Ankylosing Spinal Disease—Diagnosis and Treatment of Spine Fractures

Martin Vazan[1,2], Yu-Mi Ryang[1], Melanie Barz[1], Elisabeth Török[1], Jens Gempt[1], Bernhard Meyer[1]

■ BACKGROUND: **In patients with ankylosing spinal disease, including ankylosing spondylitis and diffuse idiopathic skeletal hyperostosis, even low-impact trauma can lead to complex injuries. The injuries seem to be highly unstable and associated with greater mortality rates compared with the general spine trauma population.**

■ METHODS: **We reviewed the medical records of a consecutive series of 41 patients (34 men, 7 women) with ankylosing spinal disease and unstable traumatic spine injuries who were admitted to our department from 2007 to 2016.**

■ RESULTS: **The mean patient age was 73.4 ± 12.7 years. Of the 41 patients, 24 (58.5%) had ankylosing spondylitis and 17 (41.5%) had diffuse idiopathic skeletal hyperostosis. Low-velocity accidents were documented in 38 patients (92.7%). The most frequent injuries were type B spine fractures (61.0%). Accompanying spinal epidural hematoma was detected using magnetic resonance imaging in 12 patients (29.3%) but was not found by radiography or computed tomography. Of the 41 patients, 24 (58.5%) presented with American Spinal Injury Association impairment scale (AIS) grade E, 6 (14.6%) with grade D, and 8 (19.6%) with grade C or worse. All the patients had undergone internal fixation. All but 1 (97.6%) had received posterior fixation. In 25 (61%), a combined approach was performed. Five patients died of early complications. Of the 36 discharged patients, 11 died during the follow-up period and 1 was lost to follow-up. The surviving 24 patients had a median follow-up of 733 ± 576 days; 21 had AIS grade E, 2 had AIS grade D, and 1 had AIS grade C.**

■ CONCLUSIONS: **A thorough diagnostic evaluation with multislice computed tomography and magnetic resonance imaging can reveal injuries that would remain undetected on conventional radiographs. A combined approach or posterior-only fixation seems safe.**

INTRODUCTION

Ankylosing spondylitis (AS) and diffuse idiopathic skeletal hyperostosis (DISH) are ankylosing spinal diseases (ASDs) that, ultimately, lead to both increased spinal rigidity and decreased impact resistance.[1] The prevalence of AS has been 0.1%—1.4%. The first manifestation usually occurs in the third decade of life. Men have been more commonly affected than women.[2] The prevalence of DISH has ranged from as low as 2.9% in the Korean population and 10.8% in Japanese patients to >30% in selected populations such as Dutch men aged >80 years (32.1%) or American Midwestern men aged >70 years (35%).[3-6] Several studies have shown a greater risk of DISH in patients with type 2 diabetes mellitus, older age, and greater body mass index.[5,7] In patients with ASD, even low-impact trauma can lead to complex injury patterns. Most spinal injuries will show fracture lines through all 3 columns and will be highly unstable. Furthermore, spine fractures in patients with DISH have been associated with greater mortality rates compared with those in the general spine trauma population.[8]

Key words
- Ankylosing spondylitis
- AS
- Diffuse idiopathic skeletal hyperostosis
- DISH
- Spine fracture
- Spinal fusion

Abbreviations and Acronyms
AIS: American Spinal Injury Association impairment scale
AS: Ankylosing spondylitis
ASD: Ankylosing spinal disease
CCI: Charlson comorbidity index
CT: Computed tomography
DISH: Diffuse idiopathic skeletal hyperostosis
MRI: Magnetic resonance imaging
PMMA: Polymethylmethacrylate
sEDH: Spinal epidural hematoma

From the [1]Department of Neurosurgery, Klinikum rechts der Isar, Technical University Munich, Munich; and [2]Department of Orthopaedics, Municipal Hospital Dresden, Academic Teaching Hospital of the Technical University of Dresden, Dresden, Germany

To whom correspondence should be addressed: Martin Vazan, M.D. [E-mail: martin.vazan@gmail.com]

Martin Vazan and Yu-Mi Ryang contributed equally to this work.

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Diagnostic Protocols

Conventional radiographic imaging has proved to be of low sensitivity in detecting nondislocated fractures in patients with AS and DISH. Up to 59.4% of fractures in the ankylosed cervical spine will remain undetected using plain radiographic imaging.[9] Therefore, the routine inclusion of multimodal imaging, including computed tomography (CT) and magnetic resonance imaging (MRI), in the diagnostic protocol should be advocated.[10]

Treatment

These injuries mandate complex vertebral column reconstruction as a single- or 2-stage procedure, because external fixation is rarely feasible and will increase overall mortality.[11-13] The highly altered bony structure and anatomy with the near to nonexistent landmarks means that even comparably simple tasks such as posterior pedicle screw fixation without the use of spinal navigation become very demanding. Therefore, image-guided spinal navigation can provide a significant advantage.[14,15]

Morbidity and Mortality Rates

As much as 81% of these patients will present with ≥1 and 54% with ≥2 major medical comorbidities.[16] Up to 67.2% of these patients can experience neurological deficits.[13] Additional complications can include life-threatening injuries such as blunt aortic lesions or, even, lacerations.[17,18] The overall mortality rates have ranged from 6.4% to 60%.

Purpose

The purpose of the present study was to analyze the results and optimize our diagnostic and treatment protocols.

METHODS

Patient Population

We reviewed the medical records of a consecutive series of 41 patients (34 men and 7 women) who had been admitted to our department from January 2007 to March 2016. These patients had an ankylosed spine and had experienced unstable traumatic spine injuries detected by CT and/or MRI. Of the 41 patients, 24 (58.5%) fulfilled the modified New York criteria for AS and 17 had DISH. The mean patient age at surgery was 73.4 ± 12.7 years (range, 45–92).

Diagnostic Routine

All patients underwent baseline physical and neurological examinations on admission. The imaging routine included a spiral CT scan of the entire spine. Additional MRI, including sagittal T2-weighted and short-TI-weighted inversion recovery images of the entire spine, was performed in 34 patients (82.9%). The main reason for performing MRI in these patients was, not only to assess the extent of the spine injuries detected on CT, but also to detect any additional spine injuries undetected by the CT evaluation. In 7 patients, MRI could not be performed because of the presence of either MRI-incompatible cardiac pacemakers or defibrillators or acute hemodynamic instability.

Radiological Assessment

The radiological assessment was performed using the institutional picture archiving and communication system. The new AO fracture classification was applied.[19]

Statistical Analysis

Statistical analysis was performed using SPSS, version 21.0, for Mac (SPSS Japan Inc., Tokyo, Japan). The Student *t* test was used to compare the continuous variables, and statistically significant differences were accepted at $P < 0.05$.

RESULTS

Radiological Classification

The most frequent injuries were type B spine fractures ($n = 25$; 61.0%; Figure 1), followed by type C ($n = 15$; 36.6%) and type A ($n = 1$; 2.4%). One patient (2.4%) developed a type II traumatic odontoid fracture.

Accompanying Injuries

Of the 41 patients, 12 had 15 additional injuries, including 5 traumatic brain injuries, 2 femoral fractures, 2 clavicular fractures, 1 shoulder luxation, 1 radius fracture, 1 nose fracture, 1 maxillary fracture, 1 serial rib fracture, and 1 humerus fracture.

Neurological Status

Of the 41 patients, 24 (58.5%) presented with American Spinal Injury Association Impairment Scale (AIS) grade E (58.5%), 6 with AIS grade D (14.6%), 2 with AIS grade C (4.9%), 2 with AIS grade B (4.9%), and 4 with AIS grade A (9.8%). In 3 patients (7.3%), the neurological status could be not established, because they had Glasgow coma scale score of 3 on admission. One of the patients required stabilization hemodynamically and was assessed as AIS grade C before surgery.

Medical Comorbidities and American Society of Anesthesiologists Scale Scores

The 41 patients had a mean Charlson comorbidity index (CCI) of 3.6 ± 2.3 (range, 1–10). Adjusted for patient age, the mean CCI was 5.9 ± 2.8 (range, 1–12). The mean American Society of Anesthesiologists scale score was 2.7 ± 0.7 (range, 2–4). The median American Society of Anesthesiologists scale score was 3 ± 0.7 (range, 2–4).

Injury Level

We found 42 distinct injuries in the 41 patients, with 1 patient exhibiting both a type B fracture at the C6 level and a type C/A3 injury at the T2-T3 level. Although the vast majority ($n = 31$; 73.8%) of fractures were located in the cervical spine, 10 (23.8%) were located in the thoracic spine, with only 1 (2.4%) in the lumbar spine.

Injury Mechanism

Of the 41 patients, 39 (95.12%) reported a recent history of trauma, 1 denied any traumatic event (2.4%), and 1 patient (2.4%) had an unclear history because the patient had had a Glasgow coma scale score of 3. Of the 39 trauma cases, only 1 (2.4%) had been a

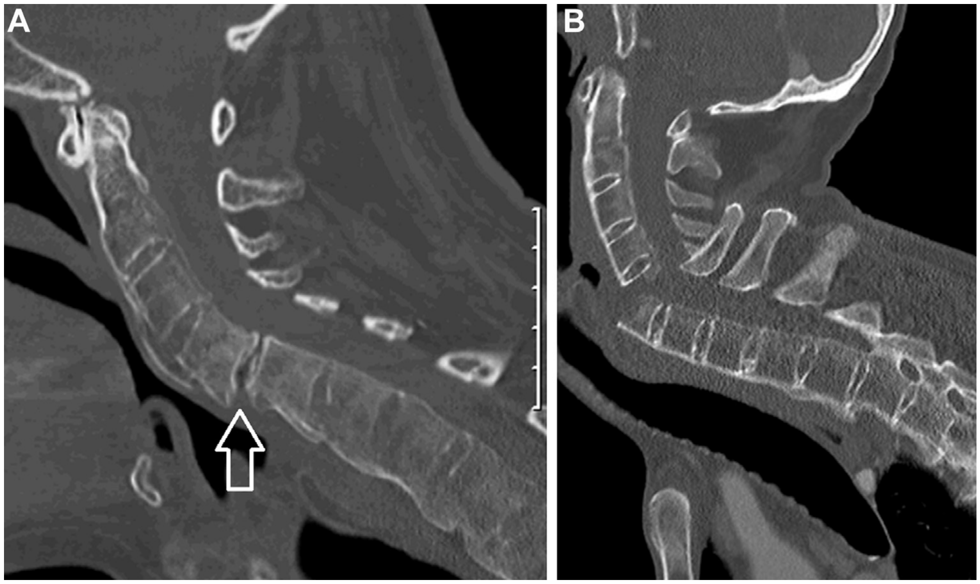

Figure 1. Imaging studies showing AO spine (**A**) type B3 injury and (**B**) type C3 injury. *Arrow* indicates fracture line.

high-velocity motorcycle accident. The remaining 38 were all low-velocity falls.

Accompanying Spinal Epidural Hematoma

Accompanying spinal epidural hematoma (sEDH) was detected by MRI in 12 patients (29.3%; Figure 2). sEDH was diagnosed in 60% of those with type C fractures (9 of 15 cases). Of the 25 patients with a type B fracture, only 3 (12%) showed sEDH. No sEDH was associated with type A fractures. All patients with sEDH presented with neurological deficits, and the sEDHs were evacuated surgically by laminectomy.

Dural Tear

Two patients (4.8%) had experienced traumatic dural tears, which were repaired during posterior surgery.

Surgical Treatment Strategy

All injuries were treated surgically according to our institutions standards.

Treatment Strategy for Cervical Spine. Of the 31 patients with cervical injuries, 12 (38.7%) had undergone primary anterior surgery with decompression, fusion, and plating. A primary anterior approach (Figure 3) was chosen in cases of compressing bony/disc fragments or epidural hematoma compressing the spinal cord from the anterior. In 5 of these 12 patients, anterior vertebral corpectomy and vertebral body replacement was required to achieve solid fusion. The remaining 7 patients were treated with anterior cervical decompression and fusion with a polyetheretherketone cage and multilevel anterior plating that included the operated level plus, where possible, 1 additional level cranially and caudally to prevent secondary fracture dislocation in these highly unstable fractures.

All 12 patients who had undergone primary anterior surgery received a rigid cervical collar to be worn daily 24 hours/day until additive posterior fixation could be performed. Of the 12 patients, 11 (91.7%) had also received supplementary posterior stabilization with pedicle and/or lateral mass screw fixation. However, the anterior plate failed (Figure 4) in 1 patient before the posterior surgery could be performed. The patient's status deteriorated from AIS grade E to grade C after plate dislocation, and the patient required posterior fixation, followed by anterior revision surgery (Figure 5). His neurological deficit did not improve. One patient was not fit for additive posterior surgery. Because of a history of severe cardiac and pulmonary disease, the patient could not tolerate surgery in the prone position. The patient was treated with a rigid cervical collar for 6 weeks and recovered fully.

The remaining 19 patients with cervical injury (61.3%) were treated by primary posterior instrumented fusion using pedicle or lateral mass screw fixation or a combination of both. Ten of them (52.6%) had received additive anterior fusion and plating because adequate realignment of the fracture ends was not possible during the posterior surgery.

Treatment Strategy for Thoracic/Lumbar Spine. All 11 patients with thoracic/lumbar injuries had undergone primary posterior instrumented stabilization with internal pedicle screw fixation. In 4 patients (36.4%), additional anterior fusion was necessary because adequate realignment and/or approximation of the fracture ends could not be achieved by posterior surgery alone. In 7 patients, no additional anterior surgery was necessary, because adequate repositioning of the fracture and alignment of the fractured segment could be achieved by posterior surgery alone.

Figure 2. Magnetic resonance imaging (short-TI inversion recovery) study of cervical spine showing epidural hematoma at C5-C6, with the fracture line at C6. *Arrow* indicates sEDH.

Posterior Surgery Technique—Cervical, Thoracic, and Lumbar Spine. The instrumentation was inserted using either a midline approach ($n = 38$; 95.0%) or a minimally invasive percutaneous technique ($n = 2$; 5.0%). Depending on the fracture level and bone quality, long-segment instrumentation was performed ≥2 levels above and below the fracture location (**Figure 6**). The only exception to this standard was surgery for an odontoid fracture, in which a short C1-C2 construct using the Harms-Goel technique was implanted. All 149 lateral mass screws were placed using a freehand technique under lateral fluoroscopic guidance. A total of 108 pedicle screws were placed using 3-dimensional image-guided navigation in 17 procedures, and 99 pedicle screws were implanted using a freehand technique. Pedicle screw augmentation was performed in 4 patients with ready-to-use polymethylmethacrylate (PMMA) bone cement, with 1.5–2.0 mL of PMMA applied per screw.

Posterior decompression via laminectomy was performed if the spinal canal was compromised by >30% by a fracture fragment or if an epidural hematoma and/or neurological deficits were present. Posterior or posterolateral fusion with autologous bone or synthetic β-tricalcium phosphate graft was performed in all but the percutaneous procedures.

Figure 3. Radiograph of cervical spine with anterior plating and pedicle screw fixation.

Anterior Surgical Technique—Cervical Spine. Anterior cervical interbody fusion was performed using the modified Smith and Robinson technique. The fracture zone was cleared. The spinal canal and dural sac were inspected in 19 of 21 anterior procedures. Of the 21 patients, 14 required an additive interbody fusion with a polyetheretherketone cage or bone graft. In 5 patients, anterior corpectomy and fusion with a vertebral body replacement were necessary to reconstruct the anterior column. Two patients with nondislocated fractures required anterior plating only, without interbody fusion. Long-segment anterior plating was performed where anatomically possible to increase the construct rigidity (10 of 21 patients).

Anterior Surgical Treatment—Thoracic and Lumbar Spine. A mini-thoracotomy or a lateral retroperitoneal approach was performed for anterior surgery of the thoracic and lumbar spine. The fracture zone was cleared of loose material and an expandable cage or autologous bone graft was inserted in the fracture zone. The

Figure 4. Computed tomography scan showing secondary dislocation of the anterior plate.

needed endplate angulation was measured on the preoperative imaging studies and confirmed by intraoperative fluoroscopy. After securing the distracted cage, a chest tube was placed in the patients undergoing thoracotomy, and the wound was closed in the usual manner.

Surgical Adverse Effects

Eight surgical adverse events occurred in 7 patients (17.1%), with 1 (2.4%) intraoperative pulmonary artery embolism from PMMA screw augmentation that required severe cardiac decompensation and resuscitation. Four patients experienced posterior wound healing disorders (9.7%) that required surgical revision. One medially displaced lateral mass screw (Gertzbein and Robbins grade 2) was revised. We observed 1 vertebral artery occlusion due to a Gertzbein and Robbins grade 3 breach of a cervical pedicle screw.[20] One patient experienced ultra-acute anterior plate dislodgement on the third postoperative day before the already scheduled additive posterior surgery. The single-level plate was corrected to a 3-level plate after the posterior fixation had been completed.

Medical Adverse Effects

A total of 23 distinct medical adverse events occurred in 16 patients (39.0%). In 12 patients (29.3%), pneumonia was diagnosed and treated. Five patients (12.2%) showed protracted weaning and required tracheotomy. Two patients (4.9%) developed acute renal failure and required hemodialysis. Another 2 patients (4.9%) experienced urinary tract infections. Two patients developed cardiac insufficiency and required intervention by the department of cardiology.

Length of Hospital and Intensive Care Unit Stays

The average length of hospital stay was 22.6 ± 16.0 days (range, 4–70). The mean intensive care unit stay was 11.7 ± 16.7 days (range, 0–63).

Intrahospital Mortality

Five patients (12.2%) died during the hospital stay of cardiopulmonary adverse events. One patient died of a lung artery embolism, 2 of severe hypotension related to intraoperative bleeding, and 2 of decompensated chronic heart failure.

Postoperative Neurological Status

In 28 of 41 patients (68.3%), the neurological status remained unchanged: 20 had AIS grade E, 5 had AIS grade D, 2 had AIS grade C, and 1 had AIS grade A. Five patients (12.2%) improved

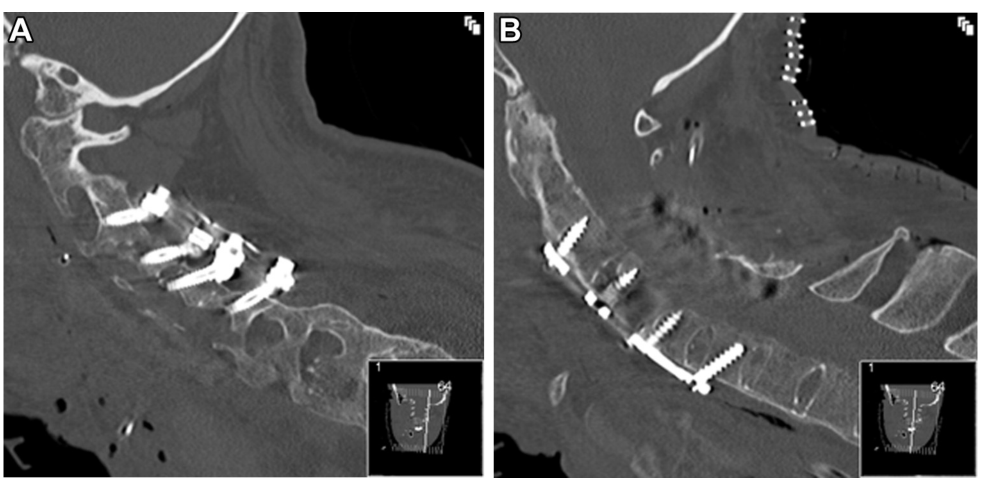

Figure 5. (**A, B**) Computed tomography scans showing the realigned spine after posterior fixation and anterior revision.

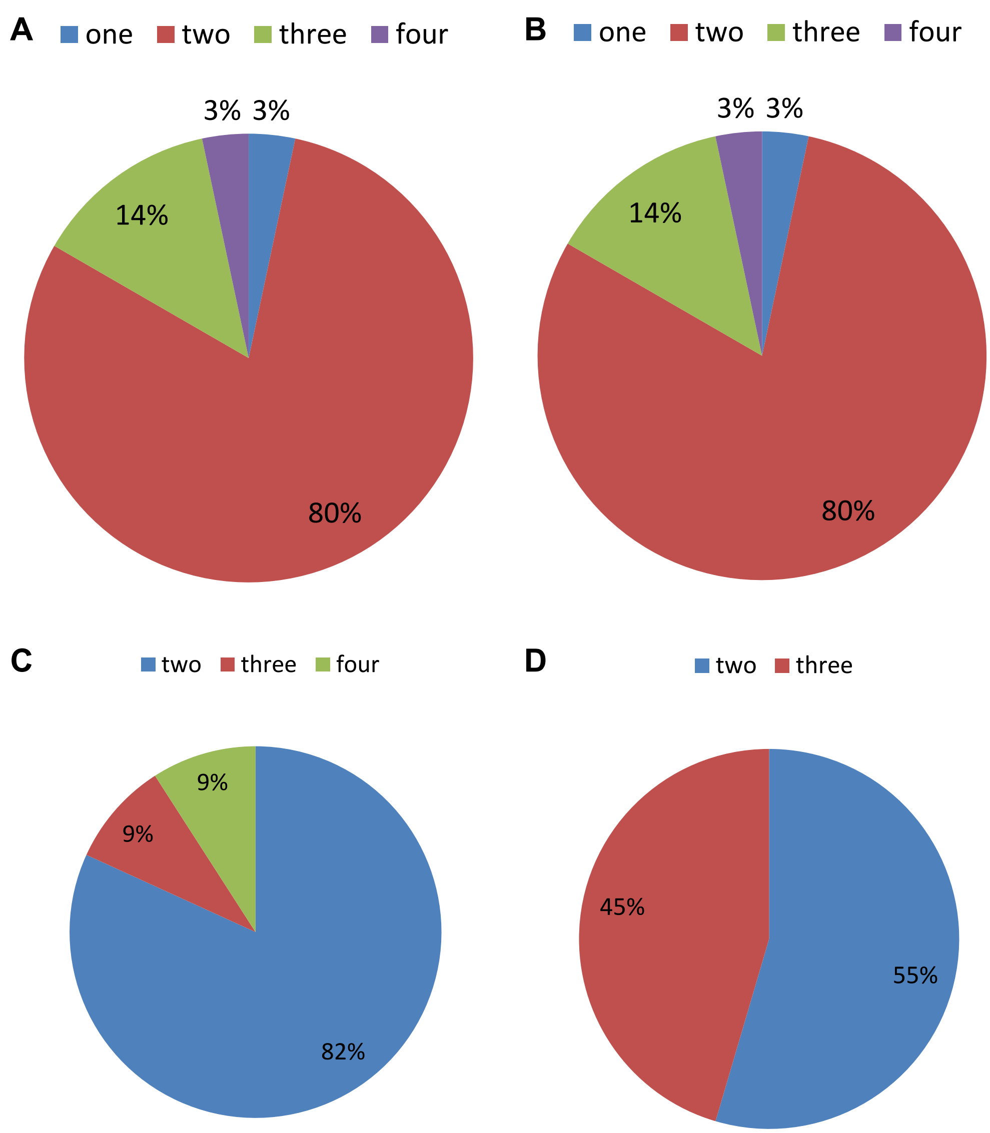

Figure 6. Graph showing number of instrumented vertebrae (**A**) above and (**B**) below fracture in cervical spine. Graph showing number of instrumented vertebrae (**C**) above and (**D**) below in thoracolumbar spine.

by ≥1 AIS grade (2 from grade B to C, 1 from grade A to C, 1 from grade C to D, and 1 from grade D to E). Neurological deterioration occurred in 3 patients (1 by 2 AIS grades from grade E to C without recovery; and 2 by 1 AIS grade from grade E to D with full recovery during follow-up). The 5 patients who died were cardiopulmonary unstable and were not able to undergo a postoperative neurological examination.

Follow-Up

Of the 36 discharged patients, 11 died during the follow-up period and 1 was lost to follow up. We were not able to ascertain whether the deaths were related to the trauma. The surviving 24 patients had a median follow-up period of 733 ± 576 days. Of these 24 patients, 21 had AIS grade E, 2 had AIS grade D, and 1 had AIS grade C.

DISCUSSION

Trauma Mechanism

Although Balling and Weckbach[21] reported high-energy trauma as a leading cause of fractures in patients with DISH, Westerveld et al.[13] cited low-energy trauma as the most common cause of fractures in their review (65.8% for patients with AS and 69.1% for those with DISH). In our study, low-energy impact (ground falls) was the leading cause of injury (95.12%).[13,21] Caron et al.[16] also reported ground-level falls as the most frequent cause of injury.

Diagnostic Protocol

The routine imaging studies for trauma in patients with ASD include CT and whole spine MRI at our institution to detect additional nondislocated CT-occult fractures that can easily be missed and to detect spinal cord injury or sEDHs.[22] This protocol could be completed in 80.5% of the patients in the present study. Eight patients had undergone only a CT scan because of potentially MRI-incompatible implants (cardiac pacemakers or defibrillators) or cardiopulmonary instability on admission. The average CCI for these patients was significantly greater than that for the patients who were able to undergo both MRI and CT (5.88 vs. 2.84; $P = 0.0051$). This routine is consistent with the recommendation of other investigators advocating a routine multimodal imaging.[10] MRI has been proved to have excellent sensitivity for discoligamentous and osseous spine lesions.[23] Another benefit of MRI is the easy identification of sEDHs.[24]

Accompanying sEDH

Epidural hematomas were diagnosed in 12 patients using MRI (29.3%). We found a fivefold increased risk of sEDH with type C (60%) compared with type B (12%) spinal injuries ($P = 0.0008$). This seems quite high compared with the review by Westerveld et al.,[13] who pooled the data from 345 patients and found epidural hematomas in only 3.5% of the patients. Other investigators have reported epidural hematoma rates of 4.4%–7.8%.[16,21] Because the investigators did not describe their diagnostic protocol, it is unclear whether MRI was routinely performed in these studies. These reported rates, therefore, might have grossly underestimated the rate of sEDH, because sEDH usually remains undetected using CT. In our series, none of the sEDHs had been identified using CT alone. Detection of epidural hematomas, however, is crucial, because they can lead to secondary neurological deterioration, with devastating effects.[25]

Injury Level

Although the vast majority ($n = 31$; 73.8%) of fractures were located in the cervical spine, almost one quarter (10; 23.8%) were located in the thoracic spine, with only 1 located in the lumbar spine (2.4%). These findings are in line with the reported data. Cervical spine injuries were the most frequent, followed by thoracic and lumbar injuries. Up to 81.2% of patients with AS and 60.0% of patients with DISH had experienced cervical spine fractures. However, thoracic spine injuries were less frequent (DISH, 34.5%; AS, 10.7%). Lumbar spine fractures were rare (AS, 7.8%; DISH, 5.5%).[13]

Radiological Classification

In our population, the most frequent injury was a type B fracture according to the AO classification (60.1%). Hyperextension or hyperflexion has been cited as the leading trauma mechanism in ASD, with a reported rate of ≤89.9%.[13,16] Our finding of type C fractures (36.6%) was high compared with the rates reported by other studies (5.4%–34.9%). Only a few fractures were type A (2.4%). This was also consistent with the reported data.[8,13]

Surgical Timing

The median interval from trauma to the first surgery was 7 ± 43 days (range, 1–200). This seems rather long, but most of our patients had been referred to our department from other primary care hospitals. In the case of neurological deficits, patients underwent diagnostic studies and surgical treatment within 24 hours of admission in accordance with our institutional policy. Anwar et al.[9] reported that only 15.6% of their patients with ASD and spinal injuries had reached a hospital immediately. However, the treatment delay often results in secondary neurological deterioration and results in a worse prognosis.[26-28]

Treatment Strategy—Cervical Spine

Anterior plating resulted in a fusion rate of 87% when treating type B cervical injuries in patients without spondylarthrosis.[29] However, in the ankylosed spine, it seems prone to failure, with a failure rate of 45.5% reported by Einsiedel et al.[27] Some investigators have preferred a posterior-only approach instead of a combined posterior to anterior or anterior to posterior approach.[12,27] If adequate fusion can be achieved posteriorly, a posterior-only approach would seem valid.[30]

Treatment Strategy—Thoracic and Lumbar Spine

Most investigators have favored posterior pedicle screw fixation with posterior graft apposition.[31] With diminished bone quality, the use of screw augmentation with PMMA should be evaluated carefully owing to the risk of pulmonary cement embolism. This is especially true for long-segment thoracic fixation and patients with ASD who often experience significant restriction of pulmonary function owing to the disease-inherent stiffness of the rib cage.[32] Some have advocated long-segment posterior fixation with instrumentation of ≥3 levels above and below the thoracic or lumbar injury.[16] Finally, reports of percutaneous and hybrid techniques have been increasing.[33-35]

Mortality

We observed a relatively low (12.2%) mortality during the hospital stay compared with the reported data (8%–60%).[8,16,21,27,31] Nonoperative treatment, in particular, has been associated with a mortality rate of ≤51%.[16] We observed no deaths for patients aged <70 years. However, the mortality rate was 11.1% for patients in their 70s. Of our 17 patients aged ≥80 years, 4 had died during the hospital stay, for a 23.5% mortality rate in this age group. Thus, mortality seems to be age dependent, with a reported mortality of 38% for patients in their 70s and 84% for those their 80s.[16]

Of our 41 patients, 16 had died within a median follow-up period of 293 days, including those who had died during their hospital stay, resulting in a 39% risk of death within the first year after trauma. In 1 review, 17.7% of the patients with AS and 20.0% of those with DISH had died within the first 3 months after their injury.[8,21] These mortality rates are very high compared with those in populations with spinal injuries but without ASD.[36]

Morbidity

A total of 23 distinct medical and 8 surgical adverse events occurred in 20 of our 41 patients (48.8%). The overall complication rates in the reported data have ranged from 10.9% to 84.0%.[8,16,27] The common medical adverse events associated with ASD, including pulmonary embolism, deep venous thrombosis, and pneumonia have been reported to be as great as 35%.[16] Pulmonary complications were the most common medical problem in our study at 29.3%. Surgical complication rates have been reported be as great as 28%, with most being implant failures.[13,16]

We had 1 implant failure with anterior plate dislocation after anterior fusion at the C4-C5 level before the scheduled posterior fixation. The plate was repositioned after the posterior fixation had been completed. This event stresses the importance of long-segment anterior plate fixation and the need for additional posterior fixation in the cervical spine when using an anterior approach as the initial surgery.[27] The most common surgical complications were wound infections ($n = 4$; 9.7%).

Postoperative Neurological Status and Follow-Up

In 28 patients (68.3%), the neurological status remained unchanged. In 5 patients (12.2%), their neurological status had improved by ≥1 AIS grade (2 from grade B to C, 1 from grade A to C, 1 from grade C to D, and 1 from grade D to E). Neurological deterioration occurred in 1 patient by 2 AIS grades (from grade E to C). This patient did not recover. In 2 patients, the AIS had worsened by 1 grade (from grade E to D). These 2 patients had recovered fully at the latest follow-up examination. Of the 36 discharged patients, 11 had died during the follow-up period and 1 was lost to follow-up. Of the 24 patients available for the latest follow-up examination, 21 had AIS grade E, 2 had AIS grade D, and 1 had AIS grade C.

CONCLUSIONS

The injured ankylosed spine poses many diagnostic and therapeutic challenges. A thorough diagnostic evaluation with multislice CT and whole spine MRI can reveal injuries that would remain undetected using conventional radiography. Patients aged >80 years seemed to experience the greatest morbidity and mortality. Internal fixation and decompression, where necessary, will increase the neurological improvement rate and decrease mortality compared with conservative treatment. Even with rapid mobilization, these patients will often experience respiratory complications. A combined approach or posterior-only fixation with adequate fusion seems safe. An anterior-only approach with plating of the cervical spine is prone to failure. Long-segment anterior plating is mandatory in these patients if an anterior approach has been performed before posterior fixation. Posterior fixation of ≥2 levels above and below the fracture line seems safe in these long-lever arm-type fractures.

REFERENCES

1. Hunter T, Dubo H. Spinal fractures complicating ankylosing spondylitis. *Ann Intern Med*. 1978;88:546-549.
2. Braun J, Sieper J. Ankylosing spondylitis. *Lancet*. 2007;369:1379-1390.
3. Weinfeld RM, Olson PN, Maki DD, et al. The prevalence of diffuse idiopathic skeletal hyperostosis (DISH) in two large American Midwest metropolitan hospital populations. *Skeletal Radiol*. 1997;26:222-225.
4. Kim SK, Choi BR, Kim CG, et al. The prevalence of diffuse idiopathic skeletal hyperostosis in Korea. *J Rheumatol*. 2004;31:2032-2035.
5. Kagotani R, Yoshida M, Muraki S, et al. Prevalence of diffuse idiopathic skeletal hyperostosis (DISH) of the whole spine and its association with lumbar spondylosis and knee osteoarthritis: the ROAD study. *J Bone Miner Metab*. 2015;33:221-229.
6. Westerveld LA, van Ufford HM, Verlaan JJ, et al. The prevalence of diffuse idiopathic skeletal hyperostosis in an outpatient population in the Netherlands. *J Rheumatol*. 2008;35:1635-1638.
7. Kiss C, Szilagyi M, Paksy A, et al. Risk factors for diffuse idiopathic skeletal hyperostosis: a case-control study. *Rheumatology (Oxford)*. 2002;41:27-30.
8. Westerveld LA, van Bemmel JC, Dhert WJ, et al. Clinical outcome after traumatic spinal fractures in patients with ankylosing spinal disorders compared with control patients. *Spine J*. 2014;14:729-740.
9. Anwar F, Al-Khayer A, Joseph G, et al. Delayed presentation and diagnosis of cervical spine injuries in long-standing ankylosing spondylitis. *Eur Spine J*. 2011;20:403-407.
10. Waldman SK, Brown C, Lopez de Heredia L, et al. Diagnosing and managing spinal injury in patients with ankylosing spondylitis. *J Emerg Med*. 2013;44:e315-e319.
11. Sapkas G, Kateros K, Papadakis SA, et al. Surgical outcome after spinal fractures in patients with ankylosing spondylitis. *BMC Musculoskelet Disord*. 2009;10:96.
12. Kanter AS, Wang MY, Mummaneni PV. A treatment algorithm for the management of cervical spine fractures and deformity in patients with ankylosing spondylitis. *Neurosurg Focus*. 2008;24:E11.
13. Westerveld LA, Verlaan JJ, Oner FC. Spinal fractures in patients with ankylosing spinal disorders: a systematic review of the literature on treatment, neurological status and complications. *Eur Spine J*. 2009;18:145-156.
14. Rajan VV, Kamath V, Shetty AP, Rajasekaran S. Iso-C3D navigation assisted pedicle screw placement in deformities of the cervical and thoracic spine. *Indian J Orthop*. 2010;44:163-168.
15. Jaiswal A, Shetty AP, Rajasekaran S. Role of intraoperative Iso-C based navigation in challenging spine trauma. *Indian J Orthop*. 2007;41:312-317.
16. Caron T, Bransford R, Nguyen Q, et al. Spine fractures in patients with ankylosing spinal disorders. *Spine (Phila Pa 1976)*. 2010;35:E458-E464.
17. Domenicucci M, Ramieri A, Landi A, et al. Blunt abdominal aortic disruption (BAAD) in shear fracture of the adult thoraco-lumbar spine: case report and literature review. *Eur Spine J*. 2011;20(suppl 2):S314-S319.
18. Fazl M, Bilbao JM, Hudson AR. Laceration of the aorta complicating spinal fracture in ankylosing spondylitis. *Neurosurgery*. 1981;8:732-734.
19. Vaccaro AR, Oner C, Kepler CK, et al. AOSpine thoracolumbar spine injury classification system: fracture description, neurological status, and key modifiers. *Spine (Phila Pa 1976)*. 2013;38:2028-2037.
20. Gertzbein SD, Robbins SE. Accuracy of pedicular screw placement in vivo. *Spine (Phila Pa 1976)*. 1990;15:11-14.
21. Balling H, Weckbach A. Hyperextension injuries of the thoracolumbar spine in diffuse idiopathic skeletal hyperostosis. *Spine (Phila Pa 1976)*. 2015;40:E61-E67.
22. Harrop JS, Sharan A, Anderson G, et al. Failure of standard imaging to detect a cervical fracture in a patient with ankylosing spondylitis. *Spine (Phila Pa 1976)*. 2005;30:E417-E419.
23. Malham GM, Ackland HM, Varma DK, et al. Traumatic cervical discoligamentous injuries: correlation of magnetic resonance imaging and operative findings. *Spine (Phila Pa 1976)*. 2009;34:2754-2759.
24. Van de Straete S, Demaerel P, Stockx L, et al. Spinal epidural hematoma and ankylosing spondylitis. *J Belge Radiol*. 1997;80:109-110.
25. Hissa E, Boumphrey F, Bay J. Spinal epidural hematoma and ankylosing spondylitis. *Clin Orthop Relat Res*. 1986;208:225-227.

26. Broom MJ, Raycroft JF. Complications of fractures of the cervical spine in ankylosing spondylitis. *Spine (Phila Pa 1976)*. 1988;13:763-766.

27. Einsiedel T, Schmelz A, Arand M, et al. Injuries of the cervical spine in patients with ankylosing spondylitis: experience at two trauma centers. *J Neurosurg Spine*. 2006;5:33-45.

28. Aoki Y, Yamagata M, Ikeda Y, et al. Failure of conservative treatment for thoracic spine fracture in ankylosing spondylitis: delayed neurological deficit due to spinal epidural hematoma. *Mod Rheumatol*. 2013;23:1008-1012.

29. Johnson MG, Fisher CG, Boyd M, et al. The radiographic failure of single segment anterior cervical plate fixation in traumatic cervical flexion distraction injuries. *Spine (Phila Pa 1976)*. 2004;29: 2815-2820.

30. Taggard DA, Traynelis VC. Management of cervical spinal fractures in ankylosing spondylitis with posterior fixation. *Spine (Phila Pa 1976)*. 2000;25: 2035-2039.

31. Chaudhary SB, Hullinger H, Vives MJ. Management of acute spinal fractures in ankylosing spondylitis. *ISRN Rheumatol*. 2011;2011:150484.

32. Janssen I, Ryang YM, Gempt J, et al. Risk of cement leakage and pulmonary embolism by bone cement-augmented pedicle screw fixation of the thoracolumbar spine. *Spine J*. 2017;17: 837-844.

33. Sedney CL, Daffner SD, Obafemi-Afolabi A, et al. A comparison of open and percutaneous techniques in the operative fixation of spinal fractures associated with ankylosing spinal disorders. *Int J Spine Surg*. 2016;10:23.

34. Yeoh D, Moffatt T, Karmani S. Good outcomes of percutaneous fixation of spinal fractures in ankylosing spinal disorders. *Injury*. 2014;45: 1534-1538.

35. Kruger A, Frink M, Oberkircher L, et al. Percutaneous dorsal instrumentation for thoracolumbar extension-distraction fractures in patients with ankylosing spinal disorders: a case series. *Spine J*. 2014;14:2897-2904.

36. Verlaan JJ, Diekerhof CH, Buskens E, et al. Surgical treatment of traumatic fractures of the thoracic and lumbar spine: a systematic review of the literature on techniques, complications, and outcome. *Spine (Phila Pa 1976)*. 2004;29: 803-814.

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