as in our two cases is rare seen in only 10% of cases; and only one case was reported of laterolisthesis with lateral TCS (1.5%).[10] TCS could englobe many anatomic aspects; we recommend to distinguish two gravity stages of TCS: in Type I, there is more than 100% slippage, but the endplates are on the same axial plan; in type II, there is a projection of the superior vertebrae in front of the inferior vertebrae (like S Tetris shape) or behind the inferior vertebrae (like Z Tetris shape), performing a double body aspect on axial CT scan [Figures 1 and 2]. Following this classification, we note that a disunion with posterior element by bilateral pedicles and/or facet joints fractures is present in 89% of type II. In anterior type II form (S Tetris shape aspect), the subjacent vertebra enters the spinal canal, and so, the disunion interests the above vertebra. In posterior type II form (Z Tetris shape aspect), the above vertebra enters the spinal canal, and so, the disunion interests the subjacent vertebra; this is specified in our two cases and another case.[13] Some interesting particular forms of TCS were reported: Tsujimoto et al. described the “locked spondyloptosis” where posterior arch including sinus process is in the spinal canal.[11] Another case was reported by Özdoğan et al. of a TCS with a single body isolated from above and beneath bodies.[14] Reduction with transcranial traction was attempted in most cases; it was successful in one-third of the cases with an average weight of ≈12 Kg in 6 days. With approximately the same weight, a partial reduction was reached in another third of reviewed cases in an average time of 10 days. In the other cases, reduction by transcranial traction totally failed. When closed reduction is not completely successful, open reduction is indicated. McLain et al.[15] specified that in high-grade spondylosthesis, isolated injury in the posterior vertebral ligament could not only be responsible for spondyloptosis, and this anatomic form could be the result of lesions in the three vertebral columns. In fact, in this review, all cases of TCS presented posterior element anomalies either dislocations and/or fractures. In case of simple locked facets, posterior reduction might be preferred; however, in case of bilateral fractures, reducing body dislocation by manipulating free posterior elements seems to be not evident though an anterior reduction is necessary. In some cases, freeing bodies with discectomy under traction was sufficient to reduce the listhesis; however, in 29% of patients, removing compressing body by total or partial corpectomy was necessary. 78% of the cases where corpectomy was performed were type II TCS to free the locked bodies. Surgery is highly indicated and can only be postponed in case of instable patients or in case of no significant neurologic deficit to give more time to close reduction. Four patients in this series were treated conservatively; one was dead, the second presented multiple complications, and the two others kept the initial deficit; and hence, nonsurgical treatment must never be an option. Anterior Smith and Robinson approach gives the possibility of discectomy, corpectomy, arthrodesis, and osteosynthesis; and hence, reduction, decompression and solid stabilization could be performed with only anterior approach. Posterior approach allows freeing locked facets, performing laminectomy giving more space to injured spinal cord, and also permits osteosynthesis. When anterior stabilization is more reliable than posterior fixation, more than 45% of the cases were treated with combined anterior and posterior approach giving more chances for durable stabilization. Most of treated patients had a good outcome; in this series, 40% of cases improved and 30% of patients stood without deficit after surgical stabilization. 14.5% of cases do not recover from their initial deficit probably because of the severity of the initial lesions. Few complications were reported related to accidental soft tissues lesions, especially esophageal laceration[9] and vocal cord paralysis[16] in anterior approach; other complications include CSF leaks and meningitis after dura tears.[14,17,18] Mortality in TCS is important; 11% of the reported cases were fatal, and still we think that it is underestimated due to the selectivity of reported cases.

CONCLUSION

TCS predominates in the lowest levels of cervical spine. This lesion is allowed in all cases by a failure in posterior elements. It is a lesion with the worst clinical presentation due to
neurologic compression and with reported risk of vertebral artery lesions. The presence of disunion with posterior elements is very frequent and almost constant in type II TCS; hence, posterior reduction is nonevident. TCS is an instable lesion, imposing urgent reduction preferably with transcranial traction followed by surgical stabilization. Anterior approach gives more chance to stabilization, but posterior fixation gives supplementary rigidity to the construct. At the limit of the reviewed cases, outcome is in general good, with total healing of most cases, but mortality is still important.

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Conflicts of interest
There are no conflicts of interest.

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