The Spine Journal 19 (2019) 1331−1339

Clinical Study

Is routine MRI of the spine necessary in trauma patients with ankylosing spinal disorders or is a CT scan sufficient?

Celeste Tavolaro, MD, Samia Ghaffar, MD, Haitao Zhou, MD, Quynh T. Nguyen, PA-C, MSH, Carlo Bellabarba, MD, Richard J. Bransford, MD*

Department of Orthopaedics and Sport Medicine, Harborview Medical Center, 325 Ninth Avenue Seattle, WA 98104, USA

Received 22 November 2018; revised 10 March 2019; accepted 12 March 2019

Abstract

BACKGROUND: Ankylosing spinal disorder (ASD) patients are at a greater risk for spinal fractures due to osteoporosis and rigidity of the spinal column. These fractures are associated with a high risk of neurologic compromise resulting from delayed or missed diagnoses. Although computed tomography (CT) is usually the initial imaging modality, magnetic resonance imaging (MRI) has been proposed as mandatory to help identify spinal injuries in ASD patients with unexplained neck or back pain or known injuries to help identify noncontiguous fractures. However, some studies have also shown that neurological injury can result from the required patient transfer and positioning for an MRI.

PURPOSE: The purpose of our study was to assess the frequency with which an MRI identified an injury not previously identified with CT, and whether this affected the treatment and outcome of the patient. Secondarily, we attempted to identify clinical or CT findings that may render an MRI particularly useful.

STUDY DESIGN: Retrospective review.

PATIENT SAMPLE: Patients with ASD who sustained acute spine fractures from 2005 to 2015.

OUTCOME MEASURES: Acute fractures identified by CT scan and MRI upon admission; neurologic status upon admission and discharge, mode of injury, type of fracture, and final intervention before and after MRI assessment.

METHODS: A total of 124 patients with a diagnosis of diffuse idiopathic skeletal hyperostosis (DISH) or ankylosing spondylitis (AS) were identified by searching the radiology database of a level I trauma center with diagnosis keywords. Final radiology reports were assessed to determine presence and type of fracture(s) from CT. MRI report was then reviewed to assess if additional fractures or injuries were identified beyond that already known from the CT. Neurologic status upon admission and discharge, mode of injury, type of fracture, and final intervention were determined by inpatient notes and/or operative reports. No source funding or conflict of interest was present pertaining to this study.

RESULTS: In the designated time frame, 124 ASD patients with injuries of the spine were identified who had obtained both a baseline CT and MRI. Six patients (4.8%) had additional injuries on MRI that had not been identified with CT. Four of these six patients had a change in treatment plan (three operative and one nonoperative) based on subsequent MRI findings. These included a (1) C4−5 hyperextension injury, (2) C6−7 hyperextension injury, (3) C7 bony fracture with C5−T4 epidural hematoma, and (4) C5−C6 hyperextension injury treated in a brace. Two of the six patients that had additional injuries identified on MRI had no change in their treatment plan. One patient had an additional lumbar extension injury identified above a previously diagnosed injury on CT, which was managed with a Thoracolumbosacral Orthosis (TLSO) according to the original plan. One patient died who had a known odontoid fracture and a suspected C6−7 hyperextension

FDA device/drug status: Not applicable.

Author disclosures: ***CS***: Nothing to disclose. ***SG***: Nothing to disclose. ***HZ***: Nothing to disclose. ***QN***: Nothing to disclose. ***CB***: Nothing to disclose. ***RB***: Globus Spine (C) and AO Spine North America (B).

* Corresponding author. Department of Orthopaedic Surgery and Sports Medicine, Harborview Medical Center, 325 Ninth Avenue, Box 359798, Seattle, WA 98104-2499, USA. Tel.: (206)731-3466.

E-mail address: rbransfo@uw.edu (R.J. Bransford).

https://doi.org/10.1016/j.spinee.2019.03.004
1529-9430/

injury, and was identified on MRI as also having a C3−C4 hyperextension injury and a C2 spinal cord transection.

CONCLUSIONS: In this study, 3.2% (4/124) of patients with ASD who presented to a level I trauma center with an acute spine injury identified with CT required a change in their treatment plan based on subsequent MRI findings. Only one fracture was missed on CT imaging, with the other missed injuries all being either disco-ligamentous hyperextension injuries through mobile discs or intracanal pathology. Our recommendation is that the routine use of MRI be limited to patients with nonankylosed levels in which a disco-ligamentous injury may have occurred, and in patients with neurological deficits that require investigation of the spinal canal to assess for causes of neurological injury.

Keywords: MRI; CT; Ankylosing spine disorders, ASD; Ankylosing spondylitis, AS; Diffuse idiopathic skeletal hyperostosis, DISH; Fracture; Trauma; Imaging; Diagnosis

Introduction

Diffuse idiopathic skeletal hyperostosis (DISH) and ankylosing spondylitis (AS) are the primary ankylosing spinal disorders (ASD) [1]. The prevalence of vertebral fractures in ASD ranges from 4% to 18%, of whom approximately 8% of patients have multilevel fractures [2]. Fractures are more prevalent in the cervical spine, followed by the thoracic, and lastly the lumbar spine [3,4]. Delays in the initial diagnosis of fractures in ASD patients, as reported in the literature, range from 19% to 60% [5]. These delays tend to be more common in nondisplaced fractures after low energy mechanisms, with a risk of neurologic worsening that has been reported to range from 17% to 81% [6].

Due to the high percentage of missed diagnosis with clinical exam and plain radiographs only, computed tomography (CT) screening of the entire spine is recommended [7−9]. Routine magnetic resonance imaging (MRI) has been recommended in addition to a CT in ASD patients, in order to identify subtle fractures, ligamentous injuries, and cord signal abnormalities [10−12]. However, we are aware of no studies to date that have shown whether MRIs are more useful than CT in recognizing additional spine injuries that will affect treatment [13,14]. In addition to the fact that MRI is expensive and time consuming, studies have also shown that MRI can cause further neurological injury due to positioning [2,12,15]. Thus, there continues to be controversy as to the optimal imaging workup in patients with suspected fractures of an ankylosed spine. There are also no clear guidelines as to what history, exam, or CT findings may lead one to obtain further imaging beyond the CT scan.

The purpose of our study was to assess the incidence in which MRI identified an injury not previously identified on CT that was severe enough to alter the patient's treatment plan or outcome. Secondarily, we attempted to identify clinical or CT findings that correlated with the need for MRI.

Material and methods

Following institutional review board approval, we conducted a retrospective cohort study of patients with ASD who sustained an acute spinal fracture between 2005 and 2015. Patients with a diagnosis of DISH or AS were identified by searching the radiology database of a regional level I trauma center with the keywords: "ankylosing spondylitis", "ankylosing spine", "AS", "diffuse idiopathic hyperostosis" and/or "DISH". Patients were included in our study if they had both a CT and MRI upon admission.

All electronic medical records and spinal imaging reports were retrospectively reviewed to collect demographic data (age, gender), type of ASD, clinical manifestations of their injury, neurologic status upon admission, neurological status on discharge (graded according to American Spinal Injury Association (ASIA)) and mechanism of injury (MOI). Final CT reports were assessed to determine the presence, type, and vertebral level of spine fracture(s). MRI reports were reviewed to determine whether additional fractures or injuries were identified beyond what had already been recognized on the CT. If the additional MRI resulted in a newly identified injury, medical reports were reviewed to evaluate for change in treatment plan, whether operative or nonoperative.

Results

During our 10-year timeframe, 124 patients (111 men and 13 women) were identified with acute spine trauma in the setting of ASD who had received both a CT and an MRI upon admission. The mean age of patients was 70.7± 12.8 years. There were 69 patients with radiological diagnosis of DISH and 55 with radiological diagnosis of AS. The MOI was a ground level fall in 64 patients (52%), motor vehicle collision in 45 (66%) and fall from height in 15 (12%). Neurologic status was classified as follows: 14 ASIA A, 5 ASIA B, 3 ASIA C, 12 ASIA D, 70 ASIA E, and 20 patients were unexaminable for neurological injury due to associated intracranial injuries and mental status compromise. Six out of 124 patients (4.8%) had additional injuries or relevant findings on MRI that had not initially been identified on CT scan. The baseline demographics, ASD condition, MOI, clinical manifestations, neurologic status, CT and MRI findings, and the pre- and post-MRI treatment plans are summarized in Table 1.

Table 1
Demographic characteristics, imaging modalities findings, and treatment of the cohort with delay diagnosis

Case number and ASD	Gender and age	Mechanism of Injury	Spine region	Injury identify by CT	Inicial treatment plan	Injury identify by MRI	Final treatment
1 DISH	Man 63y	Ground level fall	Cervical	C4−C5 spinal stenosis, with a gap between anterior osteophytes, and minor retrolisthesis.	C4−5 laminectomy	C4−5 hyperextension injury.	C4−5 laminectomy +C3−6 PSIF
2 AS	Man 69y	Motor- vehicular collision	Cervical	No acute fracture or dislocation in the cervical spine	C5−T3 laminectomy	C7 fracture with large epidural hematoma from C5 to T4, compressing the cord. High signal in C6−7 interspinous soft tissues (ligamentous injury).	C5−T2 Laminectomy +C4−T3 PSIF
3 DISH	Man 82y	Height level fall	Lumbar	L3−4−5 extension injury	TLSO	L1−2 extension injury	TLSO
4 DISH	Man 75y	Ground level fall	Cervical	T6 fracture	—	C5−6 extension injury.	C Collar
5 DISH	Man 81y	Motor- vehicular collision	Cervical	No acute fracture or dislocation in the cervical spine	C Collar	C6−7 extension	C6−7 acdf
6 DISH	Man 81y	Height level fall	Cervical	Type III odontoid fracture. Offset of the left lateral masses of C1 and C mild anterior disk widening at C6/C7	—	C3−4 and C6−7 hyperextension injuries and a complete cord transection.	Patient deceased

All six patients in whom additional findings were identified on MRI were men, with an average age of 78 years (±7 years). Five of the six had a radiologic diagnosis of DISH. A low energy mechanism was the cause of fracture in three patients. The MOI corresponded to an extension mechanism in five patients and axial load in one patient.

The missed injuries occurred in the cervical spine of five patients and the lumbar spine of one patient. Four missed injuries were cervical extension injuries through a nonankylosed disc space in DISH patients, one MRI identified a cervical hematoma in a patient with a worsening neurological exam and high signal intensity through a cervical vertebral body (fracture) in an AS patient, and one MRI identified a missed lumbar extension injury through a mobile disc space in a DISH patient. The five disco-ligamentous injuries had subtle widening of the disc spaces on CT scan, but it was uncertain whether these were just physiologically wide and “normal” or whether this was evidence of injury. The MRIs were able to identify high-signal in the disc space with evidence of high signal as well in the posterior ligamentous complex.

Interestingly, all five missed extension injuries through mobile segments were in DISH patients and the one missed fracture was in an AS patient. Axial pain was present in five patients. The sixth patient was intubated and sedated on admission and was thus unexaminable. During workup in the emergency department, one patient had worsening of his neurological exam from ASIA E to D, and one patient died due to a complete upper cervical spine cord transection. (See Table 2 for details on patients)

Based on subsequent MRI reports that identified other spine injuries, four out of six patients had a change in the treatment plan:

1. A 63-year-old man with DISH following a ground level fall had an initial treatment plan for a C4−C5 laminectomy due to an ASIA D status, however following the MRI which identified a hyperextension injury at C4−C5, the patient underwent a C3−C6 posterior instrumented fusion in combination with the laminectomy (Fig. 1).
2. A 69-year-old man with AS involved in a motor vehicle collision who had no injury identified on his initial CT developed a progressive neurologic injury. MRI demonstrated a large epidural hematoma extending from C5−T4 with high signal in the vertebral body at C7 consistent with a nondisplaced fracture. His initial neurologic grade was ASIA E which worsened to ASIA C. He underwent a C5−T2 laminectomy and C4−T3 posterior instrumented fusion (Fig. 2).
3. A 75-year-old man with DISH sustained a ground level fall and had a known T6 fracture on CT scan. His MRI demonstrated a C5−C6 mild hyperextension injury

Table 2
Clinical manifestations and neurologic status at time of injury and during the emergency department workup of the cohort with delay diagnosis

Case number	Clinical findings	Neurological status at admission	Neurological status during workup
1	Immediately after injury, patient reported transient neurologic deficit.	ASIA E	ASIA D
2	Neck pain	ASIA E	ASIA C
3	Back pain	ASIA E	ASIA E
4	Back and chest pain. Posterior head laceration.	ASIA E	ASIA E
5	Neck pain, distal paresthesias in hands and feet correlated with neck movement.	ASIA E	ASIA E
6	Intubated and sedated	Unexaminable	Unexaminable

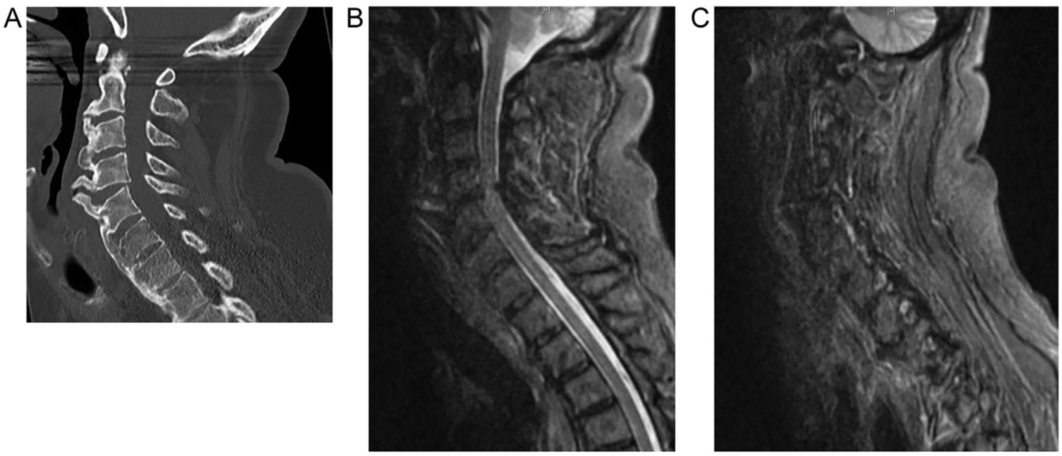

Fig. 1. (A) Cervical CT reported a gap between anterior osteophytes with some retrolisthesis of C4 on C5. (B) On the cervical MRI, we can see increased signal in the space between the anterior osteophytes, without increased signal at the disk space. Severe stenosis of the canal at C4−5 level due to mild disk herniation and ligamentum flavum hypertrophy. (C) The C4−5 facets are also mildly widened, with hyperextension at C4−C5.

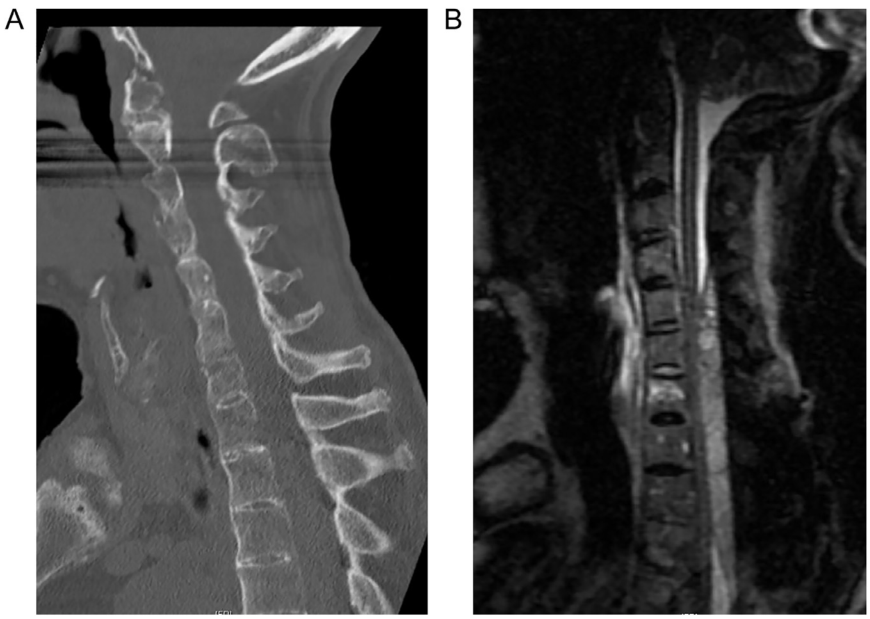

Fig. 2. (A) Cervical CT reported no evidence of acute fracture or dislocation or subluxation. No abnormal widening of the disc spaces. No prevertebral soft tissue contour abnormality. (B) Cervical MRI shows transverse fracture in the C7 vertebral body. There is compression and displacement of the cord anteriorly by a large posterior epidural hematoma extending from C5 through T4, largest at C7 level.

Fig. 3. (A) X-ray shows previous PSIF L3−S1 with a Harrington rod/laminar hook construct. (B). Lumbar CT shows unstable oblique hyperextension fracture involving the anterior and posterior elements of L5, mid L4, and posterior L3 vertebrae. (C) Lumbar MRI shows acute hyperextension injury involving L3, L4, and L5. The mid L2−L4 central canal not evaluable. Probable occult L1−2 hyperextension injury. Hardware artifacts.

through the disc space leading to a nonoperative treatment in a Miami J collar (Fig. 4).

4. An 81-year-old man with DISH involved in a motor vehicle collision had no injury diagnosed on baseline CT however his MRI showed a C6−C7 extension injury through the disc space, which was treated with a C6−C7 ACDF (Fig. 5).

Three patients therefore had changes to their operative plan based on MRI and one patient had a change in treatment plan from no known injury with no plan for treatment of the spine to treatment with a rigid collar.

All four patients in whom the treatment changed had symptoms which warranted further investigation. Two patients had incomplete spinal cord injuries (ASIA C and D) and the other two were graded as ASIA E with paresthesias and severe axial pain. Three out of the four had an injury extending through the disc with no obvious fracture and the one had a nondisplaced fracture through the C7 vertebral body.

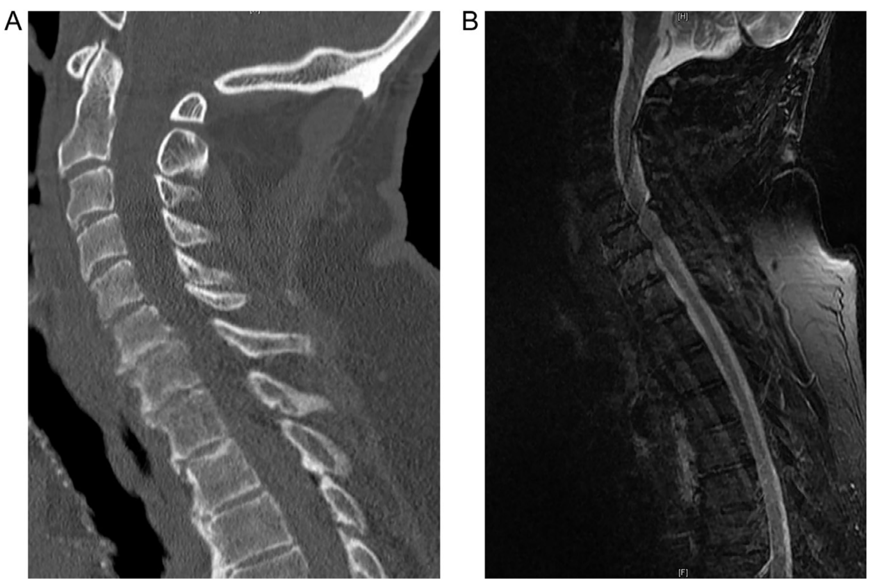

Fig. 4. (A) No findings in Cervical CT of acute fracture or displacement. (B) MRI Spine: small edema in the C5/6 anterior disc space extending anteriorly between C5 and C7 suspicious for extension injury.

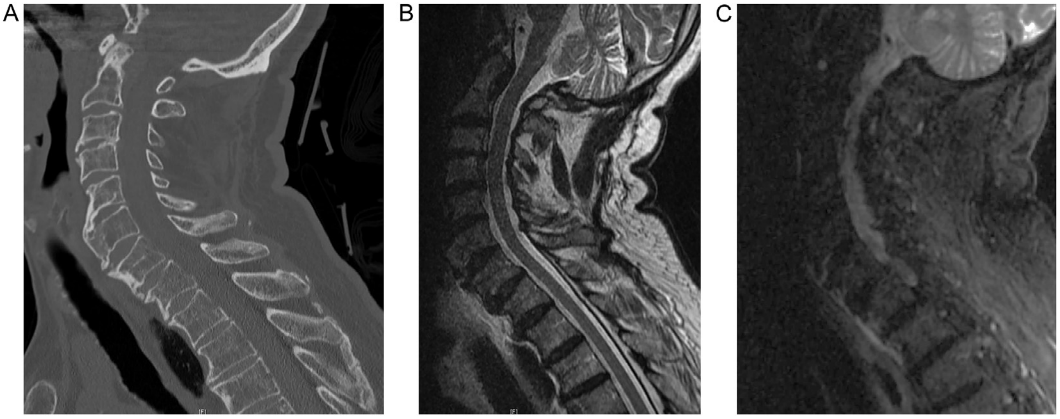

Fig. 5. (A) In the cervical CT, there is no evidence of acute fracture. There is no misalignment and no posterior element injury. (B) Cervical MRI (T2) shows at C6−7 shearing of the disk off of the superior border of C7. (C) MRI (STIR) Hyperintense show signal extending into the anterior intervertebral disk space of C6−7 with associated prevertebral soft tissue swelling and hemorrhage anterior to the C7 and T1 vertebral bodies consistent with hyperextension. Posterior longitudinal ligaments, ligamentum flavum, and posterior interspinous ligaments are intact. Spinal cord signal is normal.

Two patients had additional findings but no change in their intended treatment based on MRI:

1. 82-year-old man with a ground level fall was identified with L3−L5 extension injury by CT imaging. His MRI also suggested an injury at L1−L2. The plan to treat him with a TLSO before his MRI was not modified (Fig. 3).
2. 81-year-old man with known DISH who fell from a height had a known dens fracture and C6−7 hyperextension injury identified by CT. His MRI also demonstrated a cord transection at C2 and a C3−C4 hyperextension injury. Unfortunately, his neurological status and cord transection led to a withdrawal of care. His index exam showed a ventilator dependent quadriplegic and the index plan was no surgery and palliative care (Fig. 6).

Discussion

It has been well established that patients with ankylosing conditions are more prone to fracture due to the increased stiffness and, frequently, suboptimal bone quality of their spines [4,13,16]. Whereas the assumption in non-ASD patients is that they do not have a relevant fracture until proven by imaging, the opposite approach is warranted in ASD patients, in whom the presence of axial spine pain,

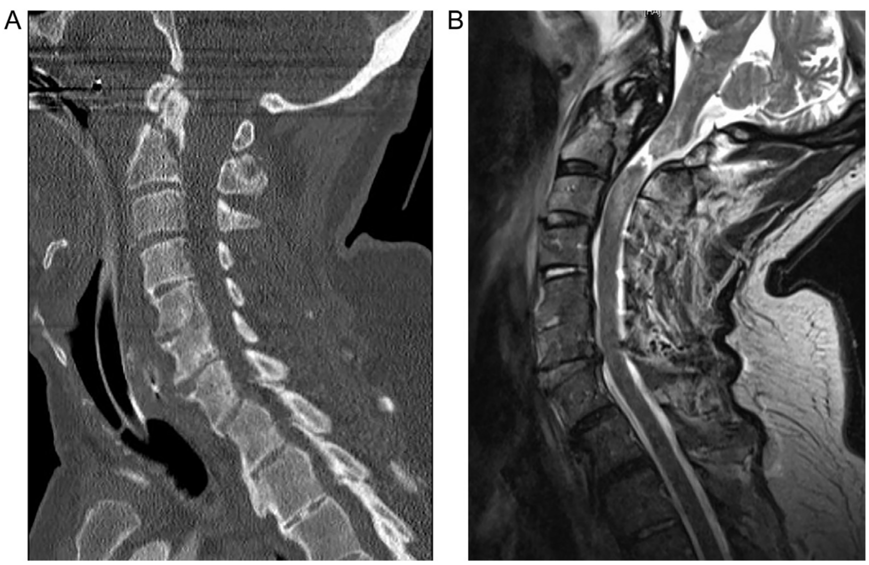

Fig. 6. (A) The CT shows a type III odontoid fracture through the base of the dens, extending into the dorsal aspect of the C2 vertebral body and the medial part of the right C1−C2 facet. The odontoid fragment is displaced posteriorly (4 mm) relative to the body of C2, mildly narrowing the central canal. At C6/C7 level is a mild anterior disk widening. (B) MRI shows a Type II odontoid fracture with C2 complete cord transection, marked cord swelling and hemorrhage in the cord cephalad to this level and down to the C3−4 level. At C3−4 and C6−7 shows acute hyperextension injuries with anterior discs widening and hyperintensity.

regardless of how trivial the MOI, assumes the presence of a spine fracture until proven otherwise by imaging the entire spine [2,10]. However, there is considerable uncertainty regarding what constitute the optimal imaging modalities to identify all clinically relevant injuries. The importance of this controversy pertains to how commonly the diagnosis of spinal injuries is delayed in patients with ASD [6,17]. It is also well known that delays in diagnosis can lead to severe neurological injury [3,18], emphasizing the need for clinicians to make a timely diagnosis and treat injuries appropriately. ASD patients are frequently lumped into one group, yet some patients are ossified from occiput to pelvis, whereas others who meet the criteria for ASD have partially ankylosed spines, maintaining functional motion segments at other levels. Thus, ASD patients are a heterogeneous patient population that may benefit from being categorized into subgroups.

The controversy pertaining to the ideal imaging study for the evaluation of fractures in ASD in many ways mirrors that for non-ASD spine injuries. Some authors consider CT of the entire spine to be the appropriate imaging study because it is typically more available and practical, requires a shorter scan time and shows better bone detail [3,5,8]. CT imaging, which is the primary screening study for spine fractures at our institution, adequately diagnosed 95.2% of injures in our 124 patients with ASD. These results are similar to those published by Koivikko et al. who reported that CT was able to show 94% of fractures, whereas MRI only had 83% accuracy [19]. Given the risk of neurological injury with delayed spine fracture diagnosis in patients with ASD, however, most would consider 94%−95% to be less than satisfactory. Fatemi et al., reported a case in which CT failed to reveal a fracture seen later on MRI [20]. The discussion is further confounded by the fact that the resolution of CT imaging has improved considerably over the past 2 decades, particularly with regard to coronal and sagittal reformations, which may invalidate some of the more outdated comparisons between MRI and CT. In our study, only one fracture (Fig. 2) was missed in 124 patients, amounting to a missed fracture rate of less than 1%. The other five missed diagnoses were all disco-ligamentous injuries at nonossified levels of the spine. This is an important differentiation as a missed fracture was not appropriately identified in only one patient (<1%) whereas the other misses were related to soft tissues.

Because of the improved ability of MRI to identify spinal cord injury, ligamentous injuries, intravertebral fluid collections, and soft tissue injuries, several authors suggest MRI as a better imaging modality, more sensitive than CT, as a screening method for patients with ASD [10−12]. Conversely, other studies have stated that MRI is technically challenging to obtain in traumatized patients with advanced ASD, due to patients body habitus, deformity, motion artifact ,and distracting injuries which cause difficulty with lying supine [8,9,15,19]. Although MRI can potentially yield more information, there is an associated cost, effort and risk associated with these studies. The fragility of the spine in patients with ASD has resulted in significant spinal injury through other types of well-intended medical care [1], with recommendations having been made, for example, that patients with ASD and kyphotic deformities should not undergo laparoscopic surgery due to the risk of iatrogenic fracture [21].

In our series the MRI only detected a missed fracture in one case. The other five injuries that were not diagnosed with CT were through disco-ligamentous complexes in mobile areas of the spine without bony injury. A missed fracture was only picked up in one case (<1%) and the other five injuries were in mobile segments of the spine in DISH patients. These mobile areas in DISH spines seem to be the more easily missed injuries in which CT scans may be inadequate. The MRI was also able to demonstrate significant spinal canal abnormalities in two patients, one with a complete spinal cord transection (Fig. 6) and one with a large compressive epidural hematoma (Fig. 2). Neither of these findings were detected by CT, however, and the physical exam in both patients was consistent with spinal cord injury, which was ASIA A pentaplegia with motor score of zero in the first patient and ASIA C at the midcervical level in the second.

Westerveld et al. found that 78% of spinal fractures in patients with AS were located in the cervical spine. These findings are consistent with those of other published reports, which have demonstrated that spinal fractures in patients with ASD occur most commonly in the lower cervical spine [2,22−24]. Some studies have suggested that cervical spine fractures are harder to identify compared with those of the lumbar spine [25]. In the study by Koivikko et al. described previously, MRI identified 2 of 20 injuries not previously seen on CT, whereas CT demonstrated 6 of 20 injuries not previously detected on MRI [12]. Therefore, CT and MRI can be considered complementary modalities for detection of fracture in patients with AS. Based on our study, we postulate that most injuries of the cervical spine that are not identified with CT are likely be disco-ligamentous injuries through nonankylosed levels, and that MRI would therefore have a greater diagnostic role in patients who have remaining mobile intervertebral levels.

All ASD patients have varying degrees of ankylosis, ranging from fusion of the entire spine to ankylosis of only enough levels to meet the diagnostic criteria. As a general rule, patients with AS will likely have more fused levels than DISH patients who are more likely to have unfused segments particularly in the cervical spine and the lumbar spine. Just as in trauma patients with nonankylosed spines, one must use judgement in using MRI to identify clinically relevant disco-ligamentous injuries. We were able to diagnose greater than 99% of bony fractures and thus, in patients with complete ankylosis of the spine, MRI is likely to have a limited role. However, in patients with ASD who still have mobile intervertebral segments, an MRI may be needed to ascertain whether there is an unstable disco-ligamentous injury, typically a hyperextension injury, which has a higher likelihood of being missed with CT imaging. The second category in which an MRI may provide benefit, as with the non-ASD spinal trauma population, is in patients with neurological deficits that are not easily explained by CT findings, or in which additional details may affect patient care. Caron et al. described a 10% rate of epidural hematoma in his description of 112 spine fracture patients with ASD [6]. In our six patients who had MRI finding not identified on CT, one had an epidural hematoma which was responsible for his spinal cord injury, and in one patient with a suspected major cord injury, the MRI was able to identify a spinal cord transection.

Certainly there are limitations to our study. This is a retrospective review which looked solely at the interpretation of a neuroradiology attending. We acknowledge that a spine surgeon may have identified some of the missed injuries, which would have reduced the missed injury rate. On the other hand, spine surgeons may not even be consulted on these patients unless an injury is actually identified by a neuroradiologist and then passed on to the emergency room personnel. Second, although four of the six patients had changes in their treatment plan based on MRI findings, we recognize that other surgeons may have chosen different treatment approaches under similar circumstances. Third, not all CT scans have the same resolution, which may also influence the rate of missed injuries. Our institution uses a 2-mm axial slice resolution to create coronal and sagittal prospective study looking at the roles of CT and MRI in ASD patients with fractures would improve our understanding of what constitutes the most appropriate imaging for these patients significantly.

Conclusions

In our study, six of 124 (4.8%) patients with ASD had spinal injuries identified on MRI that were not initially identified on CT scan and four of the 124 (3.2%) had treatment plans that were changed based on the MRI results. Only one fracture was missed. The remaining five patients had disco-ligamentous hyperextension injuries though mobile discs or intracanal pathology. Our recommendation is that MRI need not be routinely obtained in all ASD patients, but that it may have an important diagnostic role in patients with nonankylosed levels in which a disco-ligamentous injury may be present and in patients with neurological deficits that require investigation of the spinal canal to assess causes and severity of spinal cord injury.

Acknowledgment

We acknowledge Andrea L. Ball, MLS, MSIM of the Health Sciences Library, University of Washington, for her editorial assistance.

References

[1] Reinhold M, Knop C, Kneitz C, Disch A. Spine fractures in ankylosing diseases: recommendations of the spine section of the german society for orthopaedics and trauma (DGOU). Glob Spine J 2018;8 (2 Suppl):56S–68S. https://doi.org/10.1177/2192568217736268.

[2] Werner BC, Samartzis D, Shen FH. Spinal fractures in patients with ankylosing spondylitis: etiology, diagnosis, and management. J Am Acad Orthop Surg 2016;24(4):241–9. https://doi.org/10.5435/JAAOS-D-14-00149.

[3] Wang YF, Teng MMH, Chang CY, Wu HT, Wang ST. Imaging manifestations of spinal fractures in ankylosing spondylitis. Am J Neuroradiol 2005;26(8):2067–76.

[4] 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(2):145–56 https://doi.org/10.1007/s00586-008-0764-0.

[5] Charles YP, Buy X, Gangi A, Steib JP. Fracture in ankylosing spondylitis after minor trauma: radiological pitfalls and treatment by percutaneous instrumentation. A case report. Orthop Traumatol Surg Res. 2013;99(1):115–9. https://doi.org/10.1016/j.otsr.2012.09.018.

[6] Caron T, Bransford R, Nguyen Q, Agel J, Chapman J, Bellabarba C. Spine fractures in patients with ankylosing spinal disorders. Spine 2010;35(11):458–64. https://doi.org/10.1097/BRS.0b013e3181cc764f.

[7] Ambrose NL, Cunnane G. Importance of full evaluation in patients who complain of neck pain. Ir J Med Sci 2009;178(2):209–10. https://doi.org/10.1007/s11845-008-0256-6.

[8] Shah LM, Ross JS. Imaging of spine trauma. Neurosurgery 2016;79 (5):626–42. https://doi.org/10.1227/NEU.0000000000001336.

[9] Harrop JS, Sharan A, Anderson G, Hillibrand AS, Albert TJ, Flanders A, et al. Failure of standard imaging to detect a cervical fracture in a patient with ankylosing spondylitis. Spine 2005;30(14):E417–9.

[10] Mrabet D, Alaya Z, Mizouni H, Sahli H, Elleuch M, Chéour E, et al. Fractures rachidiennes au cours de la spondylarthrite ankylosante: à propos d'une nouvelle observation. Ann Phys Rehabil Med 2010;53 (10):643–9. https://doi.org/10.1016/j.rehab.2010.09.008.

[11] Taljanovic MS, Hunter TB, Wisneski RJ, Seeger JF, Friend CJ, Schwartz SA, et al. Imaging characteristics of diffuse idiopathic skeletal hyperostosis with an emphasis on acute spinal fractures: Review. Am J Roentgenol 2009;193(3 SUPPL.):10–9. https://doi.org/10.2214/AJR.07.7102.

[12] Koivikko MP, Koskinen SK. MRI of cervical spine injuries complicating ankylosing spondylitis. Skeletal Radiol 2008;37(9):813–9. https://doi.org/10.1007/s00256-008-0484-x.

[13] Finkelstein JA, Chapman JR, Mirza S. Occult vertebral fractures in ankylosing spondylitis. Spinal Cord 1999 Jun;37(6):444–7.

[14] Michel JL, Souteyrand AC, Kabre M, Dubost JJ, Soubrier M, Ristori JM. Fractures of the ankylosed spine: MRI features. J Radiol 2007 Nov;88(11 Pt 1):1703–6.

[15] Vives MJ, Harris C, Reiter MF, Drzala M. Use of stand-up magnetic resonance imaging for evaluation of a cervicothoracic injury in a patient with ankylosing spondylitis. Spine J 2008;8(4):678–82. https://doi.org/10.1016/j.spinee.2007.04.014.

[16] Jacobs WB, Fehlings MG. Ankylosing spondylitis and spinal cord injury: origin, incidence, management, and avoidance. Neurosurg Focus 2008;24(1):E12. https://doi.org/10.3171/FOC/2008/24/1/E12.

[17] McCormick JD, Werner BC, Shimer AL. Patient-reported outcome measures in spine surgery. J Am Acad Orthop Surg 2013;21(2):99–107. https://doi.org/10.5435/JAAOS-21-02-99.

[18] Milicić A, Jovanović A, Milankov M, Savić D, Stanković M. Fractures of the spine in patients with ankylosing spondylitis. Med Pregl 1995;48(11−12):429–31.

[19] Koivikko MP, Kiuru MJ, Koskinen SK. Multidetector computed tomography of cervical spine fractures in ankylosing spondylitis. Acta Radiol 2004;45(7):751–9.

[20] Fatemi G, Gensler LS, Learch TJ, Weisman MH. Spine fractures in ankylosing spondylitis: a case report and review of imaging as well

as predisposing factors to falls and fractures. Semin Arthritis Rheum 2014;44(1):20–4. https://doi.org/10.1016/j.semarthrit.2014.03.007.

[21] Mercier MF, Baghdadi H, Frosini C, Sielezneff I, Sastre B, Gouin F. Laparoscopic cholecystectomy in a patient with Steinert disease. Ann Fr Anesth Reanim 1996;15(3):310–2.

[22] Vosse D, Feldtkeller E, Erlendsson J, Geusens P, Der LSan. Clinical vertebral fractures in patients with ankylosing spondylitis. J Rheumatol 2004;31(10):1981–5.

[23] Samartzis D, Ebhc D, Anderson DG, Shen FH. Multiple and simultaneous spine fractures in ankylosing spondylitis: case report. Spine 2005;30(23):E711–5.

[24] Olerud C, Frost A, Bring J. Spinal fractures in patients with ankylosing spondylitis. Eur Spine J 1996;5(1):51–5.

[25] Anwar F, Al-Khayer A, Joseph G, Fraser MH, Jigajinni M V, Allan DB. Delayed presentation and diagnosis of cervical spine injuries in long-standing ankylosing spondylitis. Eur Spine J 2011;20(3):403–7.