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REVIEW

Spinal fractures in patients with ankylosing spinal disorders: a systematic review of the literature on treatment, neurological status and complications

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Abstract The ankylosed spine is prone to fracture after minor trauma due to its changed biomechanical properties. Although many case reports and small series have been published on patients with ankylosing spondylitis (AS) suffering spine fractures, solid data on clinical outcome are rare. In advanced diffuse idiopathic skeletal hyperostosis (DISH), ossification of spinal ligaments also leads to ankylosis. The prevalence of AS is stable, but since DISH may become more widespread due to its association with age, obesity and type 2 diabetes mellitus, a systematic review of the literature was conducted to increase the current knowledge on treatment, neurological status and complications of patients with preexisting ankylosed spines sustaining spinal trauma. A literature search was performed to obtain all relevant articles concerning the outcome of patients with AS or DISH admitted with spinal fractures. Predefined parameters were extracted from the papers and pooled to study the effect of treatment on neurological status and complications. Ninety-three articles were included, representing 345 AS patients and 55 DISH patients. Most fractures were localized in the cervical spine and resulted from low energy impact. Delayed diagnosis often occurred due to patient and doctor related factors. On admission 67.2% of the AS patients and 40.0% of the DISH patients demonstrated neurologic deficits, while secondary neurological deterioration occurred frequently. Surgical or nonoperative treatment did not alter the neurological prospective for most patients. The complication rate was 51.1% in AS patients and 32.7% in DISH patients. The overall mortality within 3 months after injury was 17.7% in AS and 20.0% in DISH. This review suggests that the clinical outcome of patients with fractures in previously ankylosed spines, due to AS or DISH, is considerably worse compared to the general trauma population. Considering the potential increase in prevalence of DISH cases, this condition may render a new challenge for physicians treating spinal injuries.

Keywords Ankylosing spondylitis · Diffuse idiopathic skeletal hyperostosis · Spine fracture · Ankylosis · Treatment

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Introduction

The ankylosed spine is prone to fracture even after trivial trauma [51]. Several authors have shown patients with ankylosing spondylitis (AS) to have a fourfold fracture risk during their lifetime compared to unaffected individuals [27, 133]. In AS spontaneous fusion of the sacroiliac joints and spine occurs due to chronic inflammation leading to initial back pain followed by generalized stiffness of the spine. The disease has a prevalence of 0.1–1.4%; typically affects males and usually becomes apparent between 20 and 30 years of age [10]. Due to multilevel bony fusion, long lever arms develop in the spinal column on which forces can act during trauma [21]. During progression of the disease the spine becomes increasingly susceptible to injury, eventually even after low energy impacts [11, 50, 113]. Fractures in the ankylosed spine are often unstable

due to the ossification of supportive and elastic soft tissues and may cause neurologic deficit as a result of dislocation [65, 112]. Moreover, because of unstable fracture configurations, initially intact patients may sustain secondary neurologic deterioration after unprotected transfers and manipulation [20]. Neurological deficit after fracture is a well known and feared complication in AS, therefore these patients should be handled with great care when a fracture is suspected [83, 94].

Diffuse idiopathic skeletal hyperostosis (DISH) is a supposedly non-inflammatory disease in which spinal longitudinal ligaments and entheses slowly become ossified leading to decreased mobility of the affected region until complete ankylosis follows [6]. DISH is diagnosed when flowing ossification of the anterior longitudinal ligament is present on spine radiographs over at least four consecutive levels [96]. Its etiology is unknown, but the associations with obesity, type 2 diabetes mellitus and advanced age have been demonstrated by several authors [18, 61]. Studies investigating the demographic characteristics of DISH have found a prevalence ranging from 2.9% in a Korean population to 25% in a selected population of Caucasian males in the United States of America [60, 127]. Acknowledging that DISH is associated with traits typical of modern affluent societies such as increasing life expectancy, obesity and type 2 diabetes, its prevalence and degree of expression can be expected to increase during the coming decades [107, 130]. Most symptoms of DISH are mild and develop slowly but an increasing amount of evidence suggests that DISH is a less innocent condition than previously assumed [104]. Serious complications of DISH in the cervical region for example, are dysphagia; difficult endotracheal intubation, myelopathy and spinal canal stenosis [70, 90, 109]. Some authors have speculated that patients with DISH are also at risk for spinal fractures after minor impacts, comparable to the fracture mechanism of AS patients [6, 88].

This systematic review aims to increase the knowledge on treatment, neurological status and complications of trauma patients with ankylosed spines (due to AS or DISH) and admitted with spine fractures, by pooling data previously published in the literature.

Materials and methods

To identify the relevant publications on this subject, a Medline and EMBASE search was performed. References were obtained from the search parameters ‘ankylosing spondylitis’ and ‘trauma’ and ‘diffuse idiopathic skeletal hyperostosis’ and ‘trauma’ (and their respective synonyms). Articles in languages other than English, French or German and articles without abstract were excluded. All articles were initially screened for relevance by title and abstract. Inclusion criteria were: publication date between 1st January 1980 and 31st December 2007, the presence of AS or DISH and a spinal fracture, a sufficiently detailed description of fracture type and trauma mechanism; an adequate description of neurological status, complications and period of follow-up [4]. The first 3 months after admission were (arbitrarily) defined as the post-treatment phase; thereafter it was defined as the follow-up phase. Consequently, patient’s data were only included in the follow-up group if this period ($\geq$ 3 months) was specifically described in the article. If not, data were only included for the post-treatment phase. Sufficiently described case reports were included to obtain as much information as possible on this subject, simultaneously acknowledging the limited number of large-scale case series expected to be available in the literature. A cross-reference search was performed to obtain the remaining articles. Two authors performed the close reading of all papers and extracted data independently to minimize selection bias and errors. The parameters obtained from the papers and their definitions are listed in Table 1. The data from both readers were compared and where they differed, the pertaining paper was reread until consensus was reached. If overlap was present in two papers from the same author or institution, the least informative paper was excluded. The level of evidence of the included articles was determined according to the guidelines proposed by the Center for Evidence Based Medicine (CEBM) [86]. The independent-samples t test was used to determine statistical significance between the AS and DISH group (SPSS version 12.0.2; SPSS Inc., Chicago, USA).

Results

The literature search and cross-referencing resulted in a total of 1,035 references (951 on AS and 84 on DISH) of which 894 were rejected due to off topic abstract content and/or failure to meet the inclusion criteria. After reading the remaining 141 full text papers (109 on AS and 32 on DISH), another 48 were excluded because of insufficient detail, overlap of same author/institution or uncertain history of trauma. The remaining 93 articles were included:

- Ankylosing spondylitis: 76 articles, describing a total of 345 patients [1, 2, 5, 9, 11, 15, 17, 19, 21–25, 27–29, 31–34, 36, 37, 39–41, 43–45, 50, 52, 55, 57–59, 62, 64, 65, 67, 68, 73, 75–77, 80, 82, 83, 85, 87, 89, 91–94, 97–102, 105, 106, 110, 112–114, 116–122, 125, 126, 128, 132].
- Diffuse idiopathic skeletal hyperostosis: 17 articles, describing a total of 55 patients [7, 12, 14, 16, 26, 30, 49, 54, 66, 74, 79, 81, 88, 108, 111, 128, 131].

Table 1 Parameters extracted from the papers

Parameter	Definition
Name and affiliation of the authors	
Year of publication and name of journal	
Study design	Prospective, retrospective, case report ($n = 1$ or $n = 2$), case study ($n \geq 3$ individuals)
Follow-up	Months
Quality of paper	Oxford Center for Evidence-based Medicine, Levels of Evidence [86]
Mean age of patients	Years
Male/total ratio	Number of males divided by the total number of patients
Traumatic impact	High: motor vehicle accident; fall >15 feet [3]
	Low: fall from standing or sitting position
Polytrauma patients (%)	Number of polytrauma patients reported divided by the total number of patients reported
Fracture level	Cervical, thoracic, lumbar, sacral
Fracture type	Hyperextension, flexion, compression, rotation
Type of treatment	Surgical: posterior fixation, anterior fixation, combined anterior-posterior fixation, laminectomy
	Conservative: traction, halo, collar, brace, plaster jacket, bed rest
Immobilization type	Traction, halo, collar, brace, plaster jacket, bed rest or none
Immobilization duration	Weeks
Neurological outcome	ASIA impairment scale [4]
Complications	Neurologic deterioration, deep venous thrombosis, pulmonary embolism, wound infection, cystitis, pneumonia, pseudoarthrosis, decubitus and miscellaneous complications
Delayed diagnosis	Diagnosis established >24 h after trauma
Mortality	Number of deceased patients

All papers described retrospective case series or case reports, therefore all were assigned grade 4 level of evidence.

General information on the study population

The mean patient age was 59.1 years for AS and 68.2 years for DISH; the difference between the mean age of both groups was statistically significant ($P = 0.004$). Both groups consisted predominantly of males (male/total ratio was 0.90 in AS; 0.84 in DISH). The mean duration of follow-up was 11.2 months for AS and 12.0 months for DISH. Male/total ratio and follow-up duration were comparable in the AS and DISH groups ($P > 0.05$). The percentage of DISH patients with multiple trauma significantly exceeded AS patients; 10.9% in DISH versus 1.4% in AS ($P = 0.034$). In Table 2 details on the characteristics of the study population are presented.

Trauma mechanism, fracture location and diagnosis

The majority of patients sustained low energy trauma causing their fracture; 227 patients with AS (65.8%) and 38 patients (69.1%) with DISH had low energy impacts. In most cases the trauma mechanism consisted of a fall from standing/sitting position. High energy impacts caused a fracture in 107 patients with AS (31.0%) and 13 patients with DISH (23.6%). In 11 patients with AS and four patients with DISH there was no recollection of trauma at all.

Most fractures were localized in the cervical spine; this was the case for 280 AS patients (81.2%) and 33 DISH patients (60.0%). Fractures of the thoracic spine were described more often in patients with DISH (34.5%) than in AS (10.7%). Fractures of the lumbar spine occurred in 27 AS patients (7.8%) and three DISH patients (5.5%). One sacral fracture occurred in a patient with AS. Hyperextension was the most frequent cause of fracture, representing the trauma mechanism for 96 patients with AS (74.4% of 129 reported cases) and 22 patients with DISH (51.2% of 43 reported cases). Flexion-type fractures occurred in 20 AS patients (15.5%) and in none of the DISH patients. Compression fractures were described in six AS patients and in six DISH patients. Rotation-type fractures were reported in seven patients with AS versus 15 patients with DISH. Details of the fracture type in relation to fracture level are listed in Tables 3 and 4.

In patients with DISH the majority of fractures observed were through the vertebral body (63.6% of the total number of fractures), whereas in AS patients, the number of

Table 2 Patient characteristics

	AS	DISH	*P* value
Number of articles	76	17	
Mean follow-up (range)	11.2 (1–65)	12.0 (1–32)	0.851
Number of patients	345	55	
Mean age (SD–range)	59.1 (12.6–32 to 82)	68.2 (10.2–44 to 82)	**0.004**
Gender ratio	0.90	0.84	0.538
Polytrauma patients	1.4%	10.9%	**0.034**

Bold entries are the *P* values for the parameters mean age and polytrauma patients

Table 3 Fracture type versus fracture level in patients with AS (based on $n = 129$)

	Cervical	Thoracic	Lumbar	Sacral	Total
Extension	68 (68.0%)	15 (93.7%)	12 (100%)	1 (100%)	96 (74.4%)
Flexion	20 (20.0%)	0	0	0	20 (15.5%)
Compression	5 (5.0%)	1 (6.3%)	0	0	6 (4.7%)
Rotation	7 (7.0%)	0	0	0	7 (5.4%)
Total	100	16	12	1	129 (100%)

Table 4 Fracture type versus fracture level in patients with DISH (based on $n = 43$)

	Cervical	Thoracic	Lumbar	Total
Extension	12 (44.4%)	10 (71.4%)	0	22 (51.2%)
Flexion	0	0	0	0
Compression	3 (11.1%)	2 (14.3%)	1 (50%)	6 (14.0%)
Rotation	12 (44.4%)	2 (14.3%)	1 (50%)	15 (34.9%)
Total	27	14	2	43 (100%)

fractures through the vertebral body equaled the number of fractures through the intervertebral disc (see also Fig. 1). The large difference in number of fracture patterns reported for AS and DISH unfortunately prevents any quantitative comparison. A delay in diagnosis often occurred; in 59 patients with AS (17.1% of the total AS population) the fracture was not diagnosed within 24 h following trauma. In 31 patients (52.5% of these 59 patients) the fracture was not timely recognized by the physician ('doctor's delay'), while 28 patients (47.6%) delayed their decision to seek medical attention ('patient's delay'). In five patients with DISH (9.1%) the diagnosis was delayed by failure to identify the fracture, thus representing 100% doctor's delay.

Treatment

Surgical treatment was performed in 187 AS patients (54.2%) and in 30 DISH patients (54.5%) and consisted mainly of posterior fixation. In AS patients posterior procedures were more often combined with decompression of the spinal cord than in patients with DISH. In most articles the rationale behind the treatment strategy was not described, but reasons reported often were: (secondary)

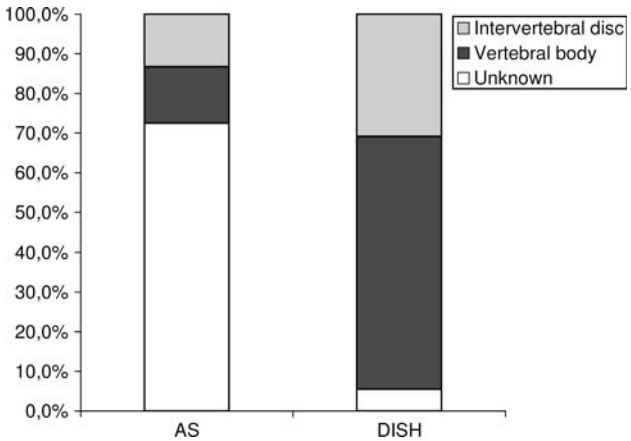

Fig 1 Fracture localization in vertebral body or intervertebral disc (based on $n = 345$ in AS and $n = 55$ in DISH)

deterioration of neurological status, unstable fracture configuration and the presence of an epidural hematoma.

Conservative treatment was performed in 158 AS patients (45.8%) and 25 DISH patients (45.5%), respectively. The main reason to refrain from surgery was high surgical risk or patient refusal. In conservative treatment patients with DISH were most frequently treated with a collar whereas patients with AS were predominantly treated with cervical traction or collar. Immobilization by braces was applied in 16.0% of the DISH patients versus 3.8% of the AS patients, possibly reflecting the larger number of thoracic fractures for DISH patients. For details see Figs. 2 and 3.

Neurological status

At the time of admission 232 AS patients (67.2%) had a neurologic deficit (ASIA A-D) versus 22 DISH patients

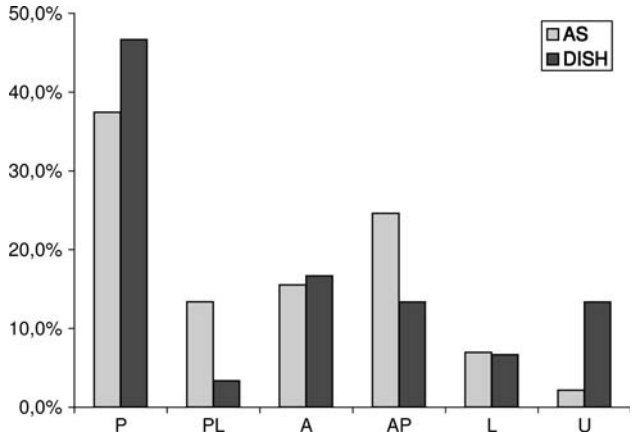

Fig 2 Surgical treatment in AS and DISH patients (based on $n = 345$ in AS and $n = 55$ in DISH). *P* posterior fixation, *PL* posterior fixation combined with laminectomy, *A* anterior fixation, *AP* anterior and posterior fixation, *L* laminectomy, *U* unknown

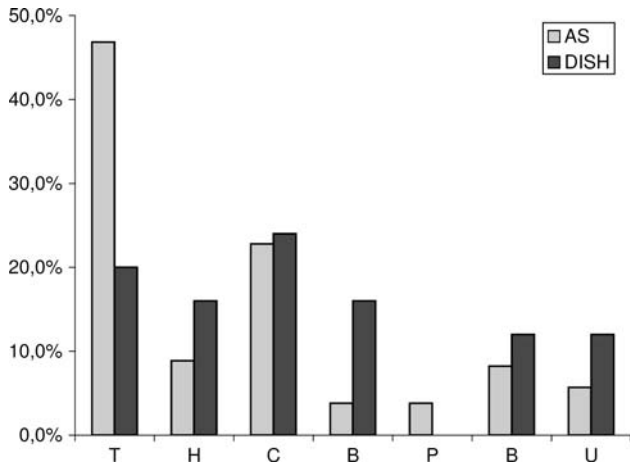

Fig 3 Conservative treatment in AS and DISH patients (based on $n = 345$ in AS and $n = 55$ in DISH). *T* traction, *H* halo frame, *C* collar, *B* brace, *P* plaster jacket, *B* bedrest, *U* unknown

(40.0%). Secondary deterioration of neurological status was observed in 48 patients AS patients (13.9%) and in eight DISH patients (14.5%) in the post-treatment phase (<3 months). In the follow-up phase (≥3 months) three AS patients and one DISH patient showed neurological deterioration. In the majority of cases the definitive treatment (whether surgical or nonoperative) did not influence the outcome of neurological status.

In the surgical group 111 AS patients (59.4%) showed no change in neurological function within the first 3 months, versus 23 DISH patients (76.7%). At follow-up the majority of patients had the same degree of neurological deficit they had in the post-treatment phase; 77 AS patients (73.3%) and 20 DISH patients (90.9%), respectively. Improvement of neurological status was described in 51 AS patients (27.3%) and two DISH patients (6.7%) in the post-treatment phase and in 28 AS patients (26.7%) and in two DISH patients (9.1%) at follow-up. In the conservatively treated patients 126 AS patients (79.7%) and 21 DISH patients (84.0%) demonstrated no change in neurological function during the post-treatment phase, at follow-up this was the case in 79 AS patients (74.5%) and 15 DISH patients (88.2%). In nine AS patients (5.7%) and one DISH (4.0%) patient neurological status improved in the post-treatment phase; at follow up 24 AS patients (22.6%) and one DISH patient (5.9%) showed improvement of neurological function. Overall, surgical treatment seemed to lead to neurological improvement in more AS and DISH patients than conservative treatment; both in the post-treatment phase and at follow-up.

Most patients improved one ASIA scale; this was the case in 36 patients with AS and three patients with DISH. A total of 13 AS patients improved two scales, nine patients improved three scales and in two patients an improvement of four ASIA scales was reported. In DISH patients improvements of only one ASIA scale were observed (see also Tables 5 and 6).

Complications

In seven patients with AS, uncommon complications of spinal fractures were described, such as aortic dissection ($n = 4$) [25, 100, 101, 120], aortic pseudoaneurysm ($n = 1$) [68] and tracheal rupture ($n = 1$) [59]. Most of these complications were lethal ($n = 4$). Besides these uncommon findings, general complications such as postoperative wound infections, deep venous thrombosis, pneumonia and respiratory insufficiency were frequently reported complications in both AS and DISH patients; the latter two complications were common and led to fatal outcome in many cases. In some articles complications (whether fatal or not) may not have been fully reported. Based on the data provided, however, the complication and mortality rate seemed to be higher in conservatively treated patients than in surgically treated patients (see Table 7 for details).

Mortality

The overall mortality in the post-treatment phase was comparable in both study groups; 6.4% in AS versus 7.3% in DISH in the surgically treated patients and 11.3% in AS versus 12.7% in DISH in the nonoperatively treated group. At follow-up the mortality in the surgically treated group was 4.9% for patients with AS and 10.9% for patients with DISH. The mortality in nonoperatively treated patients with DISH was also higher than in AS at follow-up; 7.3 versus 2.6%, respectively. These differences were not statistically significant (see also Fig. 4).

Table 5 Neurological status in patients with AS (based on $n = 345$)

Surgical treatment						
	N/K	A	B	C	D	E
Post-treatment (<3 months)						
N/K		1				
A		**28**	3	1	5	2
B			**6**	4	7	4
C			1	**8**	5	5
D		1	2	3	**23**	15
E		7	1	7	3	**45**
Follow-up (>3 months)						
A		**17**				1
B			**2**		5	
C				**5**	8	2
D					**16**	12
E						**37**
Conservative treatment						
	N/K	A	B	C	D	E
Post-treatment (< 3 months)						
N/K	**1**					
A		**47**				
B			**8**			
C		4		**10**	1	
D		2		2	**27**	8
E		9	1	2	3	**33**
Follow-up (>3 months)						
A		**26**	1	2	1	1
B			**1**	1	3	
C				**1**	8	
D				1	**18**	7
E		1				**33**

Bold values stand for the number of patients in which neurological status was unchanged after treatment, resulting in an ASIA classification that did not alter (so A–A, B–B, C–C etc)

Patients admitted with EMV = 3; therefore ASIA classification could not be assessed

N/K not known

A small number of AS patients died in the acute phase after trauma or intraoperatively as a result of severe complications such as lacerations of the aorta or trachea (see complications). The most frequent cause of death for both study groups, however, was pneumonia and/or respiratory failure; both in the post-treatment phase and at follow-up. The cause of death was not reported in 21 AS patients and in 13 patients with DISH.

Table 6 Neurological status in patients with DISH (based on $n = 55$)

Surgical treatment					
	A	B	C	D	E
Post-treatment (<3 months)					
A	**5**	1			
B					
C			**3**	1	
D	1			**4**	
E	1			3	**11**
Follow-up (>3 months)					
A	**6**				
B		**1**			
C			**2**	1	
D				**3**	1
E					**8**
Conservative treatment					
	A	B	C	D	E
Post-treatment (<3 months)					
A	**5**				
B					
C				**1**	
D				1	
E	2			1	**15**
Follow-up (>3 months)					
A	**1**				
B					
C					
D				**1**	1
E	1				**13**

Bold values stand for the number of patients in which neurological status was unchanged after treatment, resulting in an ASIA classification that did not alter (so A–A, B–B, C–C etc)

Discussion

In the present study a systematic review of the literature was performed to increase the knowledge of treatment, neurological status and complications of patients with an ankylosed spine, due to AS or DISH, sustaining spinal fracture. The study groups were comparable with respect to gender ratio and follow-up duration. The mean age and the number of polytrauma patients were significantly higher in the DISH group than in the AS group. This renders in the authors' opinion direct quantitative comparison of the treatment strategies, neurological outcome and complica-

Table 7 Complications in patients with AS and DISH: number of patients reported (fatal outcome)

Complication	AS		DISH	
	Surgical	Conservative	Surgical	Conservative
Aortic dissection	3 (2)	1 (1)		
Aortic pseudoaneurysm	1			
Cervical myelopathy		1 (1)		
Cardiac arrest	1 (1)	4 (4)		1 (1)
Cerebrovascular accident	4 (3)			
Decubitus	1	2		
Deep venous thrombosis	2			1
Epidural hematoma	7	4	1	
Epilepsy		1 (1)		
Esophago-cutaneus fistula from tracheotomy		1		
Gastrointestinal tract bleeding	1	6		
Hemothorax	1	1	1	1
Heterotopic ossification		1		
Instrumentation failure	33	3	1	
Massive hemorrhage during surgery	3			
Multiple organ failure				1 (1)
Nonunion/pseudoarthrosis		6		
Pneumonia	12 (10)	22 (18)	2	3 (2)
Pulmonary embolus	3 (3)	2 (2)		
Respiratory insufficiency	10 (6)	24 (10)		5 (4)
Septicaemia	2 (1)	2 (2)		
Tracheal rupture		1 (1)		
Wound infection	9	1	1	
Total number reported (fatal outcome)	93 (26)	83 (40)	6	12 (8)
% of total reported patients (% fatal outcome)	27.0 (7.5)	24.1 (11.6)	10.9	21.8 (14.5)

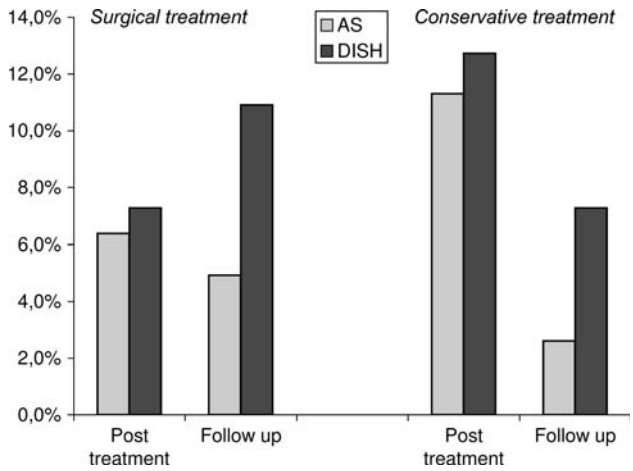

Fig 4 Mortality in AS and DISH patients (based on $n = 345$ in AS and $n = 55$ in DISH)

tions of both groups impossible. Regarding the limited number of papers available; the weak study designs and low level of evidence of all articles, it follows that evidence is rather limited (immediately uncovering a weakness of the present study since it is based on these papers). The absence of adequate follow-up data can be considered the most significant weakness of the majority of papers included and may reflect the remarkably high morbidity/mortality rates of trauma patients with ankylosed spines compared to a 'regular' trauma population. From studies conducted previously to establish the outcome of traumatic spine fracture treatment, it was concluded that sufficient long-term follow-up has invariably been difficult to establish in these cohorts of patients [35, 63]. Some findings of the present study, however, deserve special attention.

The majority of fractures was caused by low energy impacts and was localized in the cervical spine. The cervical region is the most vulnerable part of the spinal column because of increased mobility, small vertebral bodies, oblique articular facets and the mobility of the heavy skull on the cervical spine [103, 129]. Mac Millan et al. [69] stated that traumatic fractures in patients with a partially fused spine tend to occur adjacent to the fused segments, rather than through the fused region itself. Paley et al. [88] also reported fractures to occur at the junction of the mobile and the fused spine. Hendrix et al. [42] found an association between the number of contiguously ankylosed

segments of the spine and increased fracture instability. It can be hypothesized that the biomechanically vulnerable cervicothoracic junction becomes even more susceptible to injury in case of ankylosis since forces can act on longer lever arms.

In patients with AS, both doctor's delay and patient's delay in diagnosis occurred. Patient's delay may have been caused by preexisting back pain not instantly distinguishable from fracture pain. Indeed, in some cases AS patients did not notice any symptoms as a result of fracture until abrupt neurological deterioration occurred [102, 122]. This phenomenon is referred to as 'the fatal pause' because of the delayed development of neurological deficits [20]. The absence of major trauma in the patient's history may also lead to doctor's delay, since spinal fractures will be suspected less after a trivial fall. Furthermore, radiographs of patients with ankylosing spine disorders may be difficult to interpret, due to preexisting pathologic osseous changes [42]. In DISH patients all delayed diagnoses were caused by doctor's delay, possibly because of low awareness for this condition. This low awareness may also be responsible for the limited number of cases reported in the literature.

In patients with DISH the fracture was more often through the vertebral body than through the intervertebral disc (IVD). Some authors have previously suggested that the fracture mechanism may be different for AS and DISH, since AS fractures tend to occur more often at the level of the IVD while DISH fractures tend to occur at the level of the vertebral body [37]. A functional degradation of the IVD because of chondroid metaplasia and loss of elasticity due to calcification of the annulus fibrosis and nucleus pulposus making the IVD the weakest link in the AS affected spine, may contribute to this level dependent fracture configuration [88]. In advanced stages of DISH exuberant bone/calcifications are formed in the anterior longitudinal ligament, especially at the level of the IVD. It is suggested that at this level fractures may develop less easily than through the vertebral body where ligament ossification is minimal. Stress shielding as a result of load transfer through ossified ligaments leading to weakening of the vertebral body may also play a role in DISH fracture initiation and propagation [8]. Unfortunately, fracture patterns were only described in 95 AS patients (27.5% of the total AS group) so no solid conclusions could be drawn on this interesting subject.

The number of patients suffering from a neurological deficit was high in both groups; many patients with AS and DISH were admitted with a degree of neurological deficit. Worsening of neurological function due to inadequate immobilization, inconsiderate transfers or application of a hard collar on the cervical spine with pre-existing kyphotic deformity was reported in several articles [68, 74, 89, 122]. Compared to studies describing (healthy and considerably younger) individuals sustaining traumatic spine fractures where only 0.08% of the patients deteriorated in neurological function, these numbers are of major concern [124]. It is suggested that patients with traumatic fractures of the ankylosed spine are not only susceptible to initial neurological deficit but also to secondary neurological deterioration due to highly unstable fracture configurations between the fused segments [11]. In the absence of a definite stabilization method, transfer and manipulation of these patients should proceed with utmost care.

Different types of complications were reported for patients with AS and DISH. In some articles concerning AS patients, rare complications such as aorta laceration and rupture of the trachea were described. Aortitis is a known complication of AS, in which adventitial scarring, intimal proliferation and fibrous thickening of the aortic wall are commonly seen [25, 123]. Thoracic and lumbar injuries in AS patients may be associated with injury to the aorta either due to direct mechanical trauma or to blunt forces associated with the spinal fracture [100]. However, laceration may be most likely the result of pathophysiological changes that cause the aorta to become firmly adherent to the anterior longitudinal ligament and subject this structure to shearing forces during fracture dislocation [25, 101].

The mortality of surgically treated trauma patients with an ankylosing spinal disorder was high compared to previously healthy individuals with traumatic spine fractures. A total of 17.7% from the cohort of patients with AS and 20.0% from the patients with DISH deceased within 3 months after injury whereas the previously reported mortality in individuals treated surgically for traumatic spinal fractures was only 0.4% [124]. The mortality in the follow-up phase was higher in DISH patients than in AS patients, regardless of type of treatment received. Several authors have stated that advancing age, obesity and diabetes mellitus are associated with higher mortality rates in trauma patients [13, 46, 53, 56, 72, 78, 84]. In addition, some authors have reported the treatment with a halo frame or other immobilization device in elderly patients with cervical fractures to be associated with higher morbidity and mortality rates [47, 71, 115]. Finally, it is also known from the literature that surgery in elderly people is associated with higher rates of morbidity and mortality probably due to preexisting medical conditions [38, 48, 95]. Since DISH has been associated with obesity, type 2 diabetes and advancing age, this could explain the higher mortality [18, 61].

The prevalence of AS is stable and is estimated to be 0.05–1.4% [10]. Studies investigating DISH have found a prevalence ranging from 2.9 to 25% in selected populations [60, 127]. Acknowledging the association of DISH with typical traits of modern affluent societies (obesity and diabetes for example) its prevalence and degree of

expression can be expected to increase during the coming decades, therefore clinicians should be prepared to admit more trauma patients with DISH [18, 61].

Recognizing the limitations of the current study, we suggest the following conclusions can be drawn (Level of Evidence 4; Grade of Recommendation C) [86].

- Patients with an ankylosed spine have an increased fracture risk even after minor trauma.
- Delayed diagnosis of fractures in patients with ankylosing spinal disorders often occur due to both doctor and patient related factors.
- Fractures of the ankylosed spine tend to be unstable, because ossified ligaments and surrounding tissue also fracture.
- An intrinsic unstable fracture configuration may lead to primary and secondary neurological deficit.
- The clinical outcome of patients fracturing their ankylosed spine is worse compared to the general spine trauma population.
- Surgical treatment may be favorable for patients with an ankylosed spine and spinal fracture, as this treatment option may be associated with lower complication and mortality rates and may lead to neurological improvement more frequently.
- The presence of ankylosed spine segments should alert the treating physician for unstable spine fractures in every trauma patient.
- In trauma registries ankylotic conditions of the spine should be registered separately, in order to acquire more knowledge on the patterns and prognosis of these injuries.
- As DISH may be a rapidly increasing condition in affluent societies, awareness of this condition should be raised among physicians assessing trauma patients and treating spinal injuries.

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