Magnetic resonance tomography for the early detection of occult fractures of the spinal column in patients with ankylosing spondylitis

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Abstract

Purpose The purpose of this study was to determine the extent to which magnetic resonance imaging (MRI) performed in patients with ankylosing spondylitis (AS) after low- and no-energy trauma leads to an improved diagnosis and, as a result, to a change in the therapeutic strategy.

Methods All patients with AS, who underwent surgery after minor traumas (low-energy traumas, LETs) and patients without trauma history (NET: no-energy trauma), were retrospectively analysed. The diagnostic and planned surgical procedure was examined initially and again after total spine MRI in patients with persistent and/or new complaints.

Results One hundred and thirty-six patients with AS after trauma were surgically treated. A total of 92 patients with LETs and 12 patients with NETs were included. After initial diagnostics (CT and X-ray) were performed in 15.4% of the patients with LET or NET ($n = 16$), we found occult fractures on MRI scans. In ten of these patients (6 LET, 4 NET) in which a previous decision was made to follow conservative therapy, no fracture indication was found on CT or X-ray. Two fracture heights were observed in six patients who experienced LET. However, on X-ray and CT, the fractures were only visible at one height. All fractures were treated surgically with stabilization and decompression if indicated.

Conclusion Considering the high percentage of our patient population with occult fractures, we recommend supplementing the basic diagnostic procedures with an MRI of the entire spinal column in patients with painful spinal column findings after minor trauma and for those with persistent pain without trauma.

Graphic abstract

These slides can be retrieved under Electronic Supplementary Material.

Keywords Occult fracture · Spinal column · Ankylosing spondylitis · MRI · Imaging

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Introduction

Ankylosing spondylitis in its severe manifestation is associated with a high risk of vertebral body fractures due to ossification of the ligaments. In the literature, there is a four-to-ten

time higher lifetime risk of a person with ankylosing spondylitis being affected by a fracture of the spine compared to a normal cohort [1].

However, the fragility of patients with Bechterew's disease is based on four substantial problems: long lever arm, osteoporosis, sarcopenia, and kyphosis with restriction of the visual axis [2, 10].

The prevalence of vertebral fractures in ankylosing spondylitis is almost 30% with the use of WHO criteria for osteoporosis [5]. Moreover, both low bone mineral density and sarcopenia are found in the early stages of Bechterew's disease [14]. Accordingly, an adequate trauma will lead to subsequent diagnostic assessment with thin-layer computed tomography (CT) if necessary in advance of plain radiographs. In contrast, for the reasons of fragility mentioned above, there is no standard diagnostic procedure for patients who experience a low-energy trauma (LET), and diagnosis is even more challenging for patients who experience a no-energy trauma (NET). However, initially overlooked fractures can lead to pain, secondary dislocations, stenosis, and neurological deficits [16].

In Europe, there is no standard recommendation to perform an initial diagnosis using magnetic resonance imaging (MRI) of the entire spinal column. Furthermore, the current literature contains only a few cases of patients with Bechterew's disease or diffuse idiopathic skeletal hyperostosis (DISH) with occult fractures, and thus, the risk of occult fractures as a consequence remains underestimated [3, 4]. DISH is the only differential diagnosis of Bechterew's disease that is associated with ventral spondylophyte formation. In the literature, however, these two clinical diagnoses are often considered combined or partly overlapping, so data on larger patient collectives are missing.

The objective of this study was to determine to what extent standard MRI of the whole spine performed in our hospital leads to an improved diagnosis in patients with Bechterew's disease after LET or NET and thus leads to a change in the therapeutic strategy.

Materials and methods

For the purpose of the study, we evaluated the data of 136 patients with confirmed Bechterew's disease who required spinal stabilization in a level-one trauma and special spinal care centre between June 2010 and June 2018. All data were collected through a review of consecutive clinical records and imaging files. In addition to demographic data, we evaluated the accident mechanism and injury levels.

The inclusion criteria were as follows:

- Complete data set with X-ray in two planes, MDCT, and subsequent whole body magnetic resonance imaging.

- Patients who were treated without trauma history, so we called this circumstance no-energy trauma (NET).
- Patients who were treated after low-energy trauma (LET) such as falling from a standing or seated position or falling from a height below 1.5 m, was the cause of trauma.

The exclusion criteria were as follows:

Patients who were treated for infections or metastases were excluded from the study. Furthermore, all patients with DISH were excluded. Patients with electronic devices that would prohibit MRI and those who experienced high-energy trauma, falls above 1.5 m, high-energy traumas, bicycle falls, or severe injuries (ISS > 16) were excluded.

All radiographs and MDCT scans were reviewed in detail and compared with the complementary MRI findings. In the MRI, we examined the fractures known from CT or X-rays for the trajectory of the fracture line and searched for possible intraspinal haemorrhages. In addition, we also looked for any other bone bruises, fracture lines, intraspinal haemorrhages, and other dorsal or ventral column injuries that were not apparent in MDCT or X-rays.

Whole spine MRI was performed on 1.5 T and 3.0 Tesla MRI using sagittal T1-weighted turbo spin-echo sequence, sagittal and axial and T2-weighted turbo spin-echo sequence, and sagittal inversion recovery sequences (short tau inversion recovery resp. turbo inversion recovery magnitude).

Furthermore, we analysed whether further surgical procedures were accomplished based on MRI diagnostics, which would not have been performed purely based on radiological diagnostics using thin-layer multidetector CT (MDCT).

Furthermore, we examined the documents to determine whether the occult fractures also corresponded to the clinical examination or anamnesis. Moreover, we analysed the history of other diseases, the patient's spinal fracture classification according to AO Spine, the previously planned and expanded surgical strategies, and the complications during and after surgery.

The study conforms to the Declaration of Helsinki and to local legislation. The study was reviewed and approved by our local ethics committee.

Statistical analyses

Fisher's exact test was applied for categorical data. The level of significance was $p < 0.05$. We utilized the SPSS (Trademark) 20.0 statistics software program (SPSS Inc., Chicago, IL, USA) for Windows.

Results

During the 8-year study period, 136 patients with Bechterew's disease after trauma were treated for spinal trauma. Of these, a total of 104 cases could be included in the study and fulfilled the inclusion criteria. In 92 cases, we found patients with low-energy trauma (LET). In 12 cases, we found no trauma anamnesis, so we called this circumstance no-energy trauma (NET). We excluded 32 cases. In addition, we found that fractures have occurred from falls above 1.5 m in eight cases, high-energy traumas in 21 cases, bicycle falls in one case, severe injuries (ISS > 16) in one case and one patient has an electronic device that would prohibit MRI. The average age was 74 ± 10 years, and the male/female ratio was 7:1.

In 16 cases (15%), occult fractures due to LET or NET were found only in MRI of the entire spinal column. However, these fractures were not visible on the previously performed imaging modalities with conventional X-ray or multidetector computed tomography (MDCT). All patients had pain in one or more regions of the spine.

Conservative therapy was initially indicated in ten patients without findings on MDCT or X-ray; four of these patients had experienced NET, and six had a LET event. The complementary total spine MRI revealed the corresponding occult fracture locations (Fig. 1). All of these with an initial conservative treatment decision had a delay in therapy until MRI and occult fracture detection over 24 h later. During the inpatient course, two patients (Patient No. 6 and 7) with NET developed neurological deficits (ASIA D and C) with spinal haematomas at the corresponding fracture levels.

Fig. 1 A 61-year-old male patient with Bechterew's disease. **a** Lateral X-ray of the cervical spine shows the limited accessibility of the cervicothoracic transition. **b** In the sagittal CT scan, the fracture of HWK seven remains occult. **c** In the sagittal TIRM, the hyperintense fracture line of C7 with involvement of the dorsal column is clearly visible

In six patients with LET, fracture localizations were found at two levels. However, on X-ray and MDCT, these fractures were only visible at one level (Table 2). In addition, MRI showed another undetected fracture in another segment or spinal section (Fig. 2). Of these six cases, four fractures were found in the cervicothoracic region. One patient with secondary occult fracture had neurological deficits upon admission (ASIA C). MDCT showed a fracture at height at T8, but intraspinal bleeding and occult fracture were found at C5/6 (Patient No. 2).

When reviewing the documentation, correlations between pain descriptions and occult fractures were found in 75% ($n=12$) of the patients. In 94% ($n=15$), we located occult fractures in the thoracic and cervical region. Nine of them were located between the fifth cervical vertebra and the fourth thoracic vertebra. As additional information to the MDCT finding, epidural haematomas were found in 37.5% ($n=6$) of patients ($p=0.0002$); three of them had paraplegic symptoms, and the other three patients remained asymptomatic, but all epidural haematomas were decompressed. Accordingly, in patients with two fractures, the surgical procedures were extended to the second segments or heights as appropriate (see Table 3). In all cases, a corresponding instability was observed intraoperatively. There were no patients with three fracture localizations. All patients

underwent open surgery, and the average operation time was 234 ± 99 min. One patient (Patient No. 12) died during surgery due to cardiovascular collapse.

The intraoperative complication rate was 25%. Post-operatively, complications occurred in 56% of cases. The pulmonary system was the most frequently affected.

Information on statistical analyses is shown in Table 1. Demographics, fracture locations, AO classification, epidural bleeding, ASIA classification, other injuries, and concomitant diseases are shown in Table 2. Intraoperative

Table 1 Information on statistical analyses between MDCT and MRI using Fisher's exact test

	MDCT	MRI	Fisher exact test
Occult fracture ($n=16$)			
Detected	6	16	$p=0.0002$
Not detected	10	0	
Occult secondary fracture ($n=6$)			
Detected	0	6	$p=0.0022$
Not detected	6	0	
Epidural haematoma ($n=6$)			
Detected	0	6	$p=0.0022$
Not detected	6	0	

Fig. 2 **a** A 78-year-old ankylosing spondylitis patient with initial lateral C-spine X-ray. **b** Preoperative sagittal CT scan shows injury with facet fracture of Th 8–9. **c** Sagittal TIRM reveals a multilevel cervical and thoracic spine fracture additional fracture of C6–7 (occult in CT scan) with detection of a discrete intraspinal haematoma

Table 2 Data of demographics, fracture locations, AO classification, epidural bleeding, ASIA classification, other injuries and concomitant diseases

No.	Age (y)	Gender	NET: no-energy trauma/LET: low-energy trauma	Findings on CT and plain film	Occult fracture on MRI	Spinal haematoma 1: yes; 2: no	Neurological status	Delayed diagnoses of occult fracture < 24 h	AO classification (subaxial and thoracolumbar)	Other traumatic injury	Concomitant diseases
1	81	m	LET	C6/7	C2	2		Yes	C6/7: type B2 F2 BL N0 M3; C2: type B1 F2 BL N0 M3		None
2	76	w	LET	T8	C5/6	1	ASIA C		T8: type B1 N3 M2; C5/6: type B2 F2 BL N3 M3		Dementia, diabetes, hypertension
3	47	m	NET	No fracture	C5/6	2		Yes	C5/6: type B2 F2 BL N0 M3		None
4	81	m	LET	T12	L2	2			T12: type B1 N0 M2; L2: type B3 N0 M2		Diabetes, hypertension, atrial fibrillation
5	76	w	LET	T12/L1	C7/T1	1			C7/T1: type B3 F2 BL N0 M3		Hypertension
6	82	m	NET	No fracture	T5/6	1	ASIA D	Yes	T5/6: type B2 N3 M2		Hypertension
7	84	m	NET	No fracture	C5/6	1	ASIA C	Yes	C5/6: type B2 F1 BL N3 M3		Diabetes, atrial fibrillation
8	77	m	LET	T10/11	C6/7	2			T10/11: type B2 N0 M2; C6/7: type B2 F2 BL N0 M3	Pneumothorax	Hypertension, atrial fibrillation
9	75	m	NET	No fracture	T12	2		Yes	T12: type B1 N0 M2		COPD
10	86	m	LET	No fracture	T10	2		Yes	T10: type B1 N0 M2		Dementia, diabetes, renal insufficiency, gout
11	60	m	LET	No fracture	T7	2		Yes	T7: type B2 N0 M2	Intracerebral bleeding	None
12	74	m	LET	No fracture	T8	2		Yes	T8: type B1 N0 M2		None
13	80	m	LET	No fracture	C6/7	1		Yes	C6/7: type B3 F2 BL N0 M3	Rib fracture	Asbestosis
14	62	m	LET	No fracture	C5/6	1		Yes	C5/6: type B2 F2 BL N0 M3		None

Table 2 (continued)

No.	Age (y)	Gender	NET: no-energy trauma/LET: low-energy trauma	Findings on CT and plain film	Occult fracture on MRI	Spinal haematoma 1: yes; 2: no	Neurological status	Delayed diagnoses of occult fracture < 24 h	AO classification (subaxial and thoracolumbar)	Other traumatic injury	Concomitant diseases
15	74	m	LET	T4	C6/7	2			T4: type B1 N0 M2; C6/7: type B3 F2 BL N0 M3		Hypertension, atrial fibrillation, renal insufficiency
16	71	m	LET	No fracture	C6/7	2		Yes	C6/7: type B3 F2 BL N0 M3		None

and post-operative complications, surgery duration, instrumented levels, and complications are shown in Table 3.

Discussion

Over the decades, several case series and articles have reported on the difficulty of identifying vertebral body fractures in patients with Bechterew's disease [9]. For various reasons, fractures in a patient with Bechterew's disease can be overlooked.

First, back pain is a symptom of the disease [16]. Second, fractures are frequently undetected on conventional X-ray images [2]. Furthermore, compression fractures are rarely obvious, especially when the ligaments have already become severely ossified. Additionally, there are often atypical fractures, such as fractures of the dorsal arch and its pedicles [15].

In our study, we found occult fractures almost exclusively in the cervical and thoracic spinal levels. In a cohort study [11], the thoracic region using conventional X-rays was found to be a region with very poor imaging quality. Analogously, we know that the cervicothoracic region (C5–T4) is also very difficult to visualize radiologically and that additional imaging is generally required here. A correlation between the painful spinal region and an occult fracture was only found in 75% of the cases presented here. We do not know why no pain was reported in the other 25% of the patients. However, in these 25%, the occult fractures were located in the cervicothoracic region.

Due to its high instability, fractures that occur in the spinal column of a patient with ankylosing spondylitis are classified by AOSpine in B- and C-type injuries with M2 or M3 modifiers for the thoracolumbar and subaxial regions, respectively, and should be surgically stabilized [12]. Whenever feasible in our clinic, every patient with Bechterew's fracture underwent surgery, and we tried to avoid conservative treatment, as it results in a worse prognosis. In addition, there is a tenfold increased risk of spinal cord injury in patients with Bechterew's disease than in the unaffected population [1]. Moreover, Robinson et al. [13] demonstrated that surgical stabilization improves the survival prognosis compared to conservative therapy.

Even a fall from standing can result in unstable fractures of the spinal column. The risk of developing a blood-related neurological deficit is high and is described in the literature to be between 29 and 91% [3]. The results of our cohort showed how difficult it can be to determine an exact diagnosis be based only on the gold standards of CT and X-ray.

Epidural haematomas were found on MDCT in 37.5% of the patients ($n=6$), three of them with paraplegic symptoms. In our analysis, we performed CT in four patients without a contrast agent. However, no epidural haematoma was visible

Table 3 Results of intraoperative and postoperative complications, surgery duration, instrumented levels and complications

No.	Dorsal stabilization planned on the basis of MDCT and X-rays	Extended therapy with dorsal stabilization after MRI	Intraoperative complications	Surgery time (min)	Post-operative complications
1	C4–T4	C0–T2	None	351	Delirium
2	T6–T11	C3–T1	None	191	Pneumonia, anaemia, deep wound infection
3	Conservative	C3–T2	Acute liver failure, compartment syndrome	536	Pneumonia, sepsis, renal insufficiency
4	T10–L3	T10–L5	Nerve root avulsion	175	Circulatory instability, requires dialysis
5	T10–L3	C5–T3	None	287	Pneumothoraxes
6	Conservative	T3–T8	None	183	None
7	Conservative	C3–T1	None	148	None
8	T8–L1	C4–T2	Bleeding	237	Acute renal insufficiency
9	Conservative	T10–L3	None	322	None
10	Conservative	T8–L1	None	188	Respiratory insufficiency
11	Conservative	T5–T10	None	187	None
12	Conservative	T5–T11	Reanimation with death	189	None
13	Conservative	C3–T3	None	155	None
14	Conservative	C4–T2	None	203	Pneumonia
15	T1–T7	C4–T7	None	217	None
16	Conservative	C3–T3	None	176	Thrombosis

in the other two patients. The reason may be that the MRI scan was performed at least 24 h after the CT scan, and intraspinal bleeding may exhibit better contrast over that period.

There are several reasons why the significance of MRI may be limited. Notably, the long delay between the onset of symptoms and a diagnosis with less fluid intensity in the fracture region is especially noteworthy [7]. Furthermore, the use of a fat-suppressed sequence is more sensitive on magnetic resonance tomography (MRT). Wang et al. [15] demonstrated good visualization of the fracture elements and fracture lines using CT but showed limitations in the evaluation of the posterior elements in Bechterew's patients with fracture of the spinal column.

Anderson lesions, called shiny corners in conventional radiological imaging, are a process that occurs when the anterior ligament is ossified. Some of these are also interpreted as chronic fractures and can also lead to misinterpretations in diagnosing occult fractures. Additional imaging with CT and MRI is always indicated in patients with persistent pain [15].

In the opinion of the authors, the positioning of patients during CT examinations is an important factor. Fixation on a straight spine board in the kyphotic spine tends to lead to an opening of the fracture. Long-term experience has shown an improvement in acute pain in patients with Bechterew's disease by closing the fracture gap, thus restoring the original alignment. In addition, the positioning of the patient on

the examination table may influence the fracture detection ability of CT imaging.

There are two case reports in the literature in which neither a single detector CT nor an MRT evaluation could provide precise fracture findings. Only MDCT permitted visualization of the occult fracture. However, indirect signs of bleeding into the spinal canal and acute intraparenchymal signal changes on MRI were observed at the painful and suspected spinal level [6]. Nevertheless, in this cohort, MDCT was performed in all cases, and unstable fractures were not detected in 15% of the overall cohort. In contrast, Khurana et al. reported that MRI imaging of the total spine provided additional fracture-related information outside of the focused zone at three segment heights above and below the known fracture site in 15% of the cases. In none of the cases did these findings lead to a change in the surgical strategy [8].

Limitations of the study are numerous. This study is retrospective and analyses a specific clinical condition. There was no comparison group. The patient age of 74 years is very high compared to that in other studies. In one of the largest reviews, the average patient age was 59.1 years [16].

However, despite the limitations of the study, the authors recommend performing a standard MRI diagnostic of the whole spine in all patients with Bechterew's disease even in the presence of a MDCT for the following reasons:

- First, we showed that even on MDCT, a high proportion (15%) of fractures could not be detected.
- Second, there is a high percentage of osteoporosis in this patient population for whom MRI is generally recommended.
- Third, due to the known delayed detection which may lead to a worsening of the symptoms. In our patient population this has been demonstrated by three patients with incomplete paraplegia.
- Fourth, there is a risk of intraspinal bleeding in this patient population due to the accompanying comorbidities, particularly cardiovascular diseases, which lead to the intake of blood thinners in the majority of patients.

Conclusion

The gold standard imaging modality for detecting fractures in patients with ankylosing spondylitis, in particular Bechterew's disease, is CT along with classical radiological imaging. In this study, the surgical procedure was adjusted, and the corresponding segments were stabilized when secondary occult fracture was discovered. In addition, occult fractures detected by MRI in patients without imaging information after CT and X-ray were also stabilized and if necessary, an epidural haematoma in the region was decompressed immediately.

If patients with Bechterew's disease who experience NET or LET are suffering from acute back pain, even without trauma, it is always recommended to proceed to the assumption of a fracture until it is safely excluded. In addition to the basic diagnostics with X-rays and MDCT of the painful region, we recommend prompt MRI of the entire spinal axis (possibly only a fat-suppressed sequence is needed) due to the risk of overlooking non-dislocated fractures on MDCT. Moreover, MRI indicates that intraspinal pathologies are more reliable in this study. In addition, patients with high-energy traumas now also receive this imaging diagnostic element.

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Compliance with ethical standards

Conflict of interest None of the authors has any potential conflict of interest.

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