Screening for thoracolumbar spinal injuries in blunt trauma: An Eastern Association for the Surgery of Trauma practice management guideline

Sherry Sixta, MD, Forrest O. Moore, MD, Michael F. Ditillo, DO, Adam D. Fox, DO, Alejandro J. Garcia, MD, Daniel Holena, MD, Bellal Joseph, MD, Leslie Tyrie, MD, *and* **Bryan Cotton, MD, MPH**

BACKGROUND: Thoracolumbar spine (TLS) injuries have an incidence rate of 5% in blunt trauma patients. The Eastern Association for the Surgery of Trauma published Practice Management Guidelines for the Screening of Thoracolumbar Spine Fracture in 2007. The Practice Management Guidelines Committee was assembled to reevaluate the literature.

METHODS: A search of the United States National Library of Medicine and the National Institutes of Health database was performed using MEDLINE through PubMed (www.pubmed.gov). The search retrieved English-language articles from March 2005 to December 2011 that referenced traumatic TLS injuries and fractures. The questions posed were the following: (1) What is the appropriate imaging modality to screen patients for TLS injuries? (2) Which trauma patients require radiographic screening for TLS injuries? (3)Does a patient who is awake and alert without distracting injuries require radiologic workup to rule out TLS injuries?

RESULTS: Thirty-seven articles that referenced traumatic TLS injuries in association with screening published between March 2005 and December 2011 were collected and disseminated to the committee. Twelve were found to be relevant. Nine publications from the previous 2006 guidelines were reviewed and referenced to create and validate the updated guidelines.

CONCLUSION: Practice patterns have changed regarding screening blunt trauma patients for TLS injuries. Software reformatted multidetector computed tomographic scans are more sensitive and accurate than plain films. Multidetector computed tomographic scans have become the screening modality of choice and the criterion standard in screening for TLS injuries. The literature supports a Level 1 recommendation to validate this based on a preponderance of Class II data. Patients without altered mentation or significant mechanism may be excluded by clinical examination without imaging. Patients with gross neurologic deficits or concerning clinical examination findings with negative imaging should receive a magnetic resonance imaging expediently, and the spine service should be consulted. (*J Trauma Acute Care Surg*. 2012;73: S326–S332. Copyright © 2012 by Lippincott Williams & Wilkins)

KEY WORDS: Thoracic spine fractures; lumbar spine fractures; blunt trauma; practice management guidelines; screening for traumatic thoracolumbar injuries.

STATEMENT OF THE PROBLEM

Thoracic and lumbar spinal fractures are commonly encountered in blunt trauma patients. Approximately 50% of all vertebral fractures occur in the thoracolumbar spine (TLS), and the incidence of TLS fractures in trauma patients presenting to Level 1 trauma centers is 4% to 5%.[1] Neurologic injury to the spinal cord occurs in 19% to 50% of these patients, and a delay in diagnosis of TLS fractures can result in up to an eightfold increase in neurologic deficits.[2–9] Clinicians caring for acutely injured patients must rely on diagnostic techniques to be efficient and accurate so as to minimize the time to diagnosis and interventions. Often, blunt trauma patients that present acutely will undergo multidetector computed tomographic (MDCT) scans of the chest, abdomen, and pelvis to evaluate for injuries. Historically, plain films were also ordered for TLS screening; however, software reconstructed MDCT scans have become the universal screening modality in large-volume trauma centers. Modern computer software has the capability to reformat screening body CT scans without increased radiation, time, or cost. Magnetic resonance imaging (MRI) also plays a role in screening and evaluating patients for neurologic injury, ligamentous injury, and the need for operative intervention. The relevant questions regarding screening of the acute blunt trauma patient for TLS injuries are as follows:

1. What is the appropriate imaging modality to screen patients for TLS injuries?
2. Which trauma patients require radiographic screening for TLS injuries?
3. Does a patient who is awake and alert without distracting injuries require radiologic workup to rule out TLS injuries?

Submitted: March 31, 2012, Revised: August 14, 2012, Accepted: August 16, 2012.

From the Division of Acute Care Surgery (S.S., B.C.), Department of Trauma, University of Texas Health and Sciences, Houston, Texas; Division of Surgery (S.S.), Department of Trauma, Cooper University Hospital, Camden, New Jersey; Division of Trauma Surgery and Critical Care (A.D.F., L.T.), New Jersey Medical School, University of Medicine and Dentistry of New Jersey, Newark, New Jersey; Department of Trauma, Critical Care & Acute Care Surgery (F.O.M.), Banner Healthcare System, Phoenix, Arizona; Section of Trauma, Critical Care and Surgical Emergencies (M.F.D.), Department of Surgery, Yale New Haven Hospital, Yale School of Medicine, New Haven, Connecticut; Department of Trauma (A.J.G.), Ocala Health System, University of South Florida, Gainesville, Florida; Division of Traumatology, Surgical Critical Care, and Emergency Surgery (D.H.), University of Pennsylvania, Philadelphia, Pennsylvania; and Division of Trauma, Critical Care, and Emergency Surgery (B.J.), Department of Surgery, University of Arizona, Tucson, Arizona.

Supplemental digital content is available for this article. Direct URL citations appear in the printed text, and links to the digital files are provided in the HTML text of this article on the journal's Web site (www.jtrauma.com).

Address for reprints: Sherry Sixta, MD, Cooper University Hospital, Camden, NJ; email: Sixta-Sherry@CooperHealth.edu.

DOI: 10.1097/TA.0b013e31827559b8

PROCESS

Identification of References

A search of the National Library of Medicine and the National Institutes of Health database and MEDLINE was performed using PubMed (www.pubmed.gov). The search identified articles in the English language that addressed the screening or identification of TLS injury from March 2005 to December 2011. Articles that were categorized as review articles, letters to the editor, editorials, commentaries, and case reports were excluded from the query. Thirty-seven articles were distributed to the committee. Twelve of those articles were thought to be pertinent to the construction of the updated guidelines. An additional nine articles referenced in the previous Practice Management Guideline (PMG) were referenced to revise and validate the updated guidelines. An evidentiary table was then constructed using the 21 references (Supplemental Digital Content, Table 1 http://links.lww.com/TA/A201).

Quality of the References

Articles were classified in accordance with the Eastern Association for the Surgery of Trauma (EAST) primer on evidence-based medicine that was published in 2000. Articles are categorized as Class I, II, or II.

Class I: Prospective randomized clinical trial (no class I data exist).
Class II: Prospective clinical studies or retrospective analyses based on reliable data such as cohort, observational, prevalence, or case-control studies (14 references).
Class III: Retrospectively collected data based on database or registry review, case series, or expert opinion (7 references).

Recommendations were then classified as Level 1, 2, or 3 according to the following definitions as defined by the EAST primer on evidence-based medicine:

Level 1: The recommendation is convincingly justifiable based on the available scientific information alone. This recommendation is usually based on Class I data; however, strong Class II evidence may form the basis for a Level 1 recommendation, especially if the issue does not lend itself to testing in a randomized format. Conversely, low-quality or contradictory Class I data may not be able to support a Level 1 recommendation.
Level 2: The recommendation is reasonably justifiable by available scientific evidence and strongly supported by expert opinion. This recommendation is usually supported by Class II data or a preponderance of Class III evidence.
Level 3: The recommendation is supported by available data but adequate scientific evidence is lacking. This recommendation is generally supported by Class III data. This type of recommendation is useful for educational purposes and in guiding future clinical research.

RECOMMENDATIONS

Level 1

1. When imaging is deemed necessary, MDCT scans with axial collimation should be used to screen for and diagnose, as MDCT scans are superior to plain films in identifying TLS fractures.

Level 2

1. Patients with back pain, TLS tenderness on examination, neurologic deficits referable to the TLS, altered mental status, intoxication, distracting injuries, or known or suspected high-energy mechanisms should be screened for TLS injury with MDCT scan.
2. ii. In blunt trauma patients with a known or suspected injury to the cervical spine, or any other region of the spine, thorough evaluation of the entire spine by MDCT scan should be strongly considered owing to a high incidence of spinal injury at multiple levels within this population.
3. Patients without complaints of TLS pain that have normal mental status, as well as normal neurological and physical examinations may be excluded from TLS injury by clinical examination alone, without radiographic imaging, provided that there is no suspicion of high-energy mechanism or intoxication with alcohol or drugs.

Level 3

1. MRI should be considered in consultation with the spine service for MDCT findings suggestive of neurologic involvement and of gross neurologic deficits.

SCIENTIFIC FOUNDATION

EAST published PMGs for the screening of thoracolumbar spine fracture in 2007. The trend for screening blunt trauma patients for TLS injuries in major trauma centers has transitioned almost exclusively to the use of MDCT scans during the past several years. In addition, 12 new articles regarding screening for TLS injury have been released since the guidelines were published. With the transformation of practice patterns, the evolution of CT technology with regard to accuracy and digital capabilities and the additional publications, a reevaluation of the literature and an update to the previously published guidelines, was essential. The most significant alteration is the elimination of plain radiographs from the screening algorithm for TLS fractures. In accordance, the update endorses the use of MDCT scans for screening as a Level 1 recommendation owing to the preponderance of respective Class II evidence. Furthermore, with the advances in CT software technology and the ability to reconstruct body MDCT scans to screen for TLS injuries, the use of CT scout films was antiquated and therefore removed from the recommendations. Other modifications include the removal of specified high-energy mechanisms as well as recommendations regarding professional authority pertaining to clinical examinations and radiographic interpretation. These recommendations were extracted to comply with strictly evidence-based guidelines.

MDCT SCAN: THE CRITERION STANDARD FOR SCREENING OF TLS INJURIES

It is the current standard of care at most major trauma institutions to use MDCT scans to image the head, cervical spine, chest, abdomen, and pelvis to diagnose injuries in patients sustaining blunt trauma. Modern MDCT scanners have detectors that concurrently collect image data from multiple angles. Current software technology allows the collected data to be reformatted or reconstructed to create precise images without the need for additional imaging or radiation to the patient. The quality of the images obtained from the screening body scans, in coordination with the ability to construct sagittal and coronal views of the TLS, provides accuracy that negates the need to repeat focused vertebral imaging. The American College of Radiology Practice Guideline for the Performance of Computed Tomography of the Spine suggests that the CT slice thickness should be no greater than 3 mm for evaluation of the TLS. Diagnostic reconstruction can then be created from these images. Thinner slices can be attained; however, these are more often used for evaluating spinal fusions, lumbar disc space, or facet degeneration.[10]

Early generation single-slice CT scanners lacked the accuracy to diagnose fractures in the transverse plane. CT scan was historically introduced and promoted as a complementary examination to traditional x-ray films. It was used to visualize the extent and the stability of vertebral fractures in regions where the axis was difficult to appreciate with x-ray films. CT scans could also elucidate regions that were poorly visualized on plain films, in particular the upper thoracic and cervicothoracic junctions. It was additionally useful for identifying fractures that were questionable on plain film.[11–13] As the use of CT scans to evaluate for TLS fractures increased and the technology and software improved, concerns began to emerge about the inadequacy of plain films. In the early 1990s, Fontijne et al.[11] and Ballock et al.[14] published separate studies that demonstrated a concern for the accuracy of plain radiography in the diagnosis of TLS fractures, and in particular, burst fractures. Ballock et al. reported data that 25% of the burst fractures would have been misdiagnosed as compression fractures by plain films alone.

In 2003, Hauser et al.[15] published prospective data based on 222 patients that had both plain radiography and 5-mm helical CT scan images to evaluate for TLS fractures. The sensitivity of CT scan was 97% compared with 58% for plain radiographs, and chronic fractures could be differentiated from acute fractures. There were no unstable fractures that were missed, and most of the missed fractures were transverse process and spinous process fractures (SPFs). CT scan also significantly decreased the time to TLS clearance from 12 hours to 48 hours to approximately 3 hours with CT scan.

Sheridan et al.[2] also published data in 2003 using 2.5-mm reformatted CT images from scans of the chest, abdomen, and pelvis to evaluate 1,915 patients. Forty-three patients had spinal fractures, and plain films missed 42% of these fractures. The sensitivity for thoracic fractures was 97% for CT scan versus 62% for plain films. For lumbar fractures, the sensitivity was 95% versus 86% for plain films. Of the total 19 fractures that were missed by plain films, 3 fractures (15.7%) were unstable, and the remaining were transverse process or SPFs. Wintermark et al.[16] also showed the sensitivity for diagnosis of unstable fractures by plain film to be 33.3% as compared with 97.2% by 2.5-mm slice CT scan. In 2004, Roos et al.[17] subsequently reported the sensitivity of reformatted CT images with 3-mm slices as 98% with a specificity of 97%.

Herzog et al.[18] published a very eloquent study in 2004 in which 70 blunt polytrauma patients were imaged with conventional radiographs, 5-mm slice CT scan, 3-mm slice CT scan, and then 5-mm and 3-mm slices with multiplanar reconstruction (MDCT scan). The respective sensitivities for thoracic fractures were 57.1%, 85.7%, 100%, 95.2%, and 100%. For lumbar spine fractures, the sensitivities were 75%, 83.3%, 91.7%, 100%, and 100%, respectively. The respective unstable thoracic fracture sensitivity was 57.1%, 85.7%, 85.7%, 100%, and 100%. The unstable lumbar fracture sensitivity was 76.9% for conventional radiographs and 100% for all CT methodology. They concluded that overlapping thin-slice MDCT scans were far superior to conventional radiographs as well as single-slice CT imaging.

Several subsequent studies followed including one by Brandt et al.[19] in 2004. Although the study was retrospective and small in number (n = 55), they revealed that 24% of TLS fractures were not seen on plain films and 9% of those missed were unstable vertebral body fractures. Also in 2004, Mejia et al.[20] calculated a 59% sensitivity with plain films in comparison with 99% sensitivity with CT scan in 1,576 patients who were screened. Three percent of the fractures that were missed by plain film were considered unstable and required treatment. Berry et al.[21] showed a 73% versus 100% sensitivity for plain films in comparison with CT. In addition, 16.7% of missed fractures were unstable compression or burst fractures. Antevil et al.[22] calculated a 71% versus 100% sensitivity for plain films in comparison with CT. Smith et al.[23] published a dismal 54% versus 100%, respectively, and also calculated sensitivity for plain film diagnosis of unstable thoracic spine fractures to be only 75%, while plain film sensitivity of unstable lumbar fractures was even less at 63%. More recently, Pouw et al.[24] published a study with 620 patients evaluating pelvic fractures and TLS fractures. The sensitivity of plain films for TLS fractures was only 22%. The sensitivity of fracture identification for vertebral body fractures was 40% for thoracic spine and 76% for lumbar spine.

In summation, the sensitivity of plain films for diagnosing all TLS fractures ranged from 22% to the best published value of 75% in comparison with 95% to 100% in MDCT scans (Table 1). Most fractures missed by plain film imaging were transverse process fractures (TPFs) and SPFs. TPFs have been associated with scoliosis in rare cases, but they do not lead to vertebral column instability and rarely impact therapeutic interventions.[25–27] Providers should recognize that it requires a high energy mechanism to fracture a transverse process. These injuries have a concomitant association with injury to the abdominal viscera, the retroperitoneum, the vertebral column, long bones, the cranium, pelvic fractures, and the genitourinary system.[24,28–30] SPFs can result in vertebral column instability in some circumstances, but most are not clinically relevant.[31,32] TPFs and SPFs can both increase morbidity secondary to pain, muscle spasm, and decreased mobility. However, the most concerning issue regarding the decreased sensitivity of plain films is the number of missed unstable fractures. The publications reviewed classified unstable fractures as those involving the vertebral bodies, namely, compression fractures,

TABLE 1. Sensitivity of CT Scan and Plain X-Ray Study for Thoracolumbar Spinal Fractures

Author	Year	Class of Data	No. Patients	Sensitivity of CT, %	Sensitivity of X-Ray Study, %	Sensitivity of CT for Unstable Fractures, %	Sensitivity of X-Ray Study for Unstable Fractures, %
Hauser CJ	2004	II	215	97	58	100	100
Wintermark M	2003	II	100	78	32	97.2	33.3
Sheridan R	2003	II	78	95–97	62–86	100	—
Herzog	2004	II	70	100	57–75	100	57–77
Mejia V	2004	II	1,576	94–98	58–59	100	—
Berry GE	2005	III	103	100	73	100	93
Antevil JL	2006	III	573	100	71	—	—
Smith R	2009	II	59	89	37	100	63–75

Chance fractures, and burst fractures that required either surgical intervention or some type of orthotic with follow-up from a spine service. The sensitivity of plain films in diagnosing unstable fractures ranged from 33.3% to 76.9%, and the number of missed fractures that were unstable ranged from 0% in the 2003 study of Hauser et al. to 3%, 9%, 15.7%, 16.7%, and up to 25% in the study of Ballock et al.[14–24]

With the transition to CT scans for screening, concerns have arisen regarding radiation exposure. Hauser et al. reported that when truncal CT scans are used for screening in comparison to multiple region-specific plain radiographs, there is no excess radiation exposure. This study also noted advantages in time to diagnosis as well as cost savings by the elimination of multiple plain radiographs.[15,33] Several other studies also addressed radiation, time to diagnosis, and cost analyses and validated the same conclusions.[2,16,21,22]

With the preponderance of Class II evidence supporting the sensitivity of MDCT scan for the diagnosis of TLS fractures, the PMG Committee has established a Level 1 recommendation that MDCT scan should be considered the criterion standard screening modality for TLS injuries in blunt trauma patients.

INDICATIONS FOR THE SCREENING FOR TLS FRACTURES IN BLUNT TRAUMA PATIENTS

TLS injuries are common in blunt trauma patients. Screening for these injuries is imperative owing to the devastating impact that unrecognized fractures and resultant spinal cord injuries can have on patient outcomes.[2–9] The indications to scan patients with back pain, point tenderness, neurologic deficit, altered mental status, multiple or distracting injuries, or the presence of other spinal fractures are evident and well documented.[1,3,6,34–37] Multiple studies have also documented the phenomenon of multilevel, noncontiguous spinal fractures. This implies that a fracture identified in any region of the spine, in particular the cervical spine, is an indication for radiologic screening of the entire spine.[3,4,8,35,38–42] The referenced publications do not delineate whether patients were symptomatic with regard to their TLS examination. Therefore, the true incidence of associated TLS fractures in an asymptomatic patient with perhaps an isolated cervical spine fracture is unknown. As with any scenario, clinical judgment, mechanism, and the possibility of a distracting injury must be considered.

Nonspinal traumatic injuries are also associated with TLS fractures, either as a distraction to the physical examination or as a marker of the severity of mechanism.[3,4,6,43–47] There are multiple mechanisms of injury that have been identified as being highly correlative with TLS fractures. These include falls greater than 10 feet, ejection from a motor vehicle, motorcycle crashes, high-velocity injuries, and pedestrians struck by motor vehicles.[3,4,34,37,43,48–50,66]

Patients with alterations in sensorium from traumatic head injury, shock, or intoxication may not have a reliable clinical examination, and therefore, radiologic screening is essential.[1,3,4,34,35,37,43–45,51,52] The majority of the literature supports the notion that TLS fractures may be asymptomatic, yet several studies suggest that clinical examinations can be highly sensitive for patients with reliable physical examinations.[3,4,27,35,37,43,45,52] Terregino et al.[35] found that in conscious patients with a normal mental status and no distracting injuries, the absence of back pain or tenderness had a 95% negative predictive value for TLS fractures. Yet, Sava et al.[53] prospectively compared physical examination findings with plain films in 537 patients with reliable mental status examinations and found clinical examination to be only 80% sensitive in the identification of TLS fractures. Cooper et al.[1] reported a review of 183 TLS fractures in patients who were neurologically intact with a Glasgow Coma Scale (GCS) score between 13 and 15. Thirty-one percent of these patients were recorded as having no pain or tenderness, yet all had fractures. The evidence would suggest that many of these fractures are not truly asymptomatic but rather are occult fractures that are missed owing to the presence of intoxication or an unreliable physical examination.

There is considerable evidence to support the notion of performing radiographic screening on the basis of mechanism alone regardless of clinical examination findings. Anderson et al.[38] retrospectively evaluated 310 major TLS fractures to document the correlation of mechanism with TLS fractures despite negative findings on clinical examination. Frankel et al.[34] and Holmes et al.[45] designed separate prospective studies that defined screening criteria for TLS fractures that included mechanism and applied these criteria to 2,884 total patients with blunt traumatic mechanisms. The sensitivity and negative predictive value of their screening criteria was 100%.

The caveat to the preceding studies is that plain films were used as screening for TLS injuries. With the transition to CT scans, it is plausible that the increased sensitivity may result in the diagnosis of occult asymptomatic fractures not previously identified with plain films. In 2011, Inaba et al.[54] published a prospective study on blunt trauma patients with a reliable mental status that received body CT scans, which allowed screening of the TLS. Clinical examination was 48% sensitive for all TLS fractures and 79% sensitive for clinically significant fractures, defined as those requiring an orthotic or surgery. Currently, this is the only known study that compares clinical examination to CT scan findings. Although the data are impressive, the key limitation of this study (as pointed out by the authors in the article) is that globally asymptomatic patients did not receive imaging, regardless of mechanism. This raises the possibility that there may have been even more false-negative examination results than the collected data suggest.

Most blunt trauma patients at major trauma centers receive screening body scans that also evaluate for TLS fractures with MDCT technology. However, there are certainly a significant number of patients who can be excluded for injury by clinical examination. It remains the recommendation of the PMG Guideline Committee based on the reviewed literature that patients with a reliable mental status and negative clinical examination result can be excluded by physical examination without the need for MDCT imaging. However, if a high-energy mechanism is confirmed or suspected, the patient should be screened for TLS injuries via MDCT scan or transferred to a trauma center with MDCT scan capabilities.

THE ROLE OF MRI IN SCREENING FOR TLS INJURIES

MRI does not currently offer any advantage over CT scans, and it is actually less sensitive with respect to identifying spinal osseous injuries. Although MRI is useful for evaluating marrow edema as in compression fractures, MDCT scan should be obtained first to evaluate for fractures. MRI is more useful to evaluate spinal cord injury, ligamentous injury, hematomas, disk involvement, and facet joint involvement.[55,56] Ligamentous injury of the TLS without fracture is extremely rare, but the phenomenon does exist.[1,2,5,57–59] The indication for MRI of the TLS after blunt trauma includes the evaluation of gross neurologic deficits, MDCT findings suggestive of neurologic involvement, and neurologic examination findings despite the absence of radiographic abnormalities.[6,8,60,61] The thoracolumbar "burst" fracture occurs approximately 14% to 48% of the time, and a neurologic deficit is present in 65% of patients. The soft tissue components of the injury, including ligamentous disruption, are not reliably visualized with CT scans and therefore typically warrant an early MRI.[62–65] Several studies have demonstrated the deleterious effects of delayed intervention on neurologic outcomes and recovery.[2–9] Therefore, it is the recommendation of the PMG Committee that either the orthopedic or the neurosurgical spine service be consulted on patients with the previously mentioned findings before obtaining an MRI as to not delay potential emergent therapeutic interventions which could be based on physical examination findings alone or MDCT imaging.

SUMMARY

There have been no prospective, randomized studies to evaluate the screening of TLS injuries in blunt trauma patients. However, there is significant Class II and Class III data that demonstrate the superior sensitivity of MDCT scan in comparison with plain films for the diagnosis of TLS fractures. Furthermore, there are data that justify concerns regarding the financial implications as well as the radiation exposure involved with using MDCT scans for TLS screening. MDCT scans are the eventual outcome if a TLS injury is diagnosed or even suspected, and most blunt trauma patients already require body CT scans to screen for injuries in the chest, abdomen, and pelvis. MDCT technology has evolved so that modern CT scanners use computer software to reformat axial collimated images into saggital views, coronal views, and three-dimensional imaging. This has allowed the single admitting series of CT scans to be reformatted for a more accurate evaluation and diagnosis of TLS injuries. Neither there have been any publications that have addressed long-term follow-up to identify missed TLS injuries nor have there been any studies that have evaluated the incidence of TLS fractures in clinically benign patients with significant mechanisms of injury. Thus, the true incidence of TLS injury is not known. CT scans are not 100% sensitive, but as a whole, the evidence has shown that radiographs of the TLS are inadequate.

The 2012 updated recommendations regarding the screening for thoracolumbar spinal injuries in blunt trauma patients establish that MDCT scans should be considered the criterion standard imaging modality for the screening of TLS injuries. As stated in the previous guidelines, all blunt trauma patients with clinical symptoms, altered mental status, distracting injuries, neurologic deficits, or significant traumatic mechanisms should receive a MDCT scan to evaluate for TLS injuries. If MDCT scans are not available, the practitioner should consider transferring the patient to the closest trauma facility with MDCT scan capabilities. In accordance, patients with normal and reliable examination results, without any evidence or concern for altered mental status, intoxication, or significant mechanism, may be evaluated clinically and excluded from injury without the need for imaging. Practitioners who elect to use plain films for TLS screening should fully acknowledge and accept the limitations of plain films in relation to the clinical scenario, the mechanism, and the evidence-based recommendations that have been extrapolated in this publication.

The PMGs for the screening of TLS injuries in blunt trauma were established to assist practitioners in the screening, diagnosis, and management of TLS injuries in blunt trauma patients. These are evidence-based guidelines that should be used in accordance with clinical judgment. Individual scenarios, resource availability, and clinical variations may need to be taken into consideration when determining ultimate screening algorithms.

FUTURE INVESTIGATIONS

Future studies should prospectively evaluate blunt trauma patients who have sustained significant mechanisms with screening MDCT scans, regardless of physical examination findings, to identify the true sensitivity and positive predictive value of the clinical examination as well as the true incidence of TLS injury in blunt trauma patients.

DISCLOSURE

The authors declare no conflicts of interest.

REFERENCES

1. Cooper C, Dunham DC, Rodrigues A. Falls and major injuries are risk factors for thoracolumbar injuries: cognitive impairment and multiple injuries impede the detection of back pain and tenderness. *J Trauma*. 1995;38:692–695.
2. Sheridan R, Peralta R, Rhea J, Ptak T, Novelline R. Reformatted visceral protocol helical computed topographic scanning allows conventional radiographs of the thoracic and lumbar spine to be eliminated in the evaluation of blunt trauma patients. *J Trauma*. 2003;55:665–669.
3. Meldon S, Moettus LN. Thoracolumbar spine fractures: clinical presentation and the effect of altered sensorium and major injury. *J Trauma*. 1995;39:1110–1114.
4. Hsu JM, Joseph T, Ellis AM. Thoracolumbar fracture in blunt trauma patients: guidelines for diagnosis and imaging. *Injury.* 2003;34:426–433.
5. Brandser EA, El-Khoury GY. Thoracic and lumbar spine trauma. *Radiol Clin North Am*. 1997;35:533–537.
6. Saboe LA, Reid DC, Davis LA, et al. Spine trauma and associated injuries. *J Trauma*. 1991;31:43–48.
7. Poonnoose PM, Ravichandran G, McClelland RM. Missed and mismanaged injuries of the spinal cord. *J Trauma*. 2002;53:314–320.
8. Reid DC, Henderson R, Saboe L, et al. Etiology and clinical course of missed spine fractures. *J Trauma*. 1987;27:980–986.
9. Levi AD, Hurlbert RJ, Anderson P, et al. Neurological deterioration secondary to unrecognized spinal instability following trauma—a multicentre study. *Spine*. 2006;35:451–458.
10. ACR–ASNR–ASSR–SPR Practice guidelines for the performance of computed tomography (CT) of the spine. The Guidelines and Standards Committees of the ACR Commissions on Neuroradiology and Pediatric Radiology in collaboration with the ASNR, the ASSR, and the SPR. 2011. Available at: http://www.acr.org/guidelines. Accessed March 15, 2012.
11. Fontijne WPJ, DeKlerk LWL, Braakman R, Stijnen T, Tanghe HLJ, Steenbeek R, van Linge B. CT scan prediction of neurological deficit in thoracolumbar burst fractures. *J Bone Joint Surg Br*. 1992;74:683–685.
12. Post MD, Green BA, Quencer RM. The value of computed tomography in spinal trauma. *Spine*. 1982;7:417–431.
13. Flohr T, Stierstorfer K, Brunder H, Simon J, Polacin A, Schaller S. Image reconstruction and image quality evaluation for a 16-slice CT scanner. *Med Phys*. 2003;30:832–845.
14. Ballock RT, Mackersie R, Abitbol JJ, et al. Can burst fractures be predicted from plain radiographs? *J Bone Joint Surg Br*. 1992;74:147–150.
15. Hauser CJ, Visvikis G, Hinrichs C, Eber CD, Cho K, Lavery RF, Livingston DH. Prospective validation of computed tomographic screening of the thoracolumbar spine in trauma. *J Trauma*. 2003;55:228–235.
16. Wintermark M, Mouhsine E, Theumann N, Mordasini P, van Melle G, Leyvraz PF, Schnyder P. Thoracolumbar spine fractures in patients who have sustained severe trauma: depiction with multi-detector row CT. *Radiology.* 2003;227:681–689.
17. Roos JE, Hilfiker P, Platz A, Desbiolles L, Boehm T, Marincek B, Weishaupt D. MDCT in emergency radiology: is a standardized chest or abdominal protocol sufficient for evaluation of thoracic and lumbar spine trauma? *AJR Am J Roentgenol*. 2004;183:959–968.
18. Herzog C, Ahle H, Mack MG, Maier B, Scwarz W, Zangos S, Jacobi V, Thalhammer A, Peters J, Ackermann H, et al. Traumatic injuries of the pelvis and thoracic and lumbar spine: does thin-slice multidetector-row CT increase diagnostic accuracy? *Eur Radiol*. 2004;14:1751–1760.
19. Brandt MM, Wahl WL, Yeom K, Kazerooni E, Wang SC. Computed tomographic scanning reduces cost and time of complete spine evaluation. *J Trauma*. 2004;56:1022–1026.
20. Mejia VA, Diaz JJ, Guy J, Miller R, May AK, Guillamondegui O, Morris JA. Plain films vs. helical CT for thoracolumbar spine clearance. *J Trauma*. 2004;57:1376.
21. Berry GE, Adams S, Harris MB, Boles CA, McKernan MG, Collinson F, Hoth JJ, Meredith JW, Chang MC, Miller PR. Are plain radiographs of the spine necessary during evaluation after blunt trauma? Accuracy of screening torso computed tomography in thoracic/lumbar spine fracture diagnosis. *J Trauma*. 2005;59:1410–1413.
22. Antevil JL, Sise MJ, Sack DI, Kidder B, Hopper A, Brown CV. Spiral computed tomography for the initial evaluation of spine trauma: a new standard of care? *J Trauma*. 2006;61:382–387.
23. Smith MW, Reed JD, Facco R, Hlaing T, McGee A, Hicks BM, Aaland M. The reliability of nonreconstructed computerized tomographic scans of the abdomen and pelvis in detecting thoracolumbar spine injuries in blunt trauma patient with altered mental status. *J Bone Joint Surg Am*. 2009;91:2342–2349.
24. Pouw MH, Deunk J, Brink M, Dekker HM, Kool DR, van Vugt AB, Edwards MJR. Is a pelvic fracture a predictor for thoracolumbar spine fractures after blunt trauma? *J Trauma*. 2009;67:1027–1032.
25. Gilsanz V, Miranda J, Cleveland R, Willi U. Scoliosis secondary to fractures of the transverse processes of lumbar vertebrae. *Radiology.* 1980; 134:627–629.
26. Tewes DP, Fischer DA, Quick DC, Zamberletti F, Powell J. Lumbar transverse process fractures in professional football players. *Am J Sports Med*. 1995;23:507–509.
27. Homnick A, Lavery R, Nicastro O, Livingston DH, Hauser CJ. Isolated thoracolumbar transverse process fractures: call physical therapy, not spine. *J Trauma*. 2007;63:1292–1295.
28. Miller CD, Blyth P, Civil ID. Lumbar transverse process fractures—a sentinel marker of abdominal organ injuries. *Injury.* 2000;31:773–776.
29. Krueger MA, Green DA, Hoyt D, Garfin SR. Overlooked spine injuries associated with lumbar transverse process fractures. *Clin Orthop Relat Res*. 1996;327:191–195.
30. Patten RM, Gunberg SR, Brandenburger DK. Frequency and importance of transverse process fractures in the lumbar vertebrae at helical abdominal CT in patients with trauma. *Radiology.* 2000;215:831–834.
31. Denis F. The three column spine and its significance in the classification of acute thoracolumbar spinal injuries. *Spine*. 1983;8:817–831.
32. Chance CQ. Note on a type of flexion fracture of the spine. *Br J Radiol*. 1948;21:452.
33. Diaz JJ, Cullinane DC, Altman DT, et al. Practice management guidelines for the screening of thoracolumbar fracture. *J Trauma*. 2007;63:709–718.
34. Frankel HL, Rozycki GS, Ochsner GM, et al. Indications for obtaining surveillance thoracic and lumbar spine radiographs. *J Trauma*. 1994;37: 673–676.
35. Terregino CA, Ross SE, Lipinski MF, Foreman J, Hughes R. Trauma. *Ann Emerg Med*. 1995;26:126–129.
36. Meek S. Fractures of the thoracolumbar spine in major trauma patients. *BMJ.* 1998;317:1442–1443.
37. Durham RM, Luchtefeld WB, Wibbenmeyer L, et al. Evaluation of the thoracic and lumbar spine after blunt trauma. *Am J Surg*. 1995;170: 681–685.
38. Anderson S, Biros MH, Reardon RF. Delayed diagnosis of thoracolumbar fractures in multiple-trauma patients. *Acad Emerg Med*. 1996;3:832–839.
39. Calenoff L, Chessarc JW, Rogers LF, et al. Multiple level spinal injuries: importance of early recognition. *AJR Am J Roentgenol*. 1978;130: 665–669.
40. Frame SB, Enderson BL. The multiple fractured spine: incidence and need for complete spine radiographic evaluation. *J Trauma*. 1992;32: 954–959.
41. Gupta A, el Masri WS. Multilevel spinal injuries. Incidence, distribution and neurological patterns. *J Bone Joint Surg Br*. 1989;71:692–695.
42. Keenen TL, Antony J, Benson DR. Non-contiguous spinal fractures. *J Trauma*. 1990;30:489–491.
43. Stanislas MJC, Latham JM, Porte KM, Alpar EK, Stirling AJ. A high risk group for thoracolumbar fractures. *Injury.* 1998;29:15–18.
44. Chang CH, Holmes JF, Mower WR, Panacek EA. Distracting injuries in patients with vertebral injuries. *J Emerg Med*. 2005;28:147–152.

45. Holmes JF, Panacek EA, Miller PQ, Lapidis AD, Mower WR. Prospective evaluation of criteria for obtaining thoracolumbar radiographs in trauma patients. *J Emerg Med*. 2003;24:1–7.
46. Kirkpatrick AW, McKevitt E. Thoracolumbar spine fractures: is there a problem? *Canadian Journal of Surgery.* 2002;45:21–24.
47. Meyer PF. *Surgery of Spine Trauma*. Michigan: Churchill Livingstone; 1989.
48. Kupferschmid JP, Weaver ML, Raves JJ, et al. Thoracic spine injuries in victims of motorcycle accidents. *J Trauma*. 1989;29:593–596.
49. Robertson A, Giannoudis PV, Branfoot T, Barlow I, Matthews SJ, Smith RM. Spinal injuries in motorcycle crashes: patterns and outcomes. *J Trauma*. 2002;53:5–8.
50. Ertürer E, Tezer M, Oztürk I, Kuzgun U. Evaluation of vertebral fractures and associated injuries in adults. *Acta Orthop Traumatol Turc*. 2005;39: 387–390.
51. Enderson BL, Reath DB, Meadows J, et al. The tertiary trauma survey: a prospective study of missed injury. *J Trauma*. 1990;29:1643–1646.
52. Samuels LE, Kerstein MD. Routine radiologic evaluation of the thoracolumbar spine in blunt trauma patients: a reappraisal. *J Trauma*. 1993; 34:85–89.
53. Sava J, Williams MD, Kennedy S, Wang D. Thoracolumbar fracture in blunt trauma: is clinical exam enough for awake patients? *J Trauma*. 2006;61:168–171.
54. Inaba K, DuBose JJ, Barmparas G, Barbarino R, Reddy S, Talving P, Lam L, Demetriades D. Clinical examination is insufficient to rule out thoracolumbar spine injuries. *J Trauma*. 2011;70:174–179.
55. Looby S, Flanders A. Spine trauma. *Radiol Clin North Am*. 2011;49: 129–163.
56. Pizones J, Izquierdo E, Alvarez P, Sánchez-Mariscal F, Zúñiga L, Chimeno P, Benza E, Castillo E. Impact of magnetic resonance imaging on decision making for thoracolumbar traumatic fracture diagnosis and treatment. *Eur Spine J.* 2011;20(Suppl 3):390–396.
57. Hirsh LF, Duarte L, Wolfson EH. Thoracic spinal cord injury without spine fracture in an adult: case report and literature review. *Surg Neurol*. 1993;40:35–38.
58. Koizumi M, Ueda Y, Iida J, Matsuyama E, Yoshikawa T, Takakura Y, Hirai T, Murakami J. Upper thoracic spinal cord injury without vertebral bony lesion: a report of two cases. *Spine*. 2002;27:E467–E470.
59. Samsani SR, Calthorpe D, Geutjens G. Thoracic spinal cord injury without radiographic abnormality in a skeletally mature patient: a case report. *Spine*. 2003;28:E78–E80.
60. MacMillan M, Stauffer ES. Transient neurologic deficits associated with thoracic and lumbar spine trauma without fracture or dislocation. *Spine*. 1990;15:466–469.
61. Riggins RS, Kraus JF. The risk of neurologic damage with fractures of the vertebrae. *J Trauma*. 1977;17:126–133.
62. Denis F. The three column spine and its significance in the classification of acute spinal injuries. *Spine*. 1983;8:817–831.
63. McAfee PC, Yuan H, Fredrickson BE, Lubicky JP. The value of computer tomography in thoracolumbar fractures. *J Bone Joint Surg Am*. 1983;65: 461–472.
64. Hu R, Mustard CA, Burns C. Epidemiology of incident spinal fracture in a complete population. *Spine*. 1996;21:492–499.
65. Dai LY, Ding WG, Wang XY, Jiang LS, Jiang SD, Xu HZ. Assessment of ligamentous injury in patients with thoracolumbar burst fractures using MRI. *J Trauma*. 2009;66:1610–1615.
66. Hill D, Delaney L, Duflou J, et al. A population-based study of outcome after injury to car occupants and to pedestrians. *J Trauma*. 1996;37:673–676.