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ORIGINAL PAPER

Hyperextension-distraction fractures in ankylosing and spondylotic spines: injury profile and treatment results

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Abstract

Study design Case series study.

Purpose To describe demographic metrics, and clinical and radiographical outcomes of surgical treatment in patients with ankylosed spine (ASP) such as diffuse idiopathic skeletal hyperostosis (DISH) or ankylosing spondylitis (AS) and non-ankylosed spines (NAS) suffering from hyperextension-distraction spine fractures.

Methods Patients diagnosed with hyperextension-distraction fractures between 2012 and 2020 were identified. A retrospective analysis of clinical and surgical data was performed. Similarities between patients with ASP and NAS were evaluated by Fisher's exact test.

Results Of the 22 patients, 13 had ASP (10 patients with DISH, 3 AS) and nine NAS. Most of these injuries involved the thoracolumbar spine (45.4%). All patients with NAS presented some sign of spondylosis: facet joint degeneration, intervertebral osteochondrosis, and anterolateral osteophytes. None of the patients with NAS and 30.7% with ASP suffered low-energy mechanisms ($p = .11$). All the patients with NAS and 61% of the patients with ASP had associated injuries ($p = .04$). On average, the instrumented levels were four (range, 2–6), achieving a fusion rate of 94.7% in all groups. Most of the ASP and NAS presented post-operative complications respectively ($p = .65$).

Conclusion Hyperextension-distraction spine fractures are not unique in ASP. In patients with spondylosis and high-energy accidents, we should suspect those fractures and rule out associated injuries, fractures in other vertebral segments, and acute spinal cord injury. The four-level instrumentation achieved an effective fusion rate in all patients.

Keywords Diffuse idiopathic skeletal hyperostosis (DISH) · Ankylosing spondylitis (AS) · Spondylosis · Hyperextension-distraction spine fractures · AO type B3 · Spine fracture

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Introduction

Hyperextension-distraction fractures are non-frequent injuries, which account for 3% of the total amount of spinal fractures, reported to occur in up to 70% of patients diagnosed with ankylosing spondylitis (AS) or diffuse idiopathic skeletal hyperostosis (DISH).

In AS, chronic inflammation of sacroiliac joints, intervertebral discs, and facet joints leads to an ankylosed spine [1]. DISH, or Forestier disease, is another source of spinal stiffness which results in ossification of the ligaments and enthesis of at least four consecutive vertebrae [2].

In accordance to AO Spine's classification, injuries which occur due to this mechanism are defined as type B3 fractures [3]. Even though there is considerable evidence with regard to type B3 fractures in ankylosed spine (ASP), AS, and DISH [4–6], there are no reports that describe this type of injuries in non-ankylosed spines (NAS).

Our work outlines the demographic, radiological, and clinical characteristics of patients with ASP and NAS who present type B3 fractures.

Materials and methods

This is a retrospective, descriptive, observational study in patients over 18 years of age with type B3 fractures who received care between 2012 and 2020 at Hospital del Trabajador and received clinical imaging diagnosis of ASP, AS and DISH, in accordance to Rudwaleit [7] and Resnick [8] classification criteria, respectively, and NAS. In the NAS group, signs of anterior and posterior spine spondylosis were evaluated in accordance with criteria set by Fardon [9] and Weishaupt [10]. The three diagnoses were carried out by professional radiologists of our institution through X-rays, computed tomography (CT), and/or magnetic resonance imaging (MRI). Patients got a minimum follow-up time of 12 months.

Patients with pathological bone fractures secondary to neoplasia or infections were not included in this study.

Patient variables (age, gender, presence of AS, DISH, spondylosis, comorbidities, body mass index [BMI]), injury variables (mechanism of injury, vertebral level of injured segment, neurological deficit, associated vertebral fractures, and associated systemic injuries), and variables associated with surgery and post-operative period (fixed levels, consolidation, post-operative complications, mortality rate) are set out herein.

This work was reviewed and approved by the institutional Ethics Committee. Information pertaining to each patient was collected in a Microsoft Excel spreadsheet, in which the log was carried out through a non-sequential coding for each of the patients, guaranteeing their identity and confidentiality. Stata V.12 software was used to carry out tabulation of data and statistical analysis. In order to establish the significance of the differences or associations, Fisher's exact test was used.

Results

Patient variables

From a total of 22 patients, the mean age was 59.4 years. 81.9% corresponded to men and 18.1% corresponded to women. Three patients (13.6%) corresponded to the AS group, ten patients (45.4%) to the DISH group, and nine patients (41%) to the NAS group. Chronic comorbidities (high blood pressure or diabetes mellitus) occurred in 63.3% of the patients and 59% suffered from obesity.

Injury variables

From the total of patients, 18.1% experienced low-energy mechanisms. The distribution of the fractures, according to their location, was as follows: four (18.2%) occurred in the subaxial cervical spine, six (27.3%) in the thoracic, ten (45.4%) in the thoracolumbar, and two (9.1%) in the lumbar region. Figure 1 illustrates the spine with type B3 fractures.

A total of 36.3% of the patients suffered from neurological deficits. In addition, 36.3% presented spinal fractures in other segments, and 77.3% presented associated injuries, the

Fig. 1 Sagittal CT image of the spine with type B3 fractures in NAS (**A**), AS (**B**), and DISH (**C**). CT, computed tomography; NAS, non-ankylosed spines; AS, ankylosing spondylitis; DISH, diffuse idiopathic skeletal hyperostosis

most frequent being fractures in the appendicular skeleton (31%), rib fractures (31%), encephalocranial trauma (27%), haemopneumothorax (27%), pelvic fractures (9%), and injuries to the aorta (5%).

Three (13.6%) patients died.

Variables associated with surgery and post-operative period

The number of instrumented levels averaged four (2–6), resulting in a consolidation rate of 94.7% in patients with ASP and NAS. Figure 2 illustrates pre-operative and post-operative imaging appearances of patients with ASP and NAS.

Post-operative complications were experienced by 63.1% of the patients, the most frequent being urinary tract infection (27.7%), surgical wound dehiscence or infection (22.7%), acute kidney failure (18.1%), and pressure sore (13.6%). Table 1 summarizes the baseline characteristics of the study population.

Evaluation of differences between patients with ASP and NAS

Patient variables

The mean age of patients with AS was 43.3 years (39–46 years), 64.6 years (39–79 years) in patients with DISH, and 59.1 years (39–85 years) in patients with NAS. In the ASP and NAS groups, 92.3% and 66.6% of the patients, respectively, were males.

The nine patients with NAS presented some sign of spondylosis. The most frequent findings were facet arthrosis (88.8%), intervertebral osteochondrosis (88.8%), and anterolateral osteophytes (66.6%). Table 2/Fig. 3 illustrates spondylosis findings in the NAS group. 76.9% had chronic comorbidities in patients with ASP and 44.4% of the patients with NAS. Furthermore, 69.2% of the patients in the ASP group, 100% of the patients in the AS group, and 60% of the patients in the DISH group suffered from obesity. With respect to the NAS group, only 44.4% of the patients suffered from obesity, which did not represent a statistically significant difference ($p = 0.38$).

Injury variables

While 30.7% of the total of patients with ASP experienced low-energy mechanisms, in the NAS group, all patients suffered from high-energy traumas; this did not represent a significant difference ($p = 0.11$). A total of 30.7% (1 complete and 3 incomplete spinal cord injury) of the patients with ASP and 44.4% (2 complete and 2 incomplete spinal cord injury) with NAS suffered from neurological injury and presented noncontiguous spine fractures. No statistical difference was found between both groups as regards

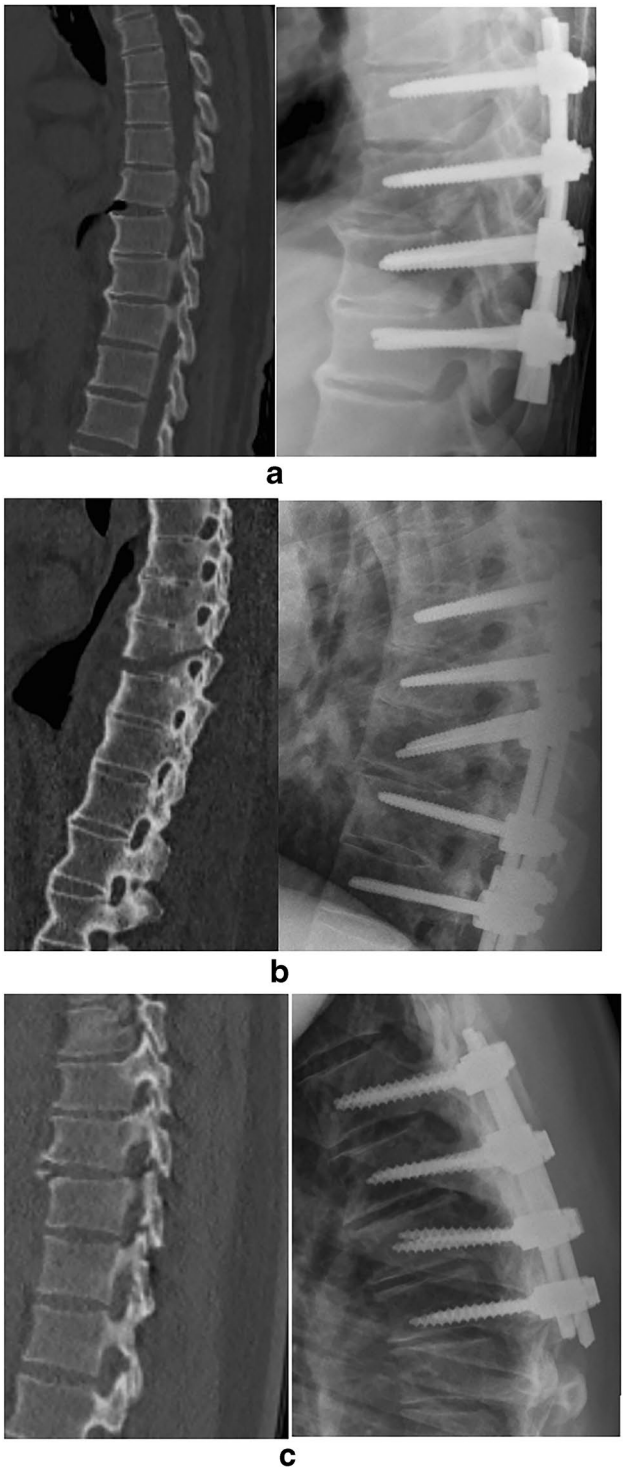

Fig. 2 Sagittal CT image of the spine with type B3 fractures in DISH (**A**), AS (**B**), and NAS (**C**) and lateral radiographs

Table 1 Baseline characteristics of the study population. *AS*, ankylosing spondylitis; *DISH*, diffuse idiopathic skeletal hyperostosis; *NAS*, non-ankylosed spines

Variables	Value ($N=22$)
Patient variables	
Age, mean, std (range)	5.94, 14.4 (39–85)
Male, *n* (%)	18 (81.9)
Diagnosis, *n* (%):	
-AS	3 (13.6)
-DISH	10 (45.4)
-NAS	9 (41)
Comorbidities, *n* (%)	14 (63.3)
Body mass index (BMI), kg/m^2, std	31.54, + −0.5
Injury variables	
Mechanism of injury, *n* (%):	
-High-energy trauma	18 (81.9)
-Low-energy trauma	4 (18.1)
Fracture level, *n* (%):	
-Cervical	4 (18.2)
-Thorax	6 (27.3)
-Thoracolumbar	10 (45.4)
-Lumbar	2 (9.1)
Neurological injury, *n* (%)	8 (36.3)
Associated spinal fractures, *n* (%)	8 (36.3)
Associated injuries, *n* (%)	17 (77.3)
Mortality, *n* (%)	3 (13.6)

Table 2 Spondylosis findings in the NAS group. NAS indicates non-ankylosed spines

Case N°	Anterior osteophytes	Lateral osteophytes	Facet joint degeneration	intervertebral osteochondrosis
1	X	X	X	X
2	X	X	X	X
3			X	
4	X	X	X	X
5	X	X	X	X
6				X
7			X	X
8	X	X	X	X
9	X	X	X	X

neurological injury variables ($p=0.6$) or noncontiguous spine fractures ($p=0.6$).

All patients with NAS and 61% of patients with ASP experienced associated injuries, which represented a statistical difference ($p=0.05$). Three patients died, one (7.6%) from the ASP group and two (22.2%) from the NAS group. No statistical difference was found between both groups ($p=0.5$).

Variables associated with surgery and post-operative period

Only one patient in the NAS experienced a failure of fixation. Post-operative complications were experienced by 58.3% of the patients with ASP and 71.4% of patients with NAS; no significant difference was found ($p=0.65$). Two patients who initially had compromised neurologic function improved by at least one ASIA grade after surgery (one in AS and one in NAS).

Table 3 summarizes the clinical and radiographical metrics between patients with ASP and NAS.

Discussion

Today, there is limited evidence available in literature that compares demographic characteristics, radiological characteristics, and clinical outcomes among patients with type B3 fractures in the ASP and NAS groups.

Not only are ASPs biomechanically stiffer, but they also present osteoporotic bone secondary to an abnormal bone formation due to inflammatory changes or associated stiffness, which overall makes them more likely to suffer from severe injuries with low-to-medium-energy mechanisms [4, 11]. However, even though 41% of our population did not have ASP, they presented signs of spondylosis such as anterolateral osteophytes, facet arthrosis, and intervertebral osteochondrosis, which could structurally and biomechanically be compared to stiff spines. This is the reason of this study to outline the characteristics in both groups.

The mean age in our group of patients with AS was lower compared to the one in the DISH group (43.3 and 64.6 years, respectively). There is evidence showing that the baseline of clinical manifestations in patients with AS would occur after the fourth decade [12]; however, studies comparing demographic characteristics between groups with AS and DISH show that patients who suffer from this injury are, overall, over the age of 60 years [4, 12–14]. The mean age in the NAS group was 59.1 years, which aligns with the literature in proving that the older the patients are, the more probabilities of suffering from degenerative changes they have [15].

Nearly a third of the patients with ASP experienced low-energy traumas, which confirmed literature findings proving that spines with long-lever arms are more fragile and require less energy to suffer fractures [1, 13, 16]. It is important to highlight that, due to the existence of low-energy mechanisms, in many instances, the treating physician underestimates the possibility of injuries occurring, which might lead to sub-diagnosis and possible worsening of the neurological prognosis [16, 17]. In our hospital, there was no late diagnosis of distraction-extension injuries. All patients who were

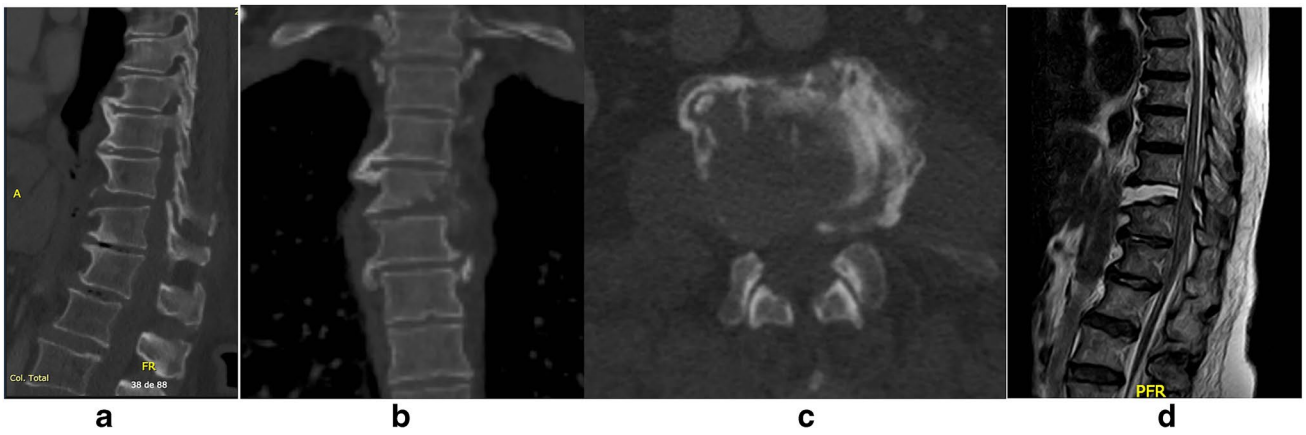

Fig. 3 Spondylosis findings in NAS: anterolateral osteophytes (**A**, **B**), facet arthrosis (**C**), and intervertebral osteochondrosis. NAS indicates non-ankylosed spines

Table 3 Comparison of clinical and radiographical metrics between patients with ASP and NAS. *ASP*, ankylosed spines; *NAS*, non-ankylosed spines. $*p < 0.05$

Variables	ASP	NAS	*p* value
Obesity (%)	9(69.2)	4(44.4)	.38
Mechanism of injury (% low energy)	4(30.7)	0(0)	.11
Neurologic injury (%)	4(30.7)	4(44.4)	.65
Noncontiguous spine fractures (%)	4(30.7)	4(44.4)	.65
Associated injuries (%)	8(61)	9(100)	.04*
Postoperative complications (%)	7(58.3)	5(71.4)	.65
Morality (%)	1(7.6)	2(22.2)	.44
Failure of fixation (%)	0(0)	1(14)	.32

admitted due to an emergency underwent a full spinal CT, and the study was followed up by MRIs in patients with neurological disorders, suspicion of injury in the posterior ligamentous complex, or nerve compression. Current evidence states that, when treating patients with ankylosed spines, we should resort to imaging such as CT/MRI in order to minimize sub-diagnosis rates and characterize the fractures [11, 16]. Degenerative changes in spines with spondylosis also make it more difficult to interpret imaging due to a sclerotic and distorted anatomy, which could lead to a sub-diagnosis of type B3 injuries in this population.

Overall, 30.7% of the patients with ASP and 44.4% with NAS presented neurological disorders. In their systematic review, Westerveld et al. [18] noted 67.2% of neurological injuries in the AS group and 40% in the DISH group. Teunissen et al., in his series of 172 patients with ankylosed spine, discovered that 34.1% of the patients suffered from spinal cord injuries, with cervical fractures and presence of epidural haematomas being a risk factor [5].

Alaranta et al. proved in their study that the incidence of spinal cord injuries in patients with AS was 11.4 times greater than that in the general population [19]. Our study aligns with the current evidence with respect to the greater risk of experiencing neurological injuries associated to fractures of the ASP. Where the NAS group is concerned, a greater incidence and severity of neurological deficits were also found, probably due to higher number of high-energy mechanisms. From a biomechanical perspective, the stiffness secondary to osteophytes, facet hypertrophy and arthrosis, disc and endplate degenerative changes, and canal stenosis might have led to a canal with a smaller diameter and reduced intersegmental mobility, resulting in an injury of the neurological elements.

A total of 36.6% of the patients presented associated fractures in other segments of the spine, similar to literature, which reports a greater risk of associated fractures than in regular population [4]. The NAS group also presented noncontiguous spinal injuries, possibly predisposed by stiffness as a result of spondylotic changes and high-energy mechanisms.

In the ASP group, 61.5% of the patients presented associated injuries, even with low-energy mechanisms. On the contrary, 100% of the patients in the NAS group presented associated injuries, which represented a statistically significant difference. The most frequent were fractures in the appendicular skeleton and rib fractures, encephalocranial traumas, and haemopneumothorax.

There is evidence on ankylosed population that indicates that surgery has better outcomes with regard to morbidity and mortality rates. In a Swedish study of patients with AS, those surgically treated presented better rates of survival than those who underwent conservative treatments. The said study proved that the ratio of patients surgically treated increased linearly over the last decade [20]. Caron et al. also

proved in retrospect that the one year mortality rate in surgically treated patients with AS/DISH was 23%, whereas in patients who did not undergo surgery was 51% [16], confirming the results in the Swedish series. However, in their systematic review, Westerveld et al. did not find significant surgery-related effects with respect to the mortality rate [18]. In general, there is a consensus in literature about the need of surgery in patients with ASP due to inherent instability.

Other frequently mentioned causes that have an influence on the decision to resort to surgery are the presence of neurological deficits, epidural haematomas, and the prevention of complications caused by extended bed rest [21]. Several studies have shown positive clinical and radiological results secondary to surgery. Lu et al. found that the fusion rate and neurological prognosis in patients with AS were better in the surgically treated group than in the group who underwent conservative treatment [22].

Normally, it is preferred to resort to extensive instrumentations through a posterior approach, from two to three levels above and below the level of injury, in order to achieve appropriate stability in fused segments with long-lever arms, resulting in optimal fusion rates [16, 22–24]. In many instances, the pedicle screw instrumentation technique becomes challenging due to a distorted anatomy in ankylosed spines or spines with spondylosis. In our study, the number of instrumented levels averaged four (2–6), resulting in an average consolidation rate of 94.7% in the three groups.

In their systematic review, Westerveld et al. found 51.1% of complications in the AS group and 32.7% in the DISH group [18]. Numerous studies have outlined the significant incidence of post-operative complications in ankylosed patients [13, 14, 16, 23]. Similarly, in our case series, 58.3% of patients with ASP and 71.4% of patients with NAS experienced post-operative complications, the most frequent ones being urinary tract infections and infections associated with the surgical wound.

Three patients died, two (22.2%) in the NAS group and one (10%) in the ASP group. In the AS group, two of the three patients experienced low-energy mechanisms, which might have had an influence in the absence of mortality in this group. On the contrary, all of the patients in the NAS group experienced high-energy mechanisms, resulting in a mortality rate of nearly a quarter of the total number of patients. The three deaths were related to high-energy traumas and encephalocranial traumas. Post-operative mortality rate in ankylosed patients is high as compared with the one in patients with previously healthy spines, with incidences of up to 32% and 0.4%, respectively. Caron et al. determine that age and comorbidities are risk factors associated with mortality [16, 18].

Our work outlines the profile of patients with hyperextension-distraction fractures in our hospital and enables a deeper understanding of this type of injury and the optimization of treatment options. This is the first work that identifies type B3 injuries in NAS and compares their characteristics with the ones in the ASP group, normally associated to this type of fractures.

The limitation of this study is its retrospective design and the small number of patients. However, publications related to these injuries do not involve a great number of participants due to their infrequent occurrences. In this regard, it is important to highlight the need to carry out multicenter prospective studies in order to improve the understanding of this pathology.

Conclusions

AO Spine B3 type fractures are not exclusive in spines with AS or DISH. They must be suspected in patients with spines with spondylosis who have experienced high-energy trauma; and, as in patients with ASP, the presence of associated injuries, fractures in other vertebral segments, and neurological injuries must be emphasized.

The four-level instrumentation achieved an effective fusion rate in both groups. Due to life expectancy being increasingly greater, the incidence of spines with spondylosis and hyperextension-distraction fractures might increase in the next decades.

Author contribution All enlisted authors had mainly contributed into the elaboration of this article.

Availability of data and materials All data and material used in the elaboration of this article is available if requested, stored only by the main author to ensure the privacy of patient information.

Declarations

Ethics approval The current article has been reviewed and approved by local Hospital Ethical committee (AOSpine Center Chile—Hospital del Trabajador).

Consent to participate Informed consent was obtained from each patient prior to data recompilation.

Consent for publication All enlisted authors had approved this article for scientific publication.

Competing interests The authors declare no competing interests.

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