Floating Spine and Other Types of Associated Multiple Simultaneous Unstable Spinal Fractures

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ABSTRACT

Introduction: We intend to present a series of patients with associated multiple and simultaneous unstable spinal fractures (Type B or C). **Materials and Methods:** A descriptive analysis of patients with high-energy spinal cord injuries and associated multiple unstable and simultaneous spinal fractures from January 2015 to January 2021 was conducted. Patients with type B (ligament injury) and/or type C (subluxation/dislocation) multiple spinal fractures were included. Patients with incomplete medical records, osteoporotic or pathological fractures, or fewer than 3 months of follow-up were excluded. **Results:** We included 5 patients (1 woman and 4 men) with two simultaneous unstable spinal fractures, including 4 cases (80%) of non-contiguous fractures and 3 (60%) with two simultaneous non-contiguous fracture dislocations ("floating spine"); 2 (40%) cases had a type B fracture associated with a type C fracture. The median age was 35 years. High-energy trauma with associated injuries occurred in all cases. All patients were surgically treated with a conventional posterior approach, reduction, and long arthrodesis. In two patients, neurological recovery was confirmed. **Conclusion:** A case series of multiple simultaneous unstable spinal fractures (type B or C) caused by high-energy trauma is presented. This is a rare injury association with significant morbidity associated with spinal, systemic, and neurological trauma.

Keywords: Multiple unstable spinal fractures; floating spine; trauma; high energy.

Level of Evidence: IV

Columna vertebral flotante y otras variantes de la asociación de múltiples fracturas vertebrales inestables simultáneas

RESUMEN

Introducción: El objetivo de este estudio fue evaluar a una serie de pacientes con la asociación de múltiples fracturas vertebrales inestables (tipo B o C) simultáneas. **Materiales y Métodos:** Estudio descriptivo de pacientes con trauma vertebromedular de alta energía y asociación de múltiples fracturas vertebrales inestables simultáneas entre enero de 2015 y enero de 2021. Se incluyó a pacientes con fracturas vertebrales múltiples tipo B (asociación de lesión ligamentaria) o tipo C (evidencia de subluxación/luxación). Se excluyó a pacientes con registros incompletos de historias clínicas, fracturas por osteoporosis o patológicas y seguimiento <3 meses. **Resultados:** Se constataron 5 pacientes (1 mujer y 4 hombres) con dos fracturas vertebrales inestables simultáneas, con 4 casos (80%) de fracturas no contiguas y 3 casos (60%) con 2 luxofracturas simultáneas no contiguas ("columna flotante"); 2 (40%) pacientes presentaron la asociación de una fractura tipo B con una tipo C. La mediana de la edad era de 35 años. Todos tenían traumatismos de alta energía con lesiones asociadas. Los pacientes fueron operados por vía posterior convencional, con reducción y artrodesis larga. Se constató la recuperación neurológica en 2 pacientes. **Conclusión:** Presentamos una serie de casos de múltiples fracturas vertebrales inestables (tipo B o C) y simultáneas por traumatismos de alta energía. Esta asociación de lesiones es poco frecuente y tiene una elevada morbilidad relacionada con el trauma vertebral, sistémico y neurológico.

Palabras clave: Fracturas vertebrales múltiples inestables; columna flotante; trauma; alta energía.

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INTRODUCTION

The association of multiple simultaneous spinal fractures has been extensively described in the literature, especially in the context of high-energy trauma.[1-5]

The subgroup of associated fractures separated by an undamaged spinal segment can be distinguished as non-contiguous fractures. Numerous publications have estimated their incidence and prioritized the importance of timely diagnosis, since approximately 28% of non-contiguous spinal fractures can go unnoticed.[5] In the last decades, some investigations that evaluated patients with magnetic resonance imaging recorded a variable incidence of non-contiguous spinal fractures (17-34%).[5,6]

In the context of this association of injuries, it should be noted that the coexistence of two non-contiguous unstable spinal fractures is less frequent and the number of publications in this regard is much lower, with case reports or brief series predominating.[7-11] The association of two non-contiguous spinal dislocations or dislocations-fractures has received different names in the literature. The "en bloc" dislocation of the lumbar spine can be mentioned in a case of simultaneous dislocations of the thoracolumbar and lumbosacral joints[8] and as "floating spine" in reference to spinal injuries that compromise the three regions at two non-contiguous levels.[7,10,11]

The objective of this study was to analyze a series of patients with spinal cord trauma and association of multiple simultaneous unstable vertebral fractures (type B or C).

MATERIALS AND METHODS

A series of patients with high-energy spinal cord trauma treated by the same surgical team was analyzed, with the objective of evaluating the cases that presented the association of multiple simultaneous unstable spinal fractures during the period between January 2015 and January 2021.

Patients with type B (association of ligament injury) and type C (evidence of subluxation/dislocation) multiple spinal fractures according to the AOSpine thoracolumbar and low cervical vertebral injury classification systems were included. Patients with incomplete medical records, osteoporotic fractures, pathological fractures, and follow-up <3 months were excluded.

The description of the cases was carried out considering the following study variables: age, sex, trauma, vertebral topography, classification according to the AOSpine system,[12] involvement of non-contiguous vertebrae; configuration of the floating spine injury; pre- and postoperative neurological status according to the *ASIA Impairment Scale* (AIS),[13] presence of associated injuries and comorbidities, surgical approach, levels of instrumentation involved, complications, radiographic evolution, clinical evolution according to the visual analog scale and the Functional Independence Measure (FIM) upon discharge. The FIM is an instrument developed as a measure of disability that includes measures of independence for self-care, sphincter control, transfers, locomotion, communication, and cognition.[14]

This research was carried out in accordance with the principles set forth in the Declaration of Helsinki, respecting the anonymous nature and confidentiality of the data. The patients gave their consent for its publication.

Statistical Analysis

In the description of our case series, categorical variables are expressed as number and percentage, and numerical variables, as median and range. Count, percentage, and summary measures were obtained using the SPSS Statistics 25 program.

RESULTS

During the study period, there were five patients (1 woman and 4 men) with two simultaneous unstable spinal fractures, with four cases (80%) of non-contiguous fractures. According to the type of associated fractures, three (60%) had two non-contiguous simultaneous dislocation fractures (AOSpine: type C), an association called 'floating spine', according to previous publications. As an injury variant, two (40%) patients had the association of a type B fracture with a type C. The median age was 35 years (range 23-49). All had suffered high-energy trauma (3 traffic accidents, 2 high-altitude falls) with associated injuries. Severe chest trauma with rib fractures and hemothorax predominated (n = 3, 60%). Few previous comorbidities were recorded: one patient with a history of major depression and suicide attempt, and one with ossification of the cervical posterior longitudinal ligament. Table 1 summarizes the description of the sample and Table 2 describes the cases (Figures 1-4).

Table 1. Sample description

Variables		Results
Age, median (min-max)		35 (23-49)
Sex, n (%)	Male	4 (80)
	Female	1 (20)
Topography, n (%)	Cervical + Thoracic	2 (40)
	Thoracic + Lumbar	2 (40)
	Lumbar	1 (20)
Number of fractured vertebrae, median (min-max)		3 (2-6)
Associated injuries, n (%)		5 (100)
Fusion levels, median (min-max)		11 (8-12)
Floating spine, n (%)		3 (60)
AIS at admission, n (%)	A	2 (40)
	C	1 (20)
	D	2 (40)
Type of trauma, n (%)	Car accident	3 (60)
	Fall from height	2 (40)

AIS = *ASIA Impairment Scale.*

Table 2. Description of the cases

n	Age (sex)	AOSpine	Injury association	AIS (pre.)	Associated injuries
1	35 (M)	C7-T1: C (T3-T4: C; T1:A1; T4:A1; N4)	FS	A	Metatarsal fracture
2	29 (F)	T7-T8: C (T12-L1: C; T7:A4; T8:A3; T9:A1; T10:A1; L1:A3; L2:A4; N3)	FS	D	Humerus, pelvis and rib fractures Chest trauma with hemothorax TBI
3	38 (M)	T1-T2: C (C3-C4: B3; T2 A1)	C + B	C	TBI with skull fracture Atlas fracture
4	49 (M)	L4-L5: C (L1-L2: B2; L2: A4; L3:A3; N3)	C + B	D	Chest trauma with rib fractures and hemothorax
5	23 (M)	T8-T9: C (T12-L1: C; L1: A3; T9: A1; N4)	FS	A	Chest trauma with rib fractures and hemothorax TBI

AIS (pre.) = preoperative *ASIA Impairment Scale*; M = male; F = female; FS = floating spine; TBI = traumatic brain injury; C + B = association of type C fracture and type B fracture.

Figure 1. Computed tomography of the cervicothoracic spine without contrast, sagittal section. **A.** Upon admission of the patient. Evidence of 'floating thoracic spine'. **B.** Postoperative period. Evidence of reduction of both injuries.

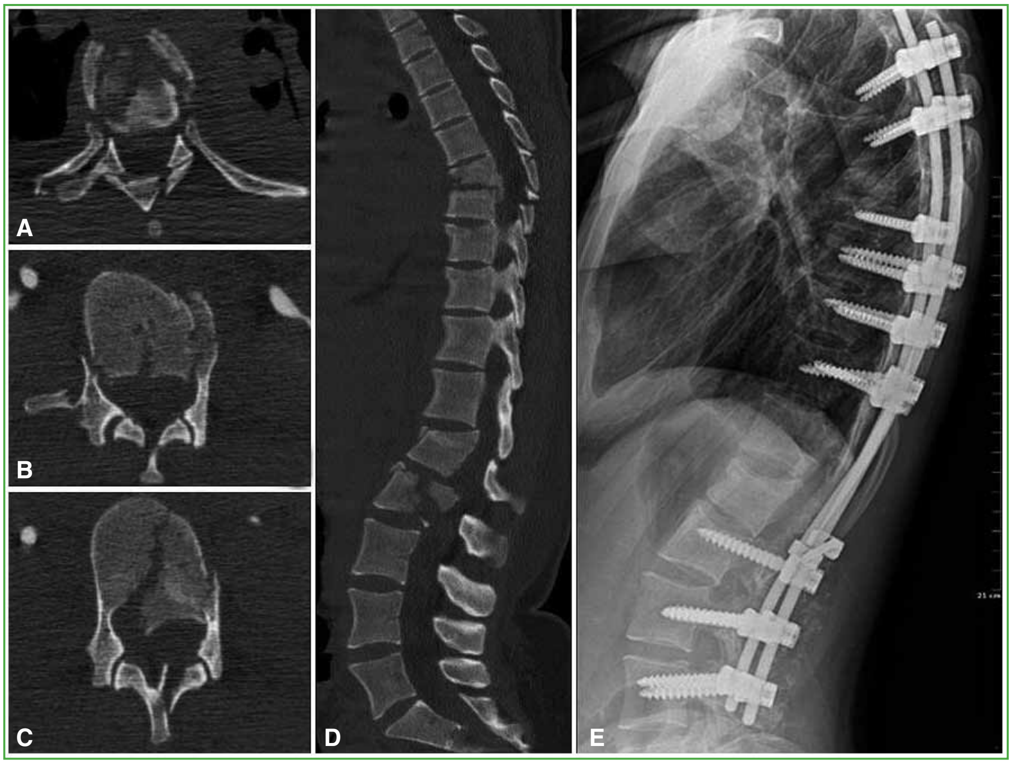

Figure 2. Case 2. **A-D.** Initial computed tomography of the thoracolumbar spine, axial sections in T7, L1, and L2, respectively. **E.** Postoperative lateral radiograph of the thoracolumbar spine. Pedicle instrumentation.

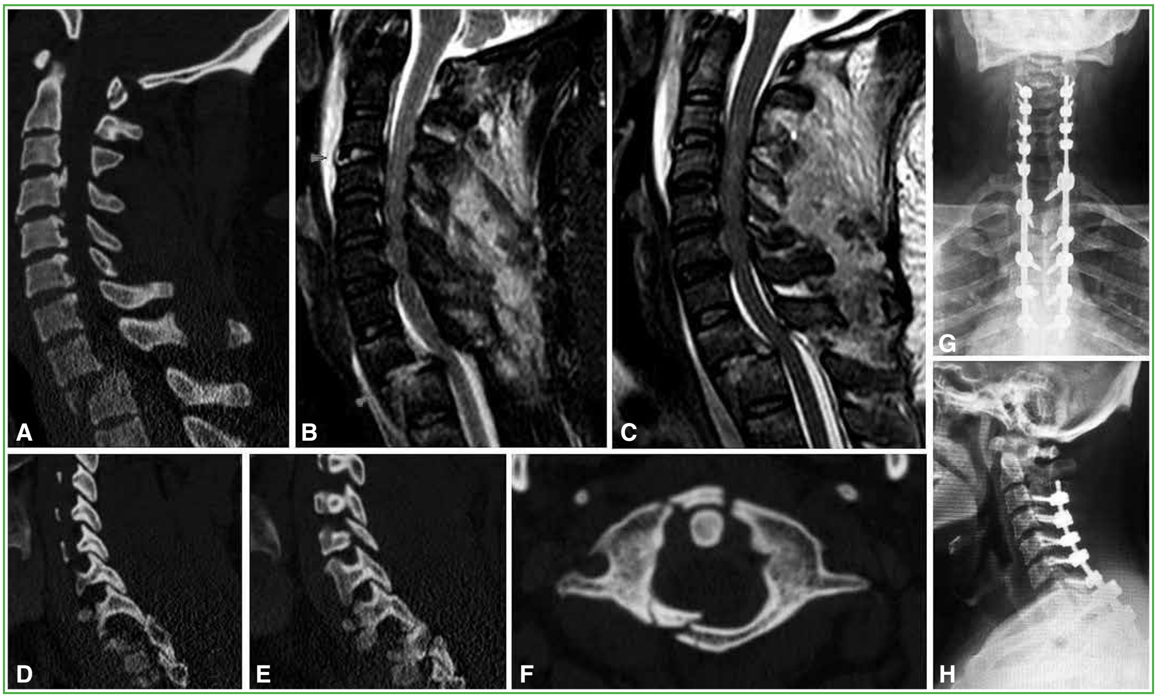

Figure 3. Case 3. **A, D-F.** Initial cervical spine computed tomography. Evidence of fracture-dislocation of C7-T1 with bilateral facet dislocation, ossification of the posterior longitudinal ligament, and atlas fracture. **B and C.** Magnetic resonance imaging of the cervical spine with evidence of a C3-C4 B3 injury. **G and H.** Anteroposterior and lateral radiographs of the cervicothoracic spine, respectively. Postoperative control.

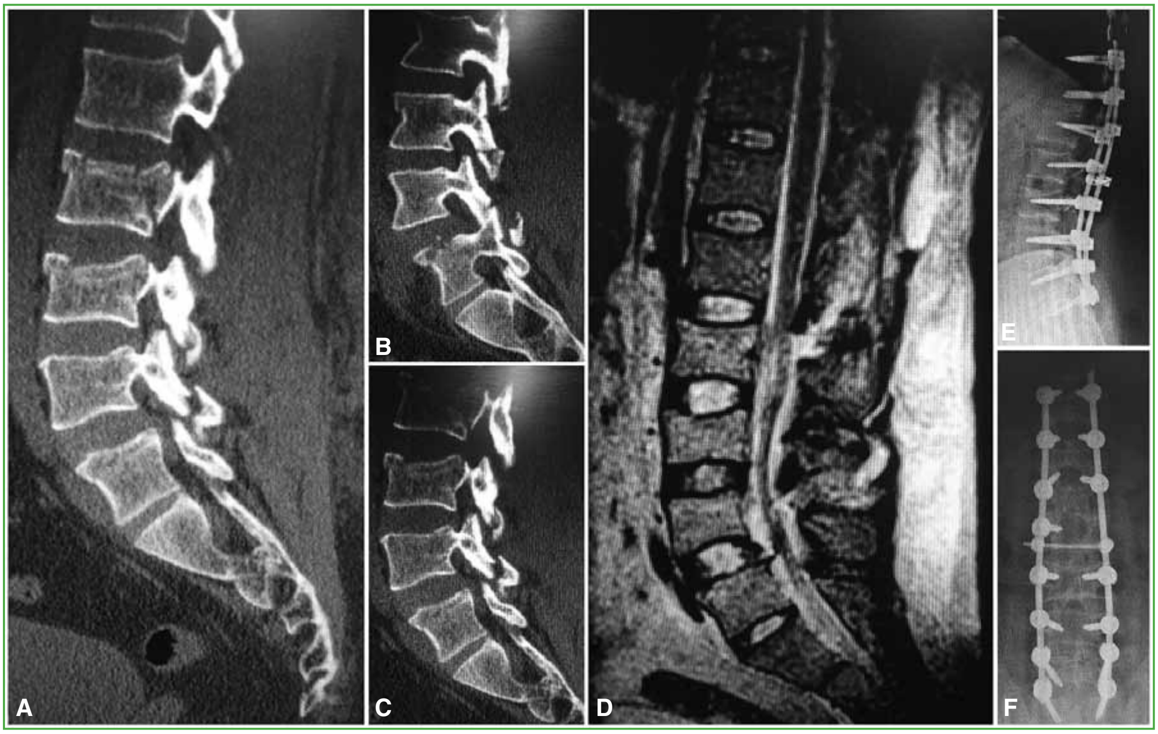

Figure 4. Case 4. **A-C.** Initial lumbosacral spine computed tomography. Evidence of fracture dislocation of L4-L5 (traumatic spondylolisthesis), associated with A3 fracture of the vertebral body of L2 and A1 of L3. **D.** Magnetic resonance imaging of the lumbosacral spine with evidence of a type B2 L1-L2 lesion. **E and F.** Postoperative radiographic control.

All patients suffered neurological injury (4, spinal cord/conus medullaris injury; 1, cauda equina injury). The degree of initial neurological injury was severe in three cases (2 with complete AIS A syndrome; one with incomplete AIS C syndrome).

All were operated using the conventional posterior approach, with release, reduction, and long arthrodesis. In one case, dural repair was also performed. One patient was referred from another center, he had been treated in the Emergency Department with laminectomy of both injuries without instrumentation (Figure 5).

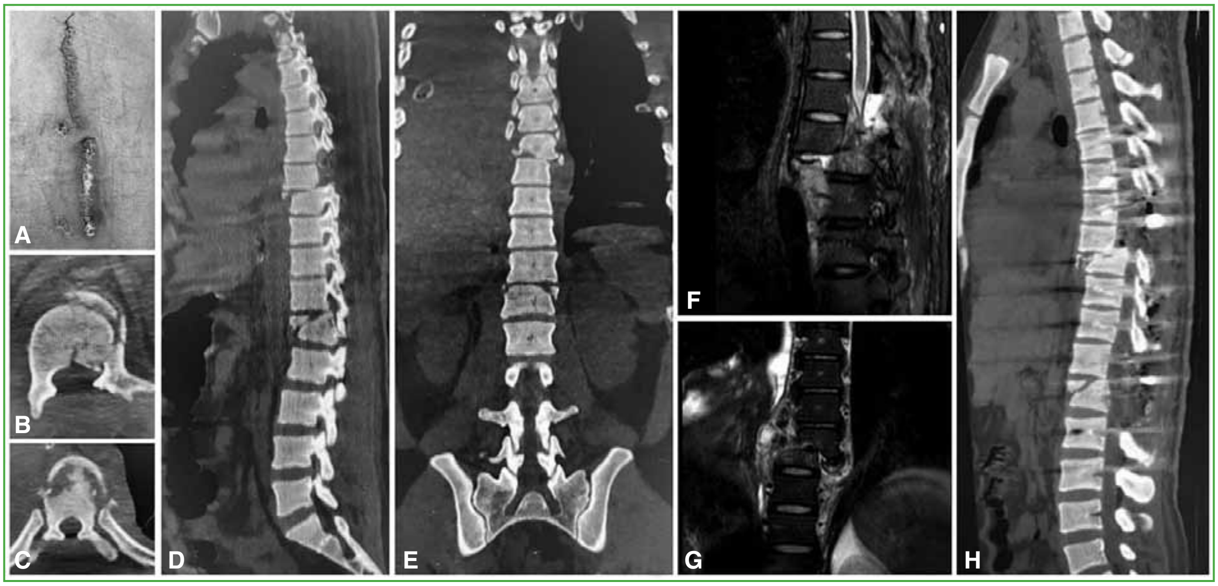

Figure 5. Case 5. **A.** Non-instrumented laminectomy scar performed in the referral Emergency Service. **B-E.** Spinal computed tomography. Evidence of associated dislocation-fractures at T8-T9 and T12-L1. **F and G.** Magnetic resonance imaging of the thoracic spine in STIR sequence. Evidence of preoperative progression of the displacement of a proximal dislocation-fracture of T8-T9. **H.** Postoperative thoracolumbar spine computed tomography with evidence of incomplete reduction of the proximal injury.

Neurological recovery was confirmed in at least 1 grade of the AIS classification in two patients. One AIS D patient fully recovered and one with severe AIS C quadriparesis partially improved to AIS D. In this last case, the recovery of the neurological state was incomplete; however, the patient was able to regain independence in walking with partial offloading. Patients with initial AIS A neurological injury did not recover their neurological status and therefore had greater postoperative functional dependence. Almost all suffered at least one complication (n = 4; 80%), most of which was related to the associated neurological injury (chronic neuropathic pain [4 cases], intrahospital urinary tract infection [2 cases]; neurogenic bladder [2 cases], neurogenic bowel [1 case]). One patient suffered septic shock with a urinary focus that forced him to be readmitted to the intensive care unit. In two (40%) cases, the complications were related to surgery: one patient with hematoma at the surgical site with ambulatory drainage (negative cultures) and one case of “floating spine” with incomplete reduction of the proximal fracture-dislocation without the need for revision (Table 3, Figure 6).

The median follow-up was 501 days (min.-max. 113-2024).

Table 3. Evolution

Variables	Results
FIM, median (min-max)	113 (72-126)
Axial VAS, median (min-max)	2 (0-5)
Complications, n patients (%) Related to surgery Clinical Associated with spinal cord trauma	4 (80) 2 (40) 2 (40) 4 (80)

FIM = *Functional Independence Scale*; EAV = visual analog scale; min-max = minimum-maximum.

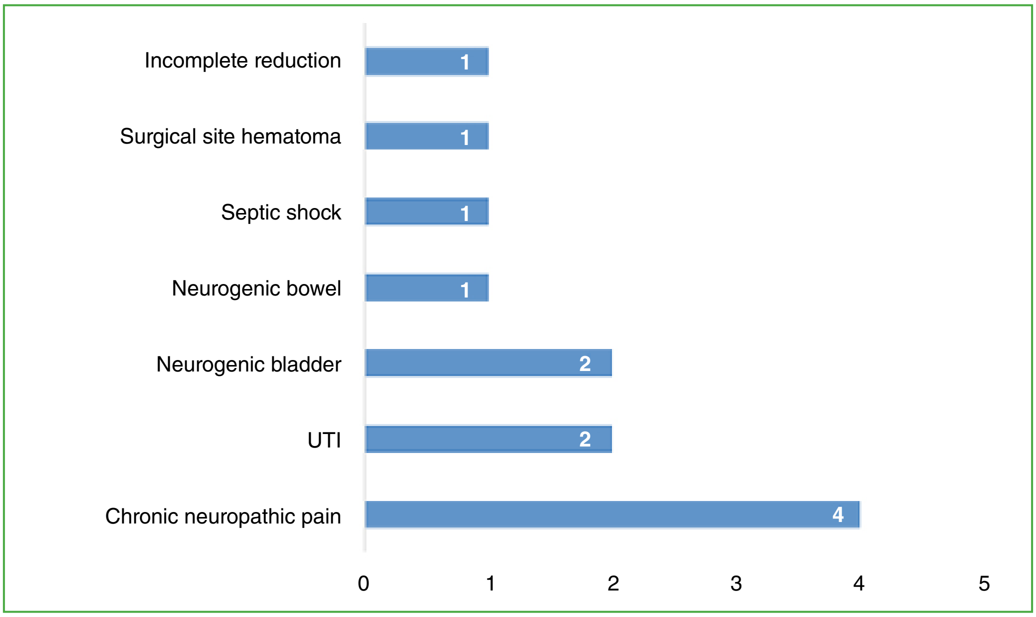

Figure 6. Distribution of complications.

DISCUSSION

In the context of the initial evaluation of patients with high-energy spinal cord trauma, it is common to detect the association of multiple adjacent or non-contiguous spinal fractures.[15] This finding is extensively described in the literature from which it appears that the altered level of consciousness that prevents the neuro-orthopedic examination and the high-energy traumatic history are risk factors for not noticing the second fracture.[16-18] In addition, the combination of cervical-thoracic and thoracic-lumbar topographies stands out as the most frequent patterns.[16-18] Therefore, the available evidence indicates that the presence of a cervical or thoracic vertebral lesion in high-energy trauma, especially in unresponsive patients, entails the imperative need to study the entire spine with computed tomography to avoid ignoring hidden or unnoticed injuries.[15-21] Even in the era of tomography and magnetic resonance imaging, a median delay in diagnosis of associated spinal fractures of 5.1 days has been reported.[15] Magnetic resonance imaging offers as an additional advantage the possibility of assessing for edema (trabecular fractures), direct estimation of ligament lesions, and complete evaluation of the neuraxis.[5]

Multilevel spinal fractures are defined as fractures of the spine at more than one site and separated by at least three normal vertebrae. Other authors define them as “non-contiguous” or “alternating” when there is at least one normal vertebral segment.[18,20]

It should be noted that the association of non-contiguous and simultaneous unstable fractures involving ligament compromise (type B) or vertebral translation (type C) is typically rare and there are few published cases.[7-11] Takami et al. reported 2.5% non-contiguous unstable spinal fractures in a registry of 710 patients, with only nine cases of floating spine.[7] In our environment, we highlight the publications by Sarotto et al., and Bazán et al.[18,22] Sarotto et al. carried out a descriptive study of 120 patients with alternating spinal fractures from the records of five hospitals in the Autonomous City of Buenos Aires over a 10-year study period with a detailed demographic and clinical description, although without emphasis on the association of simultaneous type B or C spinal injuries. In a cross-sectional and multicenter study on multiple spinal fractures that involved 15 centers, Bazán et al. reported 66 patients in two years, with no cases of associated simultaneous unstable fractures (type B or C).[22] In our opinion, this gives our series a hierarchy, despite the low number of cases (n = 5; 3 cases of ‘floating spine’).

There is agreement on the surgical treatment of associated unstable spinal fractures.[7-11] In this group of patients, aside from the factors usually considered in decision-making for spinal cord trauma (clinical stability, mechanical stability, neurological compromise, local deformity, ligament compromise, vertebral translation), other factors have been suggested, such as number of undamaged segments that separate both fractures, to estimate the possibility of carrying out focal instrumentation with preservation of mobile intermediate segments.[15] From a current perspective and with the advent of new technologies, there are alternatives to conventional long arthrodesis that include long percutaneous fixation and combined minimally invasive approaches (anterior/posterior) with the possibility of eventual material removal to recover mobility.[22] This is particularly controversial in cases of type B or C fractures. In our series, all the patients were treated by conventional posterior approach with reduction and long arthrodesis involving numerous segments in the instrumentation. This strategy was determined by the severity of the instability of the associated injuries, the presence of neurological injury in all cases in the series, and the presence of other fractures in intermediate segments.

In general, this type of injury causes high morbidity and mortality on admission and during its evolution. Takami et al. reported an associated injury rate of 66.7%.[7] In agreement with the literature, associated injuries were recorded in all the cases of our series, with a predominance of severe chest trauma. Additionally, we documented a high rate of complications, which were predominantly related to neurological injury. Neurological recovery was possible in two of the five cases.

The strength of our study is the contribution of cases on a rare association of unstable traumatic spinal injuries: three cases of floating spine. Likewise, as a novelty according to the literature, the simultaneous association of type B and type C fractures is proposed as a variant. We consider this appreciation valid, since there is a consensus regarding instability and the standard surgical management of spinal injuries with ligament involvement. These types of injuries often involve opting for long fusions. Treatment, particularly in young patients and with lumbar fractures, can be difficult in order to preserve mobile segments, which, in the author’s opinion, also occurs in non-contiguous associated vertebral dislocation-fractures.

The weaknesses of this study are its descriptive-retrospective design and the small sample size that prevent reaching generalizable conclusions. However, it has the strength of adding our knowledge in treating this association of injuries with high morbidity and mortality, complexity, and low frequency.

CONCLUSION

We present a series of patients with multiple simultaneous unstable spinal fractures (type B or C) due to high-energy trauma. A rare association of injuries, with high morbidity related to vertebral and systemic trauma and neurological injury.

Conflict of interest: Ricciardi GA is section editor of the AAOT Journal.

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