

Clinical Examination Is Insufficient to Rule Out Thoracolumbar Spine Injuries

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Purpose: The role of clinical examination in the diagnosis of thoracolumbar (TL) spine injuries is highly controversial. The aim of this study was to assess the sensitivity and specificity of a standardized clinical examination for diagnosing TL spine injuries after blunt trauma.

Methods: This was a prospective observational study conducted at a level I trauma center from March 2008 to September 2008. After Institutional Review Board approval, all evaluable blunt trauma patients older than 15 years were evaluated by a senior resident or attending surgeon for TL spine deformity, tenderness to palpation, and neurologic deficits. Patients were followed through their hospital course to capture all TL spine injury diagnoses, all imaging performed, and any immobilization or stabilization procedures.

Results: Of the 884 patients enrolled, 81 (9%) had a TL spine injury. More than half (55.6%) had two or more fractures with 30.9% having three or more. Isolated L-spine fractures occurred in 56.8%, T-spine fractures occurred in 34.6% only, and combination injuries sustained in 8.6%. The most commonly identified fractures were of the transverse process (67.9%) followed by the vertebral body (30.9%) and spinous process (12.3%). Among the 666 patients who were evaluable, 56 (8%) had a TL spine fracture. Of these, 29 (52%) had a negative clinical examination, of which 2 (7%) had clinically significant compression fractures. For evaluable patients who had localized pain or tenderness elicited on examination, although the finding triggered imaging appropriately, the site of pain correlated to the site of actual injury in only 61.5% of cases. The sensitivity and specificity of clinical examination for TL spine fractures were 48.2% and 84.9%, respectively, for all fractures and 78.6% and 83.4% for those that were clinically significant.

Conclusion: Clinical examination as a stand-alone screening tool for evaluation of the TL spine is inadequate. In this series, all the clinically significant missed fractures were diagnosed on computed tomography (CT) obtained for evaluation of the visceral torso. A combination of both clinical examination and CT screening based on mechanism will likely be required to ensure adequate sensitivity with an acceptable specificity for the diagnosis of clinically significant injuries of the TL spine. Further research is war-

ranted, targeting the at-risk patient with a negative clinical examination, to determine what injury mechanisms warrant evaluation with a screening CT. **Key Words:** Thoracolumbar spine, Injury, Trauma, Epidemiology, Prospective, Clinical examination, Clinically significant, Brace, TLSO, Pain, Tenderness, Neurologic deficit.

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Traumatic fractures of the thoracolumbar (TL) spine are common sequelae of severe blunt force trauma.¹ These injuries are highly clinically significant, because they are associated with poor short- and long-term outcomes² and have been shown to directly impact health-related quality of life.³ The early detection of those at highest risk for fractures of the TL spine is important not only for the stabilization and the prevention of neurologic deterioration but also for optimizing the resource utilization by appropriately selecting out patients who require computed tomography (CT) scanning, as modern treatment algorithms require the utilization of advanced imaging data for the development of optimal treatment plans.^{4–6}

The development of effective clinical screening criteria however, for reliably identifying those at greatest risk for TL spine fractures and therefore require imaging, remains a challenge. Although practice guidelines for clearance of the cervical spine after blunt trauma using the National Emergency X-Radiography Utilization Study (NEXUS)⁷ or Canadian C-spine Rules⁸ have been well validated, the development of similar approaches for injuries of the TL region has proven disappointing.^{9–11} To date, no screening test or constellation of clinical examination and history findings has demonstrated adequate sensitivity for the detection of these injuries. The purpose of this prospective study was to determine the sensitivity and specificity of a protocolized, structured clinical examination for the evaluation of the TL spine in trauma patients injured after blunt trauma.

PATIENTS AND METHODS

This is a prospective observational study conducted at the Los Angeles County + University of Southern California (LAC + USC) Medical Center, a level I trauma center, during a 6-month period ending in September 2008. The study protocol was approved by the USC Institutional Review Board. All blunt trauma patients older than 15 years were prospectively screened by a senior surgical resident (post-graduate year 4 or higher) or attending surgeon. Patients

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deemed unevaluable [with depressed Glasgow Coma Scale (GCS) score <15, intoxicated, or with a distracting injury] were excluded from further analysis and underwent diagnostic imaging of their TL spine. All remaining evaluable patients had a standardized physical examination of their TL spine using a checklist. Specifically, with inline immobilization in the log rolled position, the senior resident or attending surgeon inspected the skin and soft tissues for abnormalities and examined the spine for deformity and tenderness to palpation. In addition, a complete neurologic examination was performed and documented. All patients presenting with any clinical signs underwent CT evaluation of their spine, and the final attending radiologist interpretation was obtained.

All patients were evaluated using a single-detector helical CT protocol (PQ 5000 or 6000; Picker International, Cleveland, OH). For screening TL spine evaluation, reconstructed images from the chest, abdomen, and pelvis were acquired at 8 × 8 mm and reconstructed at 8 × 5 mm with overlap and the images were coned down to the spine. Images were reconstructed with the bone algorithm and were reviewed on a work station using a combination of axial, multiplanar (sagittal and coronal) and volumetric reconstructions using a variety of window levels and settings. For specific-targeted areas of interest, the following parameters were used: pitch of 1.7:1, 120 kVp, 250–300 mA, no intravenous contrast, and the field of view was adapted to the individual patient's physique. When a short segment of spine was evaluated (2–3 vertebral bodies), a collimation of 3 × 3 mm slice thickness was used. If a longer length of spine was to be evaluated, larger slice thicknesses were used, ranging from 5 × 5 mm or 8 × 8 mm, to avoid tube overheating.

The patients were followed throughout their hospital stay to document all injuries, treatments, operative interventions, and complications sustained. The sensitivity, specificity, positive and negative predictive values of the clinical examination were calculated for all TL spine injuries and for clinically significant TL spine injuries, defined as those injuries requiring surgical intervention or thoracolumbosacral orthosis (TLSO) stabilization. The aggregate gold standard used for the sensitivity calculation was the final diagnosis, including all imaging, surgical procedures, and clinical follow-up obtained.

RESULTS

During the 6-month study period, 884 patients were screened. The mean age was 40.0 years ± 17.6 years (range, 15–94 years) and 69.1% were men. The most common mechanism of injury was motor vehicle collision (40.5%), followed by auto versus pedestrian (18.8%) and fall from height (13.2%).

A diagnosis of TL spine fracture was made in 81 patients (9.2%) who had a total of 179 injuries. For this subset of patients with an injury, the most common mechanism was motor vehicle collision (33.3%), followed by falls (22.2%; Fig. 1). Of the patients with fractures, 13 (1.5%) had injuries that were clinically significant requiring surgical intervention or TLSO stabilization. Associated cer-

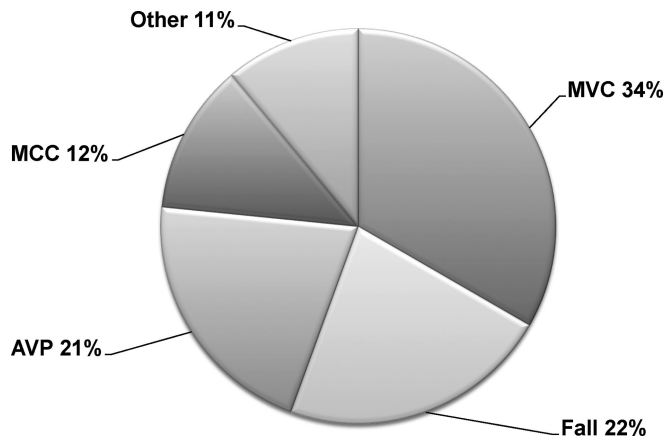


Figure 1. Mechanism of injury for patients with TL spine injury (n = 81). MVC, motor vehicle collision; AVP, auto versus pedestrian; MCC, motorcycle collision.

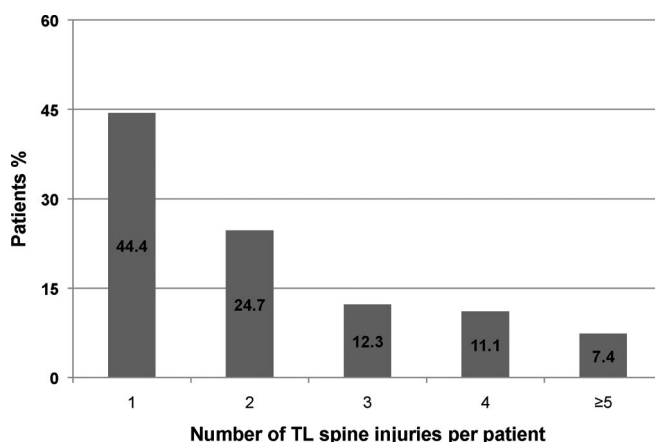


Figure 2. Number of TL spine injuries per patient (n = 81 patients with 179 TL spine injuries).

vical spine injuries were present in 16.0% of patients with a TL spine injury.

For patients sustaining a TL spine injury, 55.6% had two or more fractures, with 30.8% having ≥3 fractures (Fig. 2). Lumbar spine fractures were the only injuries in 56.8% patients; 34.6% patients sustained only thoracic spine trauma, and the remaining 8.6% had a combination of thoracic and lumbar spine injuries. Transverse process fractures were most common (67.9%), followed by vertebral body fractures (30.9%). The distribution of transverse process fractures, spinous process fractures, and body fractures is depicted in Figure 3. Other injuries sustained included lamina fractures (6.2%) and disk injuries (3.7%).

Of the 884 patients, 666 (75.3%) were deemed evaluable by the senior surgical resident or attending surgeon. The primary reason for being unevaluable was a depressed GCS score <15 (61.0%), followed by intoxication (18.3%) and the presence of a distracting injury (11.0%). Of the evaluable patients, 56 (8.3%) had a TL spine injury (Fig. 4), of which 29 (51.8%) had a normal clinical examination of their TL spine. The majority of these patients with a normal exami-

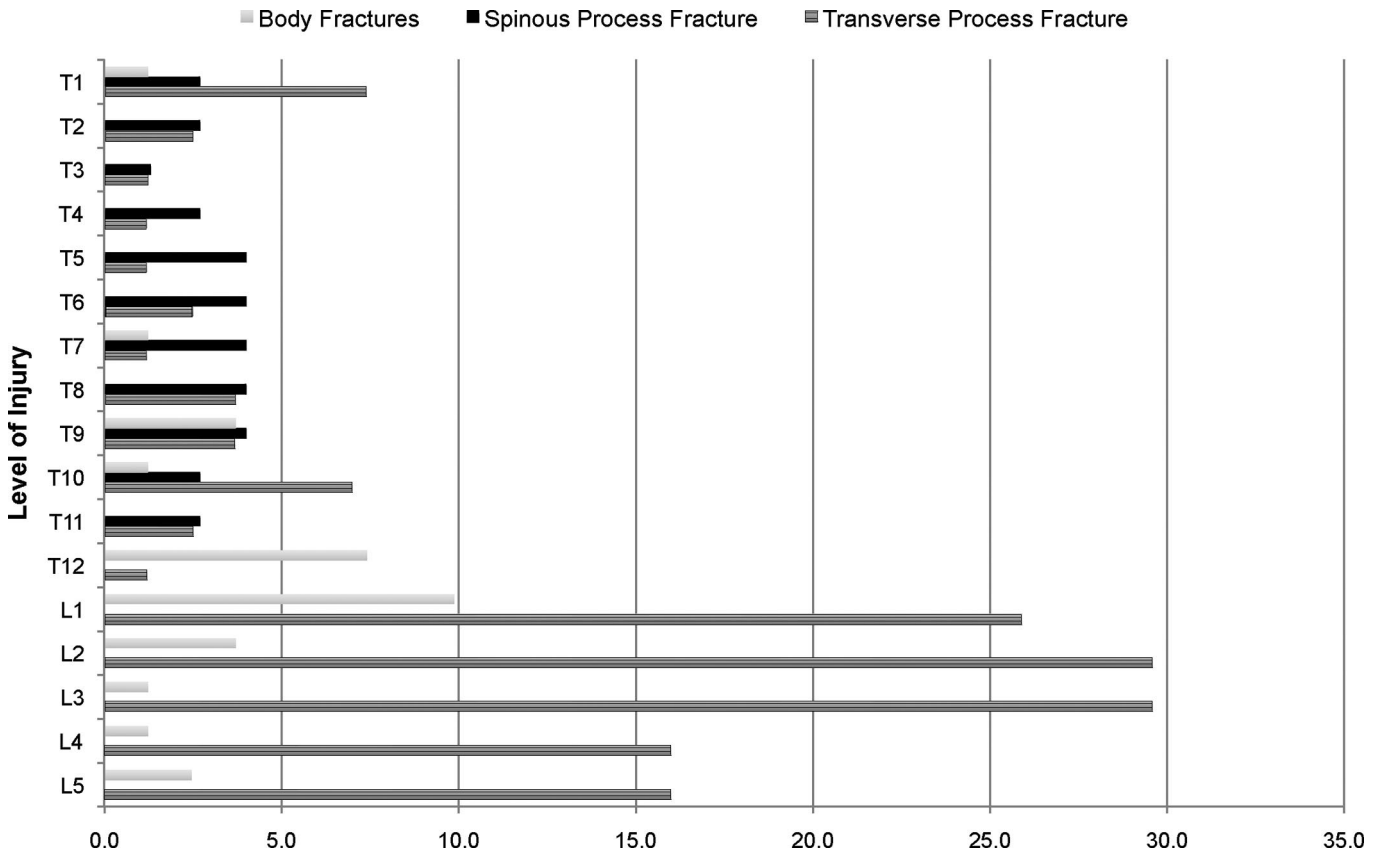


Figure 3. Stratification of TL spine fractures by location and type (n = 179 injuries).

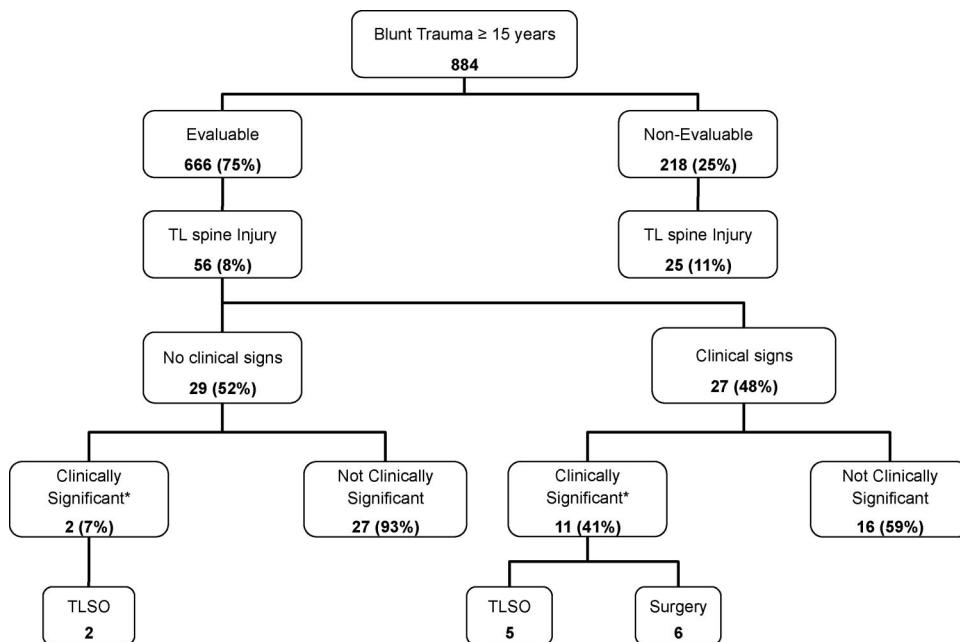


Figure 4. Stratification of evaluable patients according to clinical signs and injury significance. *Clinically significant: Injuries requiring surgical intervention or TLSO stabilization.

TABLE 1. Description of the Two Evaluable Patients With Thoracolumbar Spine Injury But No Clinical Signs

	Age	Injury Mechanism	GCS	Intoxication	Diagnosis	Management
Patient 1	20	Fall	15	No	T7 compression fracture and L3 transverse process fractures	TLSO
Patient 2	59	Fall	15	No	T9 compression fracture	TLSO

TABLE 2. Discrepancy Between Level of Clinical Tenderness and Actual Fracture

Patient	Level of Pain and/or Tenderness	Level of TL Spine Injury	Type of TL Spine Injury	Clinically Significant
1	Upper thoracic	L1, L2, L3	Transverse process fractures	No
2	Upper thoracic	T9	Compression fracture	No
3	Upper thoracic	T9	Compression fracture	No
4	Upper thoracic and upper lumbar	T9, T10, T11, T12, L1, L2, L4	Transverse process fractures	No
5	Upper and middle thoracic	L1, L2, L3, L4, L5	Transverse process fractures	No
6	Lower thoracic	L1, L2, L3, L4, L5	Transverse process fractures	No
7	Lower thoracic	L4	Transverse process fractures	No
8	Mid thoracic	T1, T2	Spinous process fractures	No
9	Lower thoracic	T2, T12, L1	Lamina fracture, compression fracture	No
10	Lower thoracic	L1	Burst fracture	Yes

TABLE 3. Sensitivity, Specificity, Positive and Negative Predictive Values of Clinical Examination for the Diagnosis of TL Spine Injuries

	Sensitivity	Specificity	PPV	NPV
All fractures	48.2	84.9	22.7	94.7
Clinically significant fractures	78.6	83.4	9.2	99.5
Fractures requiring surgical intervention	100.0	82.9	5.0	100.0
Transverse process fractures	29.7	82.8	9.2	95.2
Spinous process fractures	83.3	82.7	4.2	99.8
Vertebral body fractures	77.3	84.2	14.3	99.1
Compression fractures	70.0	82.9	5.9	99.5
Burst fractures	100.0	82.9	5.0	100.0
Thoracic spine fractures	65.0	83.6	10.9	98.7
Lumbar spine fractures	42.1	83.6	13.4	96.0

Values are represented in %.
PPV, positive predictive value; NPV, negative predictive value.

nation (93.1%) had injuries that were clinically insignificant and did not require surgical intervention or TLSO stabilization. However, two patients (6.9%) with a normal clinical examination had a TL spine injury requiring TLSSO stabilization (Table 1).

For the remaining 27 evaluable patients with a fracture and symptoms, 85.2% had pain, 100.0% had tenderness to palpation, and 11.1% had neurologic deficit. For patients with pain or tenderness to palpation on examination, only in 61.5% did the clinical signs correlate with the location of the injury sustained (Table 2). Localization was better for clinically significant injuries with 90.9% of the clinical signs correlating to the actual injury site.

The combinations of sensitivity, specificity, positive and negative predictive values of clinical findings for the diagnosis of TL spine injury in evaluable patients are summarized in Table 3. Overall, the sensitivity of clinical examination for diagnosing a TL spine injury was 48.2%. The sensitivity decreased further to only 29.7% for the diagnosis of transverse process fractures. For injuries that were clinically significant, the sensitivity of clinical examination reached only 78.6%. If patients with a clinically significant fracture and examination findings that did not correlate to the site of the injury were categorized as a negative physical examination, the sensitivity would be further reduced to 71.4%.

DISCUSSION

For the multisystem blunt trauma patient, the initial evaluation of the cervical spine can be performed in a systematic, evidence-based manner using guidelines that are based on well-validated, large prospective studies such as NEXUS⁷ and the Canadian C-Spine Rules.⁸ However, for the acute evaluation of the TL spine, no such evidence base exists.¹² Several critical questions remain before the development of a protocol that is adequately sensitive and specific. First, are there findings on clinical examination that have the ability to discriminate with a 100% sensitivity, those patients with clinically significant fractures with adequate specificity such that all clinically significant fractures are diagnosed while minimizing the cost, time, and radiation burden to those patients without a fracture. Second, if the sensitivity of clinical examination is insufficient to diagnose all fractures, is there a combination of physical examination findings and injury mechanisms that can detect all patients at risk of having a fracture while again minimizing the imaging burden.

The goal of this study was to prospectively assess the utility of a structured physical examination in a continuous series of multisystem blunt trauma patients. A quarter of the initial patient load was unevaluable, primarily because of traumatic brain injury or intoxicants, and these patients had injury excluded by imaging. For the remainder of the patients who were evaluable, clinical examination had an unacceptably low sensitivity. Although the majority of the fractures were found not to require stabilization or operative fixation, for the 1.5% that were clinically significant, the sensitivity of physical examination was only 78.6%. This decreased to 48.2% for all fractures of the TL spine.

In the evaluable patient, physical examination missed 6.9% of all fractures and 15.4% of those that were clinically significant. These values are based on the physical examination correctly triggering imaging which then definitively diagnosed the injury. In reality, in 38.5% of cases, although the physical examination was positive and was able to trigger imaging that ultimately found an injury, the examination findings were incorrect. In these 38.5% of cases, physical examination localized the injury to an area where there was no injury. Because of this, any positive finding on clinical examination warrants full radiographic evaluation of the entire length of the spine and not just the area with tenderness or pain.

At this time, very little is available in the current literature assessing the role of clinical examination for the TL spine.^{7,9–14} In a study by Holmes et al.,⁹ clinical high-risk criteria were analyzed and reported to have a sensitivity of a 100%. In their study design, however, it was unclear how patients were selected for entry into the analysis as several fractures were missed without an assessment of the six high-risk data points. As clinically relevant fractures make up a small percentage of the total number of fractures, the sensitivity calculations would have been significantly impacted by these cases. In addition, plain radiographs supplemented by CT were used for the sensitivity calculation. The use of plain radiographs for the sensitivity calculation is inadequate, because it is clear from the available literature that the reported sensitivity is only 33% to 74% with poor interobserver variability.^{15–20} In a subsequent small study by Terregino et al.,¹⁴ a similar problem with the gold standard imaging modality existed. In the analysis by Hsu et al.,¹⁰ although it was a small cohort and tested retrospectively, the absence of clinical signs was found to be inadequate for safely excluding fractures. In a subsequent study by Sava et al.¹³ looking at the patient population that presents specifically with altered mental status but is able to accurately report pain as judged by the treating physician, they found that in this group as well, clinically silent TL spine fractures existed even when patients appear to be reliably able to report pain. This group recommended screening imaging for this patient population.

This is the first prospective study to analyze the fully evaluable patient using computer tomography as a gold standard imaging modality for evaluating the sensitivity of a structured clinical examination for clinically significant fractures. The sensitivity of clinical examination was found to be inadequate. Based on the results of this study, what is re-

quired so that clinically significant fractures are not missed is a combination of physical examination and an assessment of injury mechanism. For any patient with a physical finding, imaging is warranted. For those with a negative examination, the mechanism will determine who requires imaging. In our study, all of the missed injuries on physical examination had sufficient mechanism to warrant the clinical team obtaining a CT evaluation of the chest and of the abdomen, which ultimately diagnosed the spinal fracture that was missed on physical examination. This is not surprising, because patients suffering sufficient force to cause a clinically significant TL spine fracture likely are at risk of visceral chest or abdominal injuries that require evaluation by CT. The collateral data from these CT scans ordered to evaluate the chest and abdominal viscera can then be used to exclude spinal fractures. In our study, there were no patients with a negative physical examination who did not get a CT of the chest or abdomen in the initial work-up who went on to have a clinically significant fracture diagnosed during their hospital stay. It is possible, however, that this could occur and needs to be considered in any further prospective trials. Therefore, practically, all blunt multisystem patients should have a physical examination. If positive, imaging is obtained. If negative and undergoing CT for assessment of the chest and abdomen, their spine can also be imaged. The specific subset of patients with a negative examination who are not undergoing imaging require further investigation to determine what the risk of having an occult TL spine injury is and to delineate specific risk factors such as mechanism that can help predict who among these patients should undergo screening imaging.

This study had several limitations. First, not all patients enrolled had a CT. It is conceivable that a patient was evaluated with no physical findings, had no CT scan performed, and yet had a missed injury. This would have decreased the calculated sensitivity of physical examination even further. In addition to this, we are currently running the newer generation CT scanners compared with the ones used for the duration of this study. It is possible that both clinically insignificant and, less likely, clinically significant fractures were missed as a result. If so, again, the reported sensitivities would actually be decreased strengthening the conclusions of this article.

CONCLUSION

Clinical examination as a stand-alone screening tool for evaluation of the TL spine is inadequate. In this series, all of the clinically significant missed fractures were diagnosed on CT obtained for evaluation of the visceral torso. A combination of both clinical examination and CT screening based on mechanism will likely be required to ensure adequate sensitivity with an acceptable specificity for the diagnosis of clinically significant injuries of the TL spine. Further research is warranted, targeting the at risk patient with a negative clinical examination, to determine what injury mechanisms warrant evaluation with a screening CT.

REFERENCES

1. Hu R, Mustard CA, Burns C. Epidemiology of incident spinal fracture in a complete population. *Spine (Phila Pa 1976)*. 1996;21:492–499.

2. Hebert JS, Burnham RS. The effect of polytrauma in persons with traumatic spine injury. A prospective database of spine fractures. *Spine (Phila Pa 1976)*. 2000;25:55–60.
3. Briem D, Behehtnejad A, Ouchmaev A, et al. Pain regulation and health-related quality of life after thoracolumbar fractures of the spine. *Eur Spine J*. 2007;16:1925–1933.
4. Harrop JS, Vaccaro AR, Hurlbert RJ, et al; Spine Trauma Study Group. Intrarater and interrater reliability and validity in the assessment of the mechanism of injury and integrity of the posterior ligamentous complex: a novel injury severity scoring system for thoracolumbar injuries. Invited submission from the Joint Section Meeting On Disorders of the Spine and Peripheral Nerves, March 2005. *J Neurosurg Spine*. 2006;4:118–122.
5. Vaccaro A. Thoracolumbar injury classification and scoring system. *J Neurosurg Spine*. 2008;9:574–575; discussion 575.
6. Lee JY, Vaccaro AR, Lim MR, et al. Thoracolumbar injury classification and severity score: a new paradigm for the treatment of thoracolumbar spine trauma. *J Orthop Sci*. 2005;10:671–675.
7. Hoffman JR, Mower WR, Wolfson AB, Todd KH, Zucker MI. Validity of a set of clinical criteria to rule out injury to the cervical spine in patients with blunt trauma. National Emergency X-Radiography Utilization Study Group. *N Engl J Med*. 2000;343:94–99.
8. Canadian CT. Head and C-Spine (CCC) Study Group. Canadian C-Spine Rule study for alert and stable trauma patients: II. Study objectives and methodology. *CJEM*. 2002;4:185–193.
9. 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.
10. Hsu JM, Joseph T, Ellis AM. Thoracolumbar fracture in blunt trauma patients: guidelines for diagnosis and imaging. *Injury*. 2003;34:426–433.
11. Junkins EP Jr, Stotts A, Santiago R, Guenther E. The clinical presentation of pediatric thoracolumbar fractures: a prospective study. *J Trauma*. 2008;65:1066–1071.
12. Diaz JJ Jr, Cullinane DC, Altman DT, et al. Practice management guidelines for the screening of thoracolumbar spine fracture. *J Trauma*. 2007;63:709–718.
13. 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.
14. Terregino CA, Ross SE, Lipinski MF, Foreman J, Hughes R. Selective indications for thoracic and lumbar radiography in blunt trauma. *Ann Emerg Med*. 1995;26:126–129.
15. Sheridan R, Peralta R, Rhea J, Ptak T. 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. *J Trauma*. 2003;55:665–669.
16. Wintermark M, Mouhsine E, Theumann N, et al. Thoracolumbar spine fractures in patients who have sustained severe trauma: depiction with multi-detector row CT. *Radiology*. 2003;227:681–689.
17. Gestring ML, Gracias VH, Feliciano MA, et al. Evaluation of the lower spine after blunt trauma using abdominal computed tomographic scanning supplemented with lateral scanograms. *J Trauma*. 2002;53:9–14.
18. Hauser CJ, Visvikis G, Hinrichs C, et al. Prospective validation of computed tomographic screening of the thoracolumbar spine in trauma. *J Trauma*. 2003;55:228–234; discussion 234–235.
19. Rhea J, Sheridan R, Mullins M, Novellin R. Can chest and abdominal trauma CT eliminate the need for plain films of the spine?—experience with 329 multiple trauma patients. *Emerg Radiol*. 2001;8:99.
20. Inaba K, Munera F, McKenney M, et al. Visceral torso computed tomography for clearance of the thoracolumbar spine in trauma: a review of the literature. *J Trauma*. 2006;60:915–920.