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Limitations of Plain Film Radiography in Identification of Hyperextension Fractures in Patients With Ankylosing Spinal Disorders

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Abstract

Study Design: Efficacy study.

Objectives: To elucidate the limitations of radiography in patients with spinal ankylosing disorders (SAD) with an emphasis on thoracolumbar injuries, which have been less focused upon.

Methods: We searched our hospital's emergency room database for patients who underwent a total spine computed tomography (CT) following a diagnosis of SAD on radiographs following a minor fall. A high-quality presentation containing 50 randomly situated anteroposterior + lateral radiographs was created. Of these, 24 contained a hyperextension type fracture diagnosed by CT. Twelve physicians—4 spine surgeons, 4 senior orthopedic residents and 4 junior orthopedic residents were requested to identify the pathologic radiographs and note the fracture level.

Results: Fracture diagnosis stood at 65% for the best reader. When examining the different subgroups, the mean rate of diagnosis for spine surgeons was 55% and for orthopedic residents 32%. Mean diagnosis of thoracic fractures was 26%, of lumbar fractures was 55%, and for the entire thoracolumbar spine was 40%. The interobserver agreement (kappa coefficient) was found to be 0.37 for the entire group and 0.39 for spine surgeons. This finding was statistically significant.

Conclusions: The simple radiograph is an inefficient modality for diagnosis of hyperextension type thoracolumbar fractures in patients with SAD. The poor interobserver agreement rate further amplifies this finding. Advanced imaging is recommended in these patients.

Keywords

thoracolumbar fractures, spinal ankylosing disorders, hyperextension fractures, radiography, advanced imaging, fracture diagnosis, minor trauma

Introduction

The management of trauma patients with spinal ankylosing disorders (SAD) such as ankylosing spondylitis (AS) and diffuse idiopathic skeletal hyperostosis (DISH) continues to pose a unique challenge for the practitioner. This population is especially susceptible to vertebral column fractures, due to long lever arms secondary to multilevel fusion,[1] resulting from the pathological process of these diseases, as well as severe osteoporosis[2] and a fixed kyphotic deformity.[3] These patients have been shown to endure unstable vertebral fractures from even minimal trauma including ground level falls,[4] with the most common fracture morphology being hyperextension type,[4,5]

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accounting for 46% to 78% of fractures. Unfortunately, vertebral fractures in these patients remain a diagnostic challenge with delays in diagnosis reported in between 15%[6] and 41%[7] of patients. These delays may result in further, preventable morbidity and mortality. Several factors leading to delays in diagnosis have been suggested. A trivial fall alongside chronic back pain in many of these patients may be misleading and not justify further evaluation by some patients and physicians.[8,9]

In SAD patients further evaluated by radiographs, fractures may still be difficult to diagnose. Factors attributed to this observation have been osseous proliferation with distortion of anatomy, increased density of ossified spinal ligaments, poorly outlined disc spaces, osteopenic bone, and a difficulty in viewing the cervicothoracic junction[8] (Figure 1). Furthermore, studies have shown hyperextension fractures as being the most common types of fractures in these patients.[4] Apart from being extremely unstable fractures, these fractures may be especially elusive owing to the fact that a significant part of these injuries involve the disc space with minimal no osseous damage.[10] This has led many researchers to recommend routine advanced imaging protocols for patients identified with SAD on radiography following even minor trauma.[4,8,9,11]

Although embraced by many, evidence supporting this practice is scarce with studies of only relatively small cohorts in the literature.[12,13] This paucity in evidence may defer medical centers from embracing the suggested imaging protocols. In this study, we aim to further elucidate the limitations of plain radiography for the diagnosis of hyperextension type injuries in SAD patients with an emphasis on thoracolumbar injuries, which have been less focused upon.

Materials and Methods

This study was approved by our institutional review board. The hospital's emergency room computerized database was searched for all patients who underwent a total spine computed tomography (CT) following a diagnosis of SAD on plain radiographs obtained after a minor fall between the years 2016-2018. A minor fall was defined as a fall with a low-energy mechanism from standing height or lower.

A fourth-year resident identified subjects confirming with the diagnosis of SAD based on accepted criteria.[10] Patients excluded were those who had a CT scan performed directly without radiography beforehand.

CT examinations of included subjects were further categorized into negative or positive for a hyperextension type thoracolumbar fracture. Fractures were diagnosed in accordance with the AOSpine thoracolumbar spine injury classification

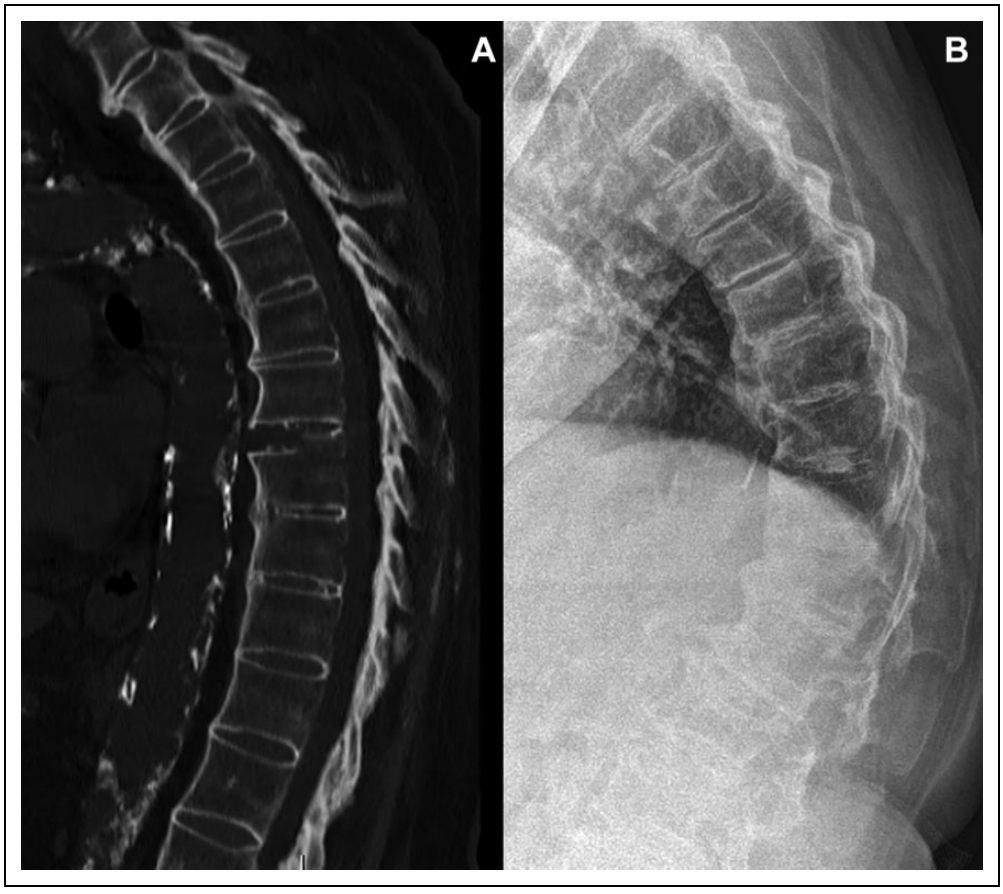

Figure 1. Computed tomographic image (a) and radiograph (b) of an 83-year-old female patient with a thoracic hyperextension type (AOSpine-B3) fracture.

system[14] (type B3). The results were validated by a senior spine surgeon with 25 years of experience.

AP and lateral spinal radiographs of the selected cohort were also scrutinized for quality by a fourth-year resident and reviewed by a senior spine surgeon. Radiographs of low quality, oblique instead of true lateral images, and those presenting with spinal instrumentation or other medical devices were excluded. High-quality radiographs were defined as those being of the greatest diagnostic value with no specific requirements. Additional factors found that may contribute to difficulty in fracture diagnosis were diagnosed osteoporosis and previous fractures. These were found in 16% and 20% of patients whose radiographs were eventually selected, respectively. Patient demographics are further presented in Table 1. A high-quality presentation with 50 randomly situated anteroposterior (AP) and lateral radiographs was created. Of these, 24 contained a hyperextension type fracture diagnosed by CT, 15 in the thoracic spine and 9 in the lumbar. Six radiographs were of patients diagnosed with AS and the remaining 44 of patients diagnosed with DISH. Vertebral level was labeled, and images were preadjusted for optimal contrast. A total of twelve physicians were given the presentation and requested to classify radiographs into negative (without a fracture) and positive (with a fracture) and to register the fracture level when present. Physicians included four practicing senior spine surgeons, 4 senior and 4 junior orthopedic residents. All physicians were certified for the interpretation of radiographs and for emergency room (ER) discharge of patients. Spine surgeons included 1 with 1 year of experience, 1 with 3 years of experience, 1 with 4 years of experience, and 1 with 25 years of experience. For each examinee, the number of detected and missed fractures was registered. Interobserver agreement for fracture detection among the entire group of observers and within each of the subgroups was evaluated by Fleiss's kappa.[15] Comparison between diagnosis of thoracic and lumbar fractures was done using *t* test for equality of means.

Table 1. Summary of Patient Demographics.

	Fracture group		Nonfracture group	
Sex	Male 57%	Female 43%	Male 54%	Female 46%
Age, years	81 (61-92)	80 (70-96)	80 (65-97)	79 (67-92)

Results

The mean percentage of identified hyperextension type fractures on AP and lateral radiographs of the thoracolumbar spine was 40%, with a range of 29% to 58% (Table2). Significantly more fractures were identified by the spine surgeon group (mean: 55%, range 50%-58%) compared with the junior or senior orthopedic resident group (mean 32% in each group, range 29%-42% and 21%-50%, respectively). Further subgroup analysis found the percentage of identified fractures in the thoracic spine to be 26% (7%-60%) and the lumbar spine 55% (33%-89%). In the spine surgeon group, the mean percentage of identified thoracic fractures was 46% (33%-60%) and in the lumbar spine 55% (44%-89%). In the resident group, mean diagnosis of thoracic fractures stood at 20% (7%-33%) and lumbar fractures at 55% (33%-78%). There was no difference between the senior and junior resident groups. Percentage of fracture identification and subgroup analysis is further specified in Table 2. False positive of a hyperextension type fracture occurred in 27%, with a range of 12% to 58%. Subgroup analysis of the false positive rates found a mean 18% (range 12%-23%) in the spine surgeon group, 38% (range 27%-30%) in the senior resident group, and 25% (range 12%-57%) in the junior resident group. Interobserver agreement was found to be 0.373 for the whole group, 0.394 for spine surgeons, 0.355 for senior orthopedic residents, and 0.326 for junior orthopedic residents ($P < .001$). The difference between identification of thoracic and lumbar fractures was statistically significant ($P = .009$).

Discussion

An increase in trauma patients with spinal ankylosing deformities may be anticipated[5] largely due to change in patient demographics, including an increase in age and prevalence of associated comorbidities such as diabetes mellitus and obesity. An example of this may be the steadily increasing number of publications studying the subject.[8] With increased focus, alongside the dread of delayed diagnosis leading to disastrous complications, recommendations for advanced imaging protocols have been made.[4,8,9] Most recently, guidelines published by the German Society for Orthopedics and Trauma[11] have recommended CT scans for all trauma patients with SAD and additional magnetic resonance imaging (MRI) when still in doubt after CT or with presence of neurological involvement. Although strongly recommended, there is a paucity in evidence supporting this protocol, especially in thoracolumbar trauma.

In their study of cervical fractures in AS patients, Koivikko et al[12] studied a cohort of 12 trauma patients with available

Table 2. Percentage of Fracture Diagnosis.

Reader	Lumbar spine, %	Thoracic spine, %	Entire spine, %
Spine surgeon 1	89	33	54
Spine surgeon 2	67	40	50
Spine surgeon 3	44	60	54
Spine surgeon 4	67	53	58
Mean percentage	67	47	54
Senior resident 1	44	7	21
Senior resident 2	33	20	25
Senior resident 3	67	13	33
Senior resident 4	78	33	50
Mean percentage	56	18	32
Junior resident 1	55	13	29
Junior resident 2	67	7	29
Junior resident 3	67	27	42
Junior resident 4	33	27	29
Mean percentage	56	19	32

radiographs and CT studies. Two emergency radiologists interpreted the studies in consensus. The majority of the cohort's radiographs failed to include the entire cervical spine (11/12, 92%), only 48% of all fractures were detected and only 33% of transverse fractures were detected. Wang et al[13] studied a series of 12 patients with AS diagnosed with spinal fractures at their institution. MRI, CT, and radiographs were evaluated by 2 radiologists separately and then discussed. In their study, 80% (8/10) of anterior longitudinal ligament tears, 55% (6/11) of posterior column fractures and none of the 2 occult fractures were identified on radiographs.

Our study supports these findings by further elucidating the reduced utility of X-rays in this patient population. Similar to Koivikko et al[12] and Wang et al,[13] we report a relatively low detection rate for unstable hyperextension thoracolumbar fractures of between 21% and 58%, depending on the observers' clinical experience. Although a mean of 55% fracture diagnosis for spine surgeons is higher than that reported in previous studies, this number is still unacceptable due to the significant number of undiagnosed patients. The lower rate of fracture diagnosis in the thoracic spine raises further concern due to possible spinal cord injury at these levels. An even more troubling finding is the lower fracture diagnosis rate of less experienced physicians. Though unfortunate, often these are the practitioners that are responsible for the primary treatment in the emergency setting of this patient population. An additional important weakness of the use of spinal radiographs for the detection of fractures in this cohort is the low interobserver agreement seen across all observer groups regardless of experience. When applying the interpretation of interobserver agreement using the kappa coefficient by Landis and Koch,[16] our finding of kappa = 0.394 for spine surgeons and 0.373 for all 12 raters can be deemed but "fair" with substantial agreement being defined by the authors as 0.6 to 0.8.

Our study has certain limitations. First, due to technical issues, radiograph contrast was preset. Although done so for the best image as perceived by the senior author, subjective reader preference may differ. Second, radiologists were not included as readers in our study. Though orthopedic surgeons are highly qualified to interpret musculoskeletal radiographs,[17] with even senior surgical residents reported to be accurate in interpreting radiographs in spinal trauma,[18,19] additional assessment of radiologists in our study may have had added value.

In our study, we assessed the limitations of plain radiography in SAD patients following spinal trauma. We believe that further research focusing on the utility of advanced imaging protocols such as MRI and CT would further complete the understanding of how to assess this patient population and establish evidence for globally accepted imaging protocols.

Conclusions

This study further supports the premise that the simple spinal radiographs are inefficient for the diagnosis of hyperextension type thoracolumbar fractures in patients with spinal ankylosis. Even for experienced spine surgeons, an unacceptable rate of fractures was left undiagnosed. The poor interobserver agreement rate further amplifies this finding. The even poorer rate of fracture diagnosis for less experienced physicians who usually treat these patients in the emergency room setting further strengthens the recommendation for advanced imaging in this patient group.

Declaration of Conflicting Interests

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