Practice Management Guidelines for the Screening of Thoracolumbar Spine Fracture

Eastern Association for the Surgery of Trauma:
Practice Management Guideline Committee

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I. Statement of the Problem

Fractures to the thoracolumbar spine (TLS) commonly occur due to major trauma mechanisms. In one series, 4.4% of all patients arriving at a level 1 Trauma Center were diagnosed as having TLS fracture. [1] Approximately 19-50% of these fractures in the TLS region will be associated with neurologic damage to the spinal cord. [2-4] Other fractures without neurologic injury can be accompanied by long term pain and diminished quality of life, particularly if the diagnosis has been delayed [4]. Reid et al found a higher incidence of neurologic deficit (10.5% vs. 1.4%) when fracture identification was delayed, underscoring the need for early diagnosis of TLS fracture. [5] Determination of the injury to this region of the spine is a common problem encountered by those caring for acutely injured patients. Radiographic screening of the spinal axis can be performed by a number of means. Plain radiography, computed tomography (CT) and magnetic resonance imaging (MRI) all have roles in the screening and evaluation of acute traumatic injuries to the thoracolumbar spine.

Although there are numerous clinical studies addressing screening of the thoracolumbar spine, to date there are no randomized studies and only a few prospective studies specifically addressing the subject. Several questions are of particular concern for medical, economic and legal reasons.

II. Process

a. Identification of references

A computerized search of the National Library of Medicine and the National Institutes of Health MEDLINE database was undertaken using the PubMed Entrez (www.pubmed.gov) interface. The primary search strategy was developed to retrieve English language articles focusing on diagnostic examination of potential thoracolumbar spine injury published between 1995 and March 2005; review articles, letters to the editor, editorials, other items of general commentary, and case reports were excluded from the search, as well as items limited to discussion of osteoporotic or malignancy-associated fractures. The primary search query retrieved approximately 500 citations: (lumbar vertebrae[mh] OR thoracic vertebrae[mh] OR (thoracic[tiab] AND (spine[tiab] OR spinal[tiab])) OR lumbar[tiab] OR thoracolumbar[tiab] OR lower spine[tiab]) AND (spinal injuries[mh] OR spinal cord injuries[mh]) AND (wounds and injuries[mh]) AND

(diagnosis[sh] OR tomography, x-ray computed[mh] OR CT[tiab] OR plain film*[tiab] OR radiography[tiab]) AND eng[la] AND humans[mh] AND 1995:2005[dp] NOT (letter[pt] OR case reports[pt] OR comment[pt] OR editorial[pt] OR news[pt] OR review[pt] OR osteoporosis[mh] OR spinal neoplasms[mh]).

Titles and abstracts were reviewed to determine relevance and identify articles which included primary data, with consultation of the full-text article when the citation/abstract data was inadequate. To supplement this search strategy, the PubMed "Related Articles" feature was used to review the first 100 related citations for each of the selected articles retrieved by the primary strategy. This process identified 29 articles which dealt with the determination of thoracolumbar spine stability in the first few hours after trauma. Additional articles that were chosen outside of the above search were primarily original studies of large groups of patients, or smaller, well-conducted studies addressing specific questions relevant to this practice guideline. Following recommendations made after presenting the practice guideline at EAST, other references were included that were not identified in the initial searches.

b. Quality of the references

The Eastern Association for the Surgery of Trauma: "Utilizing Evidence Based Outcome measures to Develop Practice Management Guidelines: A Primer" was utilized as a quality assessment instrument applied to the development of this protocol.

The workgroup for the Practice Management Guidelines for the Diagnosis of Traumatic Blunt Thoracolumbar Spine Injury consisted of: 15 Trauma Surgeons, 1 Neurosurgeon and 1 Orthopedic Spine Surgeon. Articles were distributed among committee members for formal review. Each article was entered into a review data sheet that summarized the main conclusions of the study and identified any deficiencies in the study. Furthermore, reviewers classified each reference as Class I, Class II, or Class III data. An evidentiary table was constructed using the 69 references that were identified. (Table 1) Recommendations were made on the basis of the studies included in this table. The quality assessment instrument applied to the references was that developed by the Brain Trauma Foundation and subsequently adopted by the EAST Practice Management Guidelines Committee [6]. Articles were classified as Class I, II or III according to the following definitions:

> **Class I**: A prospective randomized clinical trial. There was no Class I articles reviewed.
>
> **Class II**: A prospective non-comparative clinical study or a retrospective analysis based on reliable data. 13 Class II articles were reviewed.

Class III: A retrospective case series or database review. 56 Class III articles were reviewed.

Due to the lack of any Class I references no Level I recommendations could be made regarding the questions at hand. Level II recommendations were supported by Class II data, were thought to be reasonably justifiable by available scientific evidence and strongly supported by expert opinion. Level III recommendations were based on Class III data, where adequate scientific evidence is lacking, but the recommendation is widely supported by available data and expert opinion.

III. Recommendations

a. Does a patient who is awake without distracting injuries require radiologic workup or clinical exam?

i. Level I: There is insufficient evidence to support a Level I recommendation for the management guideline.

ii. Level II: The papers reviewed provide evidence to support (3) Level II recommendations.

1. Trauma patients should be clinically examined by a qualified attending physician.

    a. Those qualified include: Trauma surgeons, emergency physicians, or a spine surgeons (Orthopedic or Neurosurgery).

2. Trauma patients that are awake, without any evidence of intoxication with ethanol or drugs, with normal mental status, neurological, and physical examinations are able to be cleared clinically.
3. Mechanism of injury is an important determanent for further workup for this category of patients. If a high energy mechanism of injury was known or suspected, radiographic screening is warranted.
    a. Falls from significant height (> 10 feet), motor vehicle / motorcycle / all-terrain vehicle crash with or without ejection, pedestrians struck, assault, sport / crush accident, bicycle, and a concomitant cervical spine fracture were considered to have high energy mechanism of injury.

iii. Level III: There is level III evidence to further support the above mentioned level II recommendations.
    1. In general falls from significant height, motor vehicle crashes, struck pedestrians, etc. were considered to have high energy, mechanism of injury.

b. Does a patient with a distracting injury, altered mental status, or pain require radiologic examination?

i. Level I: There is insufficient evidence to support a Level I recommendations for the management guideline.

ii. Level II:

1. Radiologic workup is indicated for high energy mechanism of (previously noted) injuries including:
    a. Altered mental status, evidence of intoxication with ethanol or drugs, distracting injuries, neurologic deficits, and spine pain or palpation tenderness.
2. Multi-detector CT-scan with reformatted axial collimation is superior to plain films in the screening of the thoracolumbar spine for boney injury.
3. CT-scan scout films can be used for spine assessment.

iii. Level III:

1. CT scan may be associated with less overall radiation exposure than plain films.
2. Ligamentous injury without boney injury of the thoracolumbar spine is extremely rare. However, MRI is indicated for patients with neurologic deficits, abnormal CT scans, or clinical suspicion despite normal radiographic evaluation suggesting an unstable injury.
3. Plain films are adequate for the evaluation of the thoracolumbar spine if the patient did not require CT scan for some other reason.

c. Does the obtunded patient require radiologic examination?

i. Level I: There is insufficient evidence to support a Level I recommendation for the management guideline.

ii. Level II:

    1. Multi-detector CT-scan with reformatted axial collimation is superior to plain films for the screening of the thoracolumbar spine for boney injury.

iii. Level III:

    1. The obtunded patient, due to intoxication or closed head injury, presenting at a center without CT scan capability, should be transferred to nearest available trauma center.

Addendum:

1. The use of CT scan for screening blunt trauma patients for thoracolumbar spine injuries as the only screening modality decreases radiation exposure and decreases the time to diagnosis of an injury. Most blunt trauma patients commonly undergo CT scan of the head, chest, abdomen, and pelvis. Multi-detector CT scans have the software capability to reformat boney images in addition to soft tissue during an initial radiographic examination.
2. For patients with neurologic deficits referable to a thoracolumbar spine injury, and particularly those with normal plain films, it is extremely important to obtain an MRI scan as soon as possible after admission to the Emergency

Department. Early decompression of mass lesions, such as traumatic herniated discs or epidural hematomas, is also likely to improve neurologic outcome.

3. The ultimate evaluation of all radiographic studies will be the responsibility of attending radiologists. However, attending level trauma surgeons, emergency medicine physicians, neurosurgeons, and orthopedic spine surgeons are considered qualified to properly interpret thoracolumbar spine radiographs. Based on that interpretation, their clinical evaluation of the patient, and after proper documentation in the patients' medical record, they may "clear" the thoracolumbar spine, and remove thoracolumbar spine precautions.

IV. Scientific Foundation

a. Historical Background

Thoracolumbar spine injury remains a source of morbidity and mortality in the trauma patient. [4, 7] The need for screening radiographs of the cervical spine has been well recognized. Screening for cervical spine injury has been studied and analyzed, culminating in practice management guidelines by the Eastern Association for the Surgery of Trauma in 1998. [8, 9] Screening trauma patients for thoracolumbar injury, in contrast, has not been studied as extensively and is the subject to more controversy. [1, 10-19] Most clinicians would agree that radiographic evaluation of the spine should be obtained in

patients with back pain, tenderness, or neurologic deficit after blunt trauma, [1, 16] inability to perform an examination [20], altered mental status [12, 21], multiple or distracting injuries or the presence of other spinal fractures [4, 12]. Routine radiographic screening of alert, asymptomatic patients, however, is controversial. [18, 20, 22]

Certainly, the absence of symptoms does not exclude injury to the TLS. Frankel et al found that only 60% of trauma patients with confirmed TL fracture were symptomatic [12]. Cooper and associates reported a review from Maryland's Shock Trauma Center of 183 TLS fractures in which 110 patients who were neurologically intact with a Glasgow Coma Scale score between 13 and 15, considered amenable to clinical examination. Thirty-four (31%) of these patients were recorded as having no pain or tenderness, yet all had fractures.[1].The evidence would suggest that many of these fractures are not truly asymptomatic but rather occult fractures due to the presence of intoxication or unreliable physical exam.

Fractures of the thoracolumbar spine have historically been diagnosed with the combinations of plain radiographs (anterior-posterior and lateral) and physical exam. Plain radiographs are the current the gold standard for the evaluation of fracture to the TL spine [13, 23] despite the difficulty in interpretation of these X-rays and the rate of missed injuries [2, 13, 24-26] Screening criteria for the identification of TL fractures has been subject to

wide variation among trauma centers. The current guidelines are intended standardize practice in high risk patients to identify which patients require radiologic exam, and which radiologic exam is most appropriate.

b. Risk Factors for Thoracolumbar spine fractures

Multiple mechanisms of injury are proposed as important risk factors for the development of TLS fracture. These include falls greater than 10 feet, ejection from a motor vehicle, motorcycle crashes, high-velocity injuries; pedestrians struck by motor vehicles, and generalized tonic-clonic seizure. [12, 16, 19, 22, 27-32] With few exceptions [1, 12, 36], however, the literature does not support radiographic screening on the basis of mechanism alone.

It is generally accepted that alterations in sensorium either from head injury, shock, or intoxication may mislead the physical exam [1, 12, 16, 19, 20, 22, 29, 33-35], and all but two studies [16, 18] found that thoracolumbar spine fracture may be asymptomatic.

Multiple studies have documented the phenomenon of multi-level, non-contiguous spinal fractures, implying that a fracture identified in any region of the spine is an indication for full, radiological spinal survey. [29, 36-40]

Non-spinal injuries are associated with TLS fractures, either as a distraction to physical examination or as a marker of mechanism severity [4, 16, 19, 29, 33, 35, 41, 42]

Three prospective studies were reviewed; Terregino et al. found that in conscious patients with normal mental status and no distracting injury, the absence of back pain or tenderness had a 95% negative predictive value for TLSF. [20] Holmes et al. and Frankel et al. defined screening criteria for TLS fractures and applied these criteria prospectively to 2884 patients with blunt trauma mechanisms. The sensitivity and negative predictive value of their screening criteria was 100%. [12, 35]

The literature supports no further workup in asymptomatic patients with normal mental status, no distracting injury, and normal physical examinations. The remainder of patients should undergo radiological workup.

c. Evaluation of the Evidence Supporting Screening with plain films

There is little data to support using plain film radiographs to diagnose TLS fractures, although this has remained the radiological gold standard by default [26, 43-45]. Despite this, plain films are likely adequate for screening with one caveat: any patient with risk factors for TLS injury that does not otherwise require transfer to a trauma center or CT scan for any other reason may be cleared with plain films.

d. Evaluation of the Evidence Supporting Screening with CT Scan

Use of CT scan for evaluation of injuries to the head, chest and abdomen is common and considered routine for screening and diagnosis in trauma patients. It was inevitable that its use would expand to allow evaluation of the spine. Initially single-slice CT was used, where false diagnoses in computed tomography resulted from the difficulty in visualizing transverse fractures on first generation CT scans.[46, 47] As a result, computed tomography was historically recommended as a complementary examination to plain radiography in order to assess the extent and stability of spinal fractures, or to visualize areas of the spinal axis where plain radiography was difficult to interpret, particularly the upper thoracic region and cervicothoracic junction. [48]

First generation CT scans involve a single detector revolving around the patient. Helical CT scanning (2^{nd} generation) allows continuous motion of both the detector and the patient, resulting in continuous spiral data collection. The current multi-detector helical CT scan (3^{rd} generation), in which multiple detectors simultaneously collect source data volumetrically as the patient is advanced through rotating X-ray beams currently affords fast and accurate data collection. Multi-detector CT scans also allows reformatting of images after collection, virtually minimizing false negative exams which plagued first generation CT Scans.

The historical use of CT scan to evaluate TL fractures had been to identify poorly visualized areas of the spine or areas with questionable fracture seen on plain radiography. Ballock and Fontijne in separate studies from 1992 demonstrated the inadequacy of plain radiography in the diagnosis of TL fracture. [25, 46] Ballock's study in particular is of concern, 25% of the patients in the study would have had missed fractures if plain radiography alone was used for imaging. In a prospective study from 2002, Gestring et al used AP and Lateral scout films and axial images obtained in patients requiring abdominal/pelvis CT scan and compared these images with plain radiography [13] This study found 10 of 71 patients examined had TL fractures and the protocol rendered a 100% sensitivity and specificity in diagnosing fractures of the TL spine. Hauser in 2003, [26] prospectively studied 222 patients who required evaluation of the TL spine with both plain radiography and helical CT scan (3^{rd} generation) with 5 mm images. Thirty-six patients (17%) were found to have acute fractures of the TL Spine. Accuracy of CT scan was 99% compared with an accuracy of 87% for plain radiographs. CT scan was also able to identify acute versus old fractures.

Reformatted helical CT scan images were compared with plain radiographs by Sheridan in 2003. [2] This study reported the used 2.5 mm reformatted images. Reformatted CT scan of the chest/abdomen was accurate in screening for TL fractures. Sensitivity for thoracic fractures was 97% (compared with 62% for plain X-ray). For lumbar fractures, sensitivity was 95% (compared

with 86% by plain X-ray) Roos confirmed the accuracy of reformatted images in 2004, reporting a sensitivity and specificity if 98% and 97%. [49]

The current, available data support the use of current generation, multi-detector CT scan in the screening of trauma patients for TL spine fracture. When multi-detector helical CT scan has been performed of the chest/abdomen/pelvis, evaluation of frontal and lateral scout films with the axial images or reformatted images can replace conventional radiographs of the thoracolumbar spine [2, 13, 26, 50, 51]. Reformatting of images allows a superior visualization of the spine and may be appropriate for areas of high concern [2, 26, 49].

Routine CT scanning of the chest is not indicated for every injured patient. Selected patients who are at high risk for injury to the TL spine, however, can benefit from CT scan particularly if CT scan is simultaneously used for evaluation of the chest and intra-abdominal organs. For patients with low energy mechanisms, who require radiologic evaluation, plain radiography is likely sufficient. Areas of concern can be subjected to further exam by CT scan as needed. Concerns of radiation exposure have been addressed by Hauser et al. [26] No excess radiation exposure was reported, when integrated truncal CT scan is used, compared with organ and region specific plain radiographs. [26] This study also noted advantages in both time to diagnosis and cost savings for the trauma patient by the elimination of plain radiography.

e. Evaluation of the Evidence Supporting indication for MRI

Ligamentous injury of the thoracolumbar spine without boney injury is extremely rare [52-54](1-3).The indications for MRI of the thoracolumbar spine after blunt trauma are fractures with neurologic deficits, CT – scan findings, and pain on clinical exam without radiographic abnormalities concerning for ligamentous injury [55, 56](4,5). The thoracolumbar "burst" fracture occurs approximately 14-48% of the time, and a neurologic deficient is present 65% of patients. The soft tissue components of the injury including ligamentous disruption are not visualized with plain films or CT-scan and warrant early MRI. [57, 58](6-7)

V. Summary

There have been no prospective, randomized studies of the use (or non-use) of any single group of imaging studies for the acute determination of thoracolumbar spine stability. Therefore, there can be no "standard" for this parameter.

There have been numerous prospective and retrospective cohort studies of large and small numbers of trauma patients which provide insight into the incidence of thoracolumbar spine injuries following blunt trauma. Approximately 25% of patients meeting criteria for screening with CT-scan after blunt trauma will have a thoracolumbar spine injury. Computer tomography imaging of the boney spine has advanced with helical and

currently multi-detector images to allow reformatted axial collimation of images into 2 – dimensional and 3 – dimensional images. As a result, boney injuries to the thoracolumbar spine are commonly being identified. Most blunt trauma patients require computer tomography to screen for injuries. This has allowed the single admitting series of CT - scans to also included screening for boney spine injuries. However, all of the publications fail to clearly define the criteria used to decide who gets radiographs or CT-scans. No study has carefully conducted long-term follow-up on all of their trauma patients to identify all cases of thoracolumbar spine injury missed in the acute setting. Thus, the true incidence of thoracolumbar spine injury is not known.

It is clear from the literature that no imaging modality is accurate 100% of the time. Most studies have found that radiographs of the thoracolumbar spine (AP, lateral), are commonly inadequate, especially in obese patients, provided only a sensitivity and specificity of 60-70%. With the currently advances in computer tomography, plain films play only a limited part in the initial screening for thoracolumbar spine injuries.

VI. Future Investigation

Future studies should prospectively evaluate and identify those imaging studies which should be utilized to make an acute determination of thoracolumbar spine injury and stability.

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55. MacMillan M, Stauffer ES. Transient neurologic deficits associated with thoracic and lumbar spine trauma without fracture or dislocation. Spine, 1990. 15(6): p. 466-469.

56. Riggins RS, Kraus JF. The risk of neurologic damage with fractures of the vertebrae. Journal of Trauma, 1977. 17(2): p. 126-133.

57. Denis, F. The three column spine and its significance in the classification of acute spinal injuries. Spine, 1983. 8: p. 817-831.

58. McAfee PC, YuanH, Fredrickson BE, Lubicky JP. The value of computer tomography in thoracolumbar fracures. Journal of Bone and Joint Surgery, 1983. 65: p. 461-472.

First Author	Year	Title	Synopsis	Reference
Anderson S	1996	Delayed diagnosis of thoracolumbar fractures in multiple-trauma patients.	The decision to selectively radiograph spines should consider the mechanism of injury, confounders to physical examination, and clinical signs and symptoms of back injury	Academic Emergency Medicine 3: 832-839
Bachulis BL	1987	Clinical indications for cervical spine radiographs in the traumatized patient	Recommendation is to screen cervical spine for anyone who has neck pain, decreased level of consciousness, neurological deficit of cervical origin. Retrospective review.	American Journal of Surgery 153: 473-478
Ballock RT	1992	Can burst fratures be predicted from plain radiographs?	Plain films may misdiagnosis fracture type (burst versus wedge) in a significant number of cases. CT scan is recommended for any spinal fracture to characterize its pattern.	J Bone Jt Surg Br 1992 Jan;74(1):147-50

Bensch FV	2004	Spine fractures in falling accidents: analysis of multidetector CT findings.	CT scan is sensitive in evaluation of spinal fracture. Mechanism of injury may be predictive of need for radiographic workup of TL spine.	Eur Radiol. 2004 Apr;14(4):618-24
Blauth M	2000	Spinal fractures in the elderly and their treatment	Odontoid fractures and TL spine compression fractures are common finding in elderly patients after falls.	Orthopade 29(4): 302-317
Brandser EA	1997	Thoracic and lumbar spine trauma	A review of injury types and patterns, as well as radiologic workup of injuries.	Radiology Clinics of North America 35: 533-537.
Brandt MM	2004	Computed tomographic scanning reduces cost and time of complete spine evaluation.	CT scan is superior to plain radiographs for diagnosis and/or screening of TL spine fractures in trauma patients. Patients in this study underwent both conventional radiography as well as CT scan. Smaller study than Radiology 2003. Mechanism of injury may be predictive of need for radiographic workup of TL spine.	J Trauma. 2004 May;56(5):1022-6
Brant-Zawadzki M	1981	CT in the evaluation of spine trauma	CT shows superior imaging of bony detail and soft tissue injury compared with plain radiographs. Recommend its u se after screening studies are positive.	American Journal of Roentgenology 136(2): 369-375.
Calendine CL	2002	Is there need for thoracic spine radiographs following a negative chest CT in trauma patients?	CT evaluation is adequate for the thoracic spine and obviates the need for plain radiographs.	Emergency Radiology 9(5): 254-256.
Calenoff L	1978	Multiple level spinal injuries: importance of early recognition	A review of 710 patients yielded a 4.5% rate of multiple non-contiguous vertebral injuries. Implies that full skeletal radiography should be performed.	American Journal of Roentgenology 130: 665-669.
Chang CH	2005	Distracting injuries in patients with vertebral injuries	In patients with distracting injuries, bony fracutres of any type were important for identifying patients with vertebral injuries.	Journal of Emergency Medicine 28(2): 147-152.

Cooper C	1995	Falls and major injuries are risk factors for thoracolumbar fractures: cognitive impairment and multiple injuries impede the detection of back pain and tenderness.	Patients with altered mental status or distracting injuries require radiographic screening for TL spine fracture as clinical exam may be unreliable or unavailable.	J Trauma. 1995 May;38(5):692-6
Dai LY	2004	Thoracolumbar fractures in patients with multiple injuries: diagnosis and treatment-a review of 147 cases.	Patients with significant mechanism of injury should be suspected of having TL spine fracture and further workup is required, including plain radiographs which must be read by experienced physicians.	J Trauma. 2004 Feb;56(2):348-55
Durham RM	1995	Evaluation of the thoracic and lumbar spine after blunt trauma.	Awake patients with normal neurological and spine examinations require no further screening. Patients with altered mental status, abnormal neurological exam, or a positive or equivocal spine exam require radiographic screening for TL spine fracture.	Am J Surg. 1995 Dec;170(6):681-4
Enderson BL	1990	The tertiary trauma survey: a prospective study of missed injury	Injuries may be missed on initial examination in trauma patients because off altered LOC, severity of injury and need for immediate operation, lack of symptoms, technical problems, and low index of suspicion. Missed spinal injuries may be associated with serious morbidity.	Journal of Trauma 29(12): 1643-1646.
Flohr T	2003	Image reconstruction and image quality evaluation for a 16-slice CT scanner.	16 slice CT scanner has excellent image quality and increased diagnostic capability compared to older CT scanners and plain radiographs.	Medical Physiology, 2003. 30: p. 832-845.
Fontijne WPJ	1992	CT scan prediction of neurological deficit in thoracolumbar burst fractures.	CT scans may predict neurological deficit, but there is no mention of screening criteria.	J Bone Joint Surg Br. 1992 Sep;74(5):683-5

Frame SB	1992	The multiply fractured spine: incidence and need for complete spine radiographic evaluation.	Patients with cervical spine fracture are also likely to harbor thoracic spine fracture. The presence of cervical spine fracture should prompt full vertebral survey.	Journal of Trauma 32: 954-959.
Frankel HL	1994	Indications for obtaining surveillance thoracic and lumbar spine radiographs.	Clinical exam alone may be inadequate to exclude significant thoracic or lumbar spine fracture. Patients with abnormal neurological exam, significant mechanism, pain/tenderness on exam, intoxication, and significant associated injuries require radiographic workup. This paper advocates using plain radiographs for clearance of TL spine.	J Trauma. 1994 Oct;37(4):673-6
Gestring ML	2002	Evaluation of the lower spine after blunt trauma using abdominal computed tomographic scanning supplemented with lateral scanograms.	High definition CT scout radiographs of TL spines were superior to plain radiographs in diagnosing fracture. Asymptomatic patients may have significant fractures, and clinical exam alone is inadequate to exclude TL spine fracture, particularly in the setting of altered mental status, pain/tenderness on exam, and significant mechanism.	J Trauma. 2002 Jul;53(1):9-14
Gong	2004	Value of multidetector spiral CT in diagnosis of acute thoracolumbar spinal fracture and fracture-dislocation.	CT scan is sensitive and specific for TL spine fractures in trauma patients. There is no mention of screening criteria.	Chin J Traumatol. 2004;7(5):289-293.
Gupta A	1989	Multilevel spinal injuries. Incidence, distribution and neurological patterns.	Fractures occurred at multiple, non-contiguous levels in 9.7% of patients that were reviewed. Fracture at one level should prompt full vertebral survey.	Journal of Bone and Joint Surgery (British Volume) 71: 692-695.
Hauser CJ	2003	Evaluation of the lower spine after blunt trauma using abdominal computed tomographic scanning supplemented with lateral scanograms.	CT scan is more sensitive and specific than plain radiographs for the diagnosis of TL spine fractures. CT scan is also much faster than plain radiographs as it is usually done at the initial trauma evaluation.	J Trauma. 2003 Aug;55(2):228-34

Herzog C	2004	Traumatic injuries of the pelvis and thoracic and lumbar spine: does thin-slice multidetector-row CT increase diagnostic accuracy?	Multidetector CT scan is superior to plain radiographs for diagnosis of TL spine fractures. 3mm slices may be superior to 5mm slices for the detection of unstable fractures, but no fractures were missed with 5mm cuts.	Eur Radiol. 2004 Oct;14(10):1751-60
Hill D	1996	A population-based study of outcome after injury to car occupants and to pedestrians.	Pedestrian struck by motor vehicles are more likely to have increased severity of injury in comparison to vehicle occupants. High degree of suspicion for injury is needed for these injury patterns.	Journal of Trauma 37: 673-676.
Hirsh LF	1993	Thoracic spinal cord injury without spine fracture in an adult: case report and literature review.	Neurlogical deficit should prompt further workup, even in the absence of fracture.	Surgical Neurology, 1993. 40(1): p. 35-38.
Hoffman JR	1992	Low-risk criteria for cervical spine radiography in blunt trauma: a prospective study.	Patients that lack cervical spinous tenderness, intoxication, altered level of alertness, or other severely painful injury can be cleared clinically and do not require radiographic workup.	Annals of Emergency Medicine 21: 1454-1460.
Holmes JF	2003	Prospective evaluation of criteria for obtaining thoracolumbar radiographs in trauma patients.	Specific clinical criteria are associated with increased risk of TL spine fractures and an inability to rely on clinical examination alone for TL spine clearance. Patients with pain, tenderness, altered sensorium, abnormal peripheral neurological exam, and distracting injury require at least plain radiographs. If none of the previous risk factors are present, the patient can be cleared clinically, although no confirmatory tests were performed.	J Emerg Med. 2003 Jan;24(1):1-7
Hsu JM	2003	Thoracolumbar fracture in blunt trauma patients: guidelines for diagnosis and imaging.	Clinical examination may be inadequate to exclude TL spine injury particularly in the setting of back pain/tenderness, local exam findings consistent with fracture, decreased level of consciousness, cervical spine injury, distracting injury, and intoxication. This paper states that plain radiographs should be obtained in patients at risk, although they do say that CT is superior to plain films on the basis of other studies.	Injury. 2003 Jun;34(6):426-33
Hu R	1996	Epidemiology of incident spinal fracture in a complete population	The incidence of spinal fracture in a retrospectively reviewed population in Canada was 64/100000. TL spine fracture was more common than cervical fracture.	Spine. 21(4): 492-499.

Keenen TL	1990	Non-contiguous spinal fractures	6.4% incidence of non-contiguous spinal fractures in 817 patients retrospectively reviewed. Injury at one level should prompt full vertebral survey.	Journal of Trauma 30: 489-491.
Kim N-H	1999	Neurologic injury and recovery in patients with burst fracture of the thoracolumbar spine.	CT scan is useful in predicting outcome in the setting of vertebral fracture. Canal compromise and disruption of posterior elements is associated with greater degree of neurological impairment.	Spine. 1999 Feb 1;24(3):290-3; discussion 294.
Kirkpatrick AW	2002	Thoracolumbar spine fractures: is there a problem?	Patients without overt symptoms of spinal fracture may have their symptoms masked by concomitant injury.	Canadian Journal of Surgery 45(1): 21-24.
Koizumi M	2002	Upper thoracic spinal cord injury without vertebral bony lesion: a report of two cases	MRI is useful in the identification of spinal cord injury without vertebral fracture. The mechanisms of these injuries are speculative.	Spine, 2002. 27(21): p. E467-470.
Kreipke DL	1989	Reliability of indications for cervical spine films in trauma patients	C spine radiographs should be obtained in patients with abnormal neurologic findings or symptoms of cervical pain. In alert, asymptomatic patients, radiographs may be omitted.	Journal of Trauma 29: 1438-1439
Kupferschmid JP	1989	Thoracic spine injuries in victims of motorcycle accidents	Motorcycle accidents are associated with a high incidence of TL spine fracture. A patient with this mechanism should undergo radiographic workup.	Journal of Trauma 29: 593-596
Lund PJ	1997	Traumatic thoracolumbar facet instability: characteristic imaging findings.	Plain films, CT, and MRI are useful in identifying thoracolumbar facet instability, particularly in the setting of motor vehicle collisions and flexion-distraction injury mechanisms.	Skeletal Radiol. 1997 Jun;26(6):360-5

MacMillan M	1990	Transient neurologic deficits associated with thoracic and lumbar spine trauma without fracture or dislocation	Neurologic deficit is an indication for further workup to exclude vertebral injury in the setting of trauma.	Spine, 1990. 15(6): p. 466-469
Marion DW	1996	Practice Management Guidelines For Identifying Cervical Spine Injuries Following Trauma		EAST PMG, www.EAST.org
Martijn A	1991	The diagnostic value of interpediculate distance assessment on plain films in thoracic and lumbar spine injuries.	Specific plain film findings suggestive of spinal injury. Pre multi-row detector CT.	J Trauma. 1991 Oct;31(10):1393-5
McAfee PC	1983	value of computer tomography in thoracolumbar fracures	CT scan with reconstruction is superior to plain radiographs and myelography at delineating vertebral injury, particularly of the posterior elements. This is useful for planning fixation technique.	Journal of Bone and Joint Surgery, 1983. 65: p. 461-472
McGrory BJ	1993	Diagnosis of subtle thoracolumbar burst fractures. A new radiographic sign.	Not useful to make a statement with regard to screening, although, there is a suggestion that CT scan is more sensitive for identification of TL spine fracture.	Spine. 1993 Nov;18(15):2282-5

Meek S	1998	Fractures of the thoracolumbar spine in major trauma patients	Case reports of trauma patients with asymptomatic spinal fracture, advocating that full vertebral survey may be indicated for evaluation in trauma patients.	Britich Medical Journal, 1998. 317:1442-1443
Meldon SW	1995	Thoracolumbar spine fractures: clinical presentation and the effect of altered sensorium and major injury.	Clinical exam alone is unable to exclude TL spine fracture in the setting of altered sensorium, distracting injury, neurological deficit, or pain/tenderness on exam. Plain films should be obtained on these patients for screening.	J Trauma. 1995 Dec;39(6):1110-4
Meyer PR	1989	Surgery of Spine Trauma	Text describing various diagnostic modalities for spinal injury. Non-spinal injury thought to be significant marker of spinal injury, particularly blunt chest injury.	
Murphey MD	1989	Diagnostic imaging of spinal trauma	Review of various diagnostic modalities for spine trauma. Plain films are regarded as the gold standard	Radiology Clinics of North America 27: 855-872
Oner FC	2002	Some complications of common treatment schemes of thoracolumbar spine fractures can be predicted with magnetic resonance imaging: prospective study of 53 patients with 71 fractures.	MRI may be useful for following known fractures and predicting outcomes in TL spine fractures. Polytrauma patients were excluded from this study. Does not address screening.	Spine. 2002 Mar 15;27(6):629-36
Oner FC	2002	Classification of thoracic and lumbar spine fractures: problems of reproducibility. A study of 53 patients using CT and MRI.	MRI may be used to classify known spine fractures. No mention is made with regard to screening patients in the acute setting.	Eur Spine J. 2002 Jun;11(3):235-45

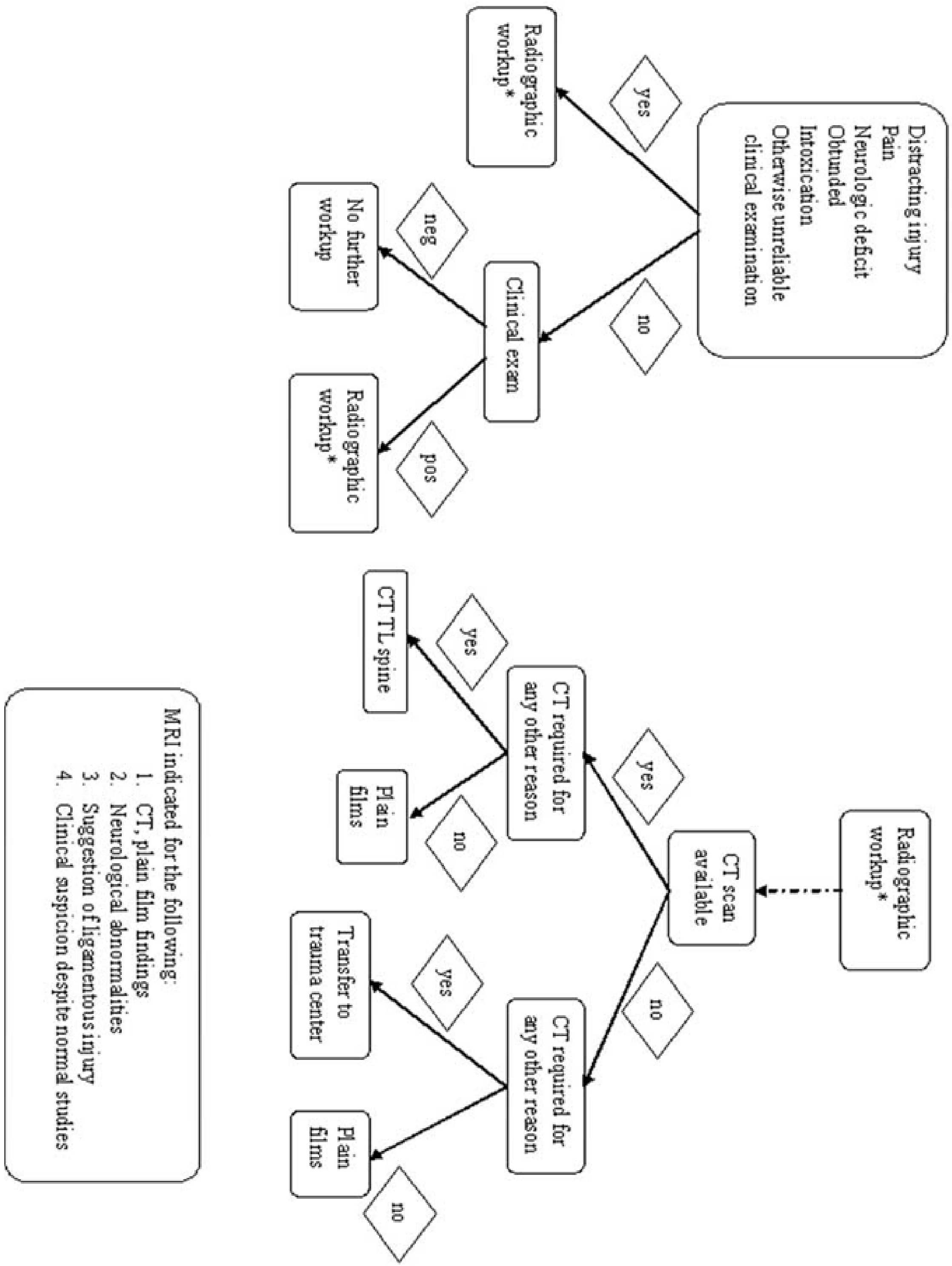
Oner FC	1999	MRI findings of thoracolumbar spine fractures: a categorisation based on MRI examinations of 100 fractures.	MRI may be used to classify known spine fractures. No mention is made with regard to screening patients in the acute setting.	Skeletal Radiol. 1999 Aug;28(8):433-43
Pathria MN	1991	Spinal Trauma.	Review that makes statements about classifications of spinal injuries. Variety of imaging modalities are discussed including plain films, tomography, CT, and MRI.	Radiology Clinics of North America 29(4): 847-865
Petersilge CA	1995	Thoracolumbar burst fractures: evaluation with MR imaging.	MRI appears useful in detecting ligamentous injury of the TL spine, and is likely more useful for fracture evaluation in the post-acute setting.	Radiology. 1995 Jan;194(1):49-54
Post MD	1982	The value of computed tomography in spinal trauma	Retrospective review of CT scans in trauma patients. CT scan with or without myelography is superior to plain films or conventional radiography.	Spine, 1982. 7: p. 417-431.
Reid DC	1987	Etiology and clinical course of missed spine fractures.	Prospectively obtained review of trauma patients with vertebral injury. 22.9% of cervical injuries and 4.9% of TL spine injuries were diagnosed in a delayed fashion. Risk factors for delay were intoxication, multiple injuries, altered level of consciousness, and multilevel spinal injury.	Journal of Trauma 27(9): 980-986
Rhea JT	1989	frequency and significance of thoracic injuries detected on abdominal CT scans of multiple trauma patients	CT scan is more sensitive than plain films in the detection of spinal fracture than plain films. Patients that only undergo abdominal CT scans should be scrutinized for signs of chest injury.	Journal of Trauma 29: 502-505.

Riggins RS	1977	The risk of neurologic damage with fractures of the vertebrae	Vertebral injury has a high association with neurological deficit, most notably with cervical fracture (39%). Motor vehicle collisions are major cause for these injuries.	Journal of Trauma, 1977. 17(2): p. 126-133.
Roberge RJ	1988	Selective application of cervical spine radiography in alert victims of blunt trauma: a prospective study.	Retrospective review of risk factors for cervical spine injury in trauma patients. No injuries were noted in alert, non-intoxicated, neurolgically intact patients who had no complaints of neck discomfort upon questioning or palpation. Radiographs are unnecessary in this population.	Journal of Trauma 28: 784-788.
Robertson A	2002	Spinal injuries in motorcycle crashes: patterns and outcomes	Review of motorcyclists and patterns of injury. Thoracic spine was most common vertebral level injured, although protocols concentrate on cervical spine clearance. Thoracic or lumbar spine was injured in 84.2% of their popluation.	Journal of Trauma 53(1): 5-8.
Roos JE	2004	MDCT in emergency radiology: is a standardized chest or abdominal protocol sufficient for evaluation of thoracic and lumbar spine trauma?	CT with 2.5mm cuts is as sensitive as 1mm cuts for evaluation of TL spine fractures.	AJR Am J Roentgenol. 2004 Oct;183(4):959-68

Saboe LA	1991	Spine trauma and associated injuries	Review of trauma patients found that 82% of thoracic and 72% of l umbar fractures were associated with other nonspinal injuries. Multi-trauma patients should be treated as if a spinal injury exists.	Journal of Trauma 31(1): 43-48.
Samsani SR	2003	Thoracic spinal cord injury without radiographic abnormality in a skeletally mature patient: a case report	Case report of spinal cord injury without skeletal abnormality in the thoracic spine.	Spine, 2003. 28(4): p. E78-80.
Samuels LE	1993	'Routine' radiologic evaluation of the thoracolumbar spine in blunt trauma patients: a reappraisal.	Patients with pain on physical exam require further radiographic workup to evaluate for TL spine fracture. Patients without signs/symptoms of pain or tenderness are unlikely to have fractures, although other clinical characteristics need to be considered before one can rely solely on clinical examination.	J Trauma. 1993 Jan;34(1):85-9
Sheridan R	2003	Reformatted visceral protocol helical computed tomographic scanning allows conventional radiographs of the thoracic and lumbar spine to be eliminated in the evaluation of blunt trauma patients.	CT scan (particularly helical reformatted 2.5mm cuts) is more sensitive and specific for diagnosis of TL spine fracture than plain radiographs. One noted advantage was a decreased time to clearance or diagnosis. There is potentially less radiation exposure with plain radiographs than CT.	J Trauma. 2003 Oct;55(4):665-9
Silvestro C	1995	On the predictive value of radiological signs for the presence of dural lacerations related to fractures of the lower thoracic or lumbar spine.	There is no statistically significant association between radiologic findings and the incidence of dural laceration. Dural laceration, however, is common in lower thoracic and lumbar fractures.	J Spinal Disord. 1991 Mar;4(1):49-53.

Stanislas MJC	1998	A high risk group for thoracolumbar fractures.	Patients with high velocity mechanism, decreased level of consciousness (GCS <= 10), head injury, or pelvis/lower extremity injury require radiographic workup for TL spine fracture. Plain radiographs are advocated, no mention of routine use of CT for screening.	Injury. 1998 Jan;29(1):15-8
Terregino CA	1995	Selective indications for thoracic and lumbar radiography in blunt trauma.	Patients with altered mental status, pain, or distracting injury require radiological workup of TL spine as clinical exam may be unreliable. Awake patients with normal mental status, neurological, and physical examinations are able to be cleared clinically.	Ann Emerg Med. 1995 Aug;26(2):126-9
Vaccaro AR	2001	The significance of thoracolumbar spinal canal size in spinal cord injury patients.	CT scan is useful in detecting spinal canal size and abnormalities. Changes in sagittal and transverse diameters are predictive of neurological deficit.	Spine. 2001 Feb 15;26(4):371-6.
van Beek EJR	2000	Upper thoracic spinal fractures in trauma patients - a diagnostic pitfall.	Patients in whom a complete neurological examination cannot be performed or is likely to be unreliable require radiological workup of spine for clearance.	Injury. 2000 May;31(4):219-23
Wintermark M	2003	Thoracolumbar spine fractures in patients who have sustained severe trauma: depiction with multi-detector row CT.	Multi-row detector CT scan is superior to plain radiographs for diagnosis and/or screening of TL spine fracture in trauma patients. Patients in this study underwent both conventional radiography as well as CT scanning for evaluation.	Radiology. 2003 Jun;227(3):681-9

Youssef JA	1995	Seizure-induced lumbar burst fracture	Case report of TL spine fracture in patient after generalized tonic-clonic seizure.	Spine 20(11): 1301-1303.


Distracting injury
Pain
Neurologic deficit
Obtunded
Intoxication
Otherwise unreliable clinical examination
yes
Radiographic workup*
no
Clinical exam
neg
No further workup
pos
Radiographic workup*
Radiographic workup*
CT scan available
yes
CT required for any other reason
yes
CT TL spine
no
Plain films
no
CT required for any other reason
yes
Transfer to trauma center
no
Plain films
MRI indicated for the following:
1. CT, plain film findings
2. Neurological abnormalities
3. Suggestion of ligamentous injury
4. Clinical suspicion despite normal studies