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Original Contribution

# Prediction of blunt traumatic injury in high-acuity patients: bedside examination vs computed tomography

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**Abstract**

**Objective:** The addition of spiral computed tomography (SCT) to bedside assessment in patients with major trauma may improve detection of significant injury. We hypothesized that in high-acuity trauma patients, emergency physicians' ability to detect significant injuries based solely on bedside assessment would lack the sensitivity needed to exclude serious injuries when compared with SCT.

**Methods:** This was a prospective single-cohort study of high-acuity trauma patients routinely undergoing whole-body SCT at a level 1 trauma center from January to September 2006. Before SCT, emergency physicians assigned ratings for likelihood of injury to 5 body regions on the basis of bedside assessment. These ratings were compared with final SCT interpretations.

**Results:** We enrolled 400 patients as a convenience sample; 71 were excluded. When a "very low" rating was considered negative and "low," "intermediate," "high," and "very high" were considered positive, emergency physicians were able to detect head, cervical spine, chest, abdominal/pelvic, and thoracic/lumbar spine injuries with sensitivities (95% confidence interval) of 100% (98.6%-100%), 97.4% (94.9%-98.8%), 96.9% (94.2%-98.4%), 97.9% (95.5%-99.1%), and 97.0% (94.3%-98.5%), respectively. For overall diagnostic accuracy, areas under the receiver operating characteristics curve (95% confidence interval) were 0.87 (0.82-0.92), 0.71 (0.62-0.81), 0.81 (0.76-0.86), 0.77(0.71-0.83), 0.74 (0.65-0.84), respectively.

**Conclusions:** Bedside assessment by emergency physicians before SCT was sensitive in ruling out serious injuries in high-acuity trauma patients with a "very low" rating for injury. However, overall diagnostic accuracy was low, suggesting that SCT should be considered in most high-acuity patients to prevent missing injuries.


## 1. Introduction

### 1.1. Background

Standard bedside assessment (consisting of history, physical examination, focused abdominal sonogram for trauma [FAST] examination, and plain radiography) in

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patients with major trauma frequently fails to detect clinically significant injuries [1-4]. It is known that historical facts may be helpful in determining which patients will have significant injuries; several factors, such as mechanism of injury, particularly with motor vehicle crashes, tend to correlate with more severe injury [5-8]. However, the precise details of the traumatic event are often unknown. The physical examination in trauma patients is also extremely important in discovering clinically significant injuries, but it is known that patients with 1 severe injury often have additional significant injuries that may not be readily apparent on the initial examination [9-10]. In addition, missed injuries occur with greater frequency in patients who present with intoxication, altered mental status due to head trauma, and painful, distracting soft tissue or orthopedic injuries [11-13]. The more numerous a patient's injuries, the greater the likelihood for missing other significant injuries [14]. Patients taking warfarin and potent antiplatelet therapy also make the detection of injury more difficult, as seemingly minor initial injuries can rapidly progress and pose a threat to the patient's life [15-16].

### 1.2. Importance

Given the danger to the patient of missing clinically significant injuries [14] and the liability associated with missed injuries [17], some have suggested that liberal spiral computed tomography (SCT) evaluation is prudent [1]. The practice of ordering a complete SCT of the head, cervical spine, chest, abdomen/pelvis, and thoracic/lumbar spine on patients with major trauma is common in many emergency departments (EDs) [18,19]. Often, body regions are scanned, despite a low suspicion for clinically significant injury, based on the traumatic mechanism, an equivocal physical examination, or at the request of the trauma surgery team. Although a liberal SCT scanning policy may detect previously unsuspected injuries, the serious risks associated with exposure to ionizing radiation and intravenous (IV) contrast must be balanced against this potential benefit [20-22].

### 1.3. Goals of this investigation

This study sought to prospectively evaluate the ability of emergency physicians (EPs) to exclude predefined clinically significant injuries on the basis of their initial bedside assessment, which consisted of history, head-to-toe physical examination (according to Advanced Trauma Life Support [ATLS] recommendations) [23], plain radiography, and FAST examination, if performed. Emergency physicians assigned pretest ratings for likelihood of injury to the head, cervical spine, chest, abdomen/pelvis, and thoracic/lumbar spine. At our institution, attending physicians were actively involved in the physical assessment of high-acuity trauma patients. Bedside assessment was compared with injuries diagnosed on SCT. We hypothesized that in a cohort of high-acuity trauma patients, EPs' ability to exclude clinically significant injuries based on bedside assessment alone would have sensitivity and negative predictive values (NPVs) too low to rule out serious injuries when compared with SCT.

## 2. Methods

### 2.1. Setting

This was a prospective cohort study of a convenience sample that evaluated only high-acuity trauma patients. The study was carried out in an urban, university-affiliated, level 1 trauma center from January 1 through September 16, 2006. There were 1476 adult level 1 trauma alerts during the study period, and there was an adult ED volume of approximately 51 000 patients that year. Approval was obtained from the hospital's institutional review board. Participating attending physicians were consented before participation, and the institutional review board granted waiver of individual patient consent.

### 2.2. Selection of participants

This was a convenience sample of all adult trauma patients (age ≥15 years) who were determined to be "level 1" acuity by our hospital's predefined criteria (Appendix 1) and underwent a complete SCT who were eligible for inclusion in the study. A complete SCT was defined as computed tomography (CT) of the head and cervical spine without IV contrast; chest and abdomen/pelvis with IV contrast; and thoracic/lumbar spine axial images with computed sagittal and coronal reconstructions of the entire spine. All SCT scans were ordered as a routine part of the patient's workup. The ED works closely with the trauma department, and it was their policy at the time of the study to obtain a complete SCT on all level 1 trauma patients presenting with blunt traumatic injury with few exceptions. Patients were excluded if they were younger than 15 years, did not have a complete SCT, had a penetrating ballistic or stab wound as the reason for level 1 acuity designation, or were transferred from another facility with prior SCT results or the EP became aware of the SCT results before filling out the study worksheet.

This study was concerned with only attending EPs at our institution. All 31 faculty members who staffed the adult ED at that time were invited to participate; all were board certified in emergency medicine. Participating physicians were blinded to the outcome measures.

### 2.3. Methods of measurement

After obtaining a history, performing (or directly supervising) an ATLS-recommended physical examination, and obtaining plain radiographs and/or a FAST examination, the

EP filled out a data collection sheet attached to the trauma history and physical examination form (Appendix 2) and assigned a pretest rating for likelihood of clinically significant injury to the head, cervical spine, chest, abdomen/pelvis, and thoracic/lumbar spine. All level 1 trauma alerts in our institution follow a routine approach as recommended by ATLS, with the exception of pelvis and cervical spine plain radiographs. The data collection sheet indicated the EP's pretest rating for clinically significant injury as "very low," "low," "intermediate," "high," or "very high" for each body region. The worksheets also recorded each patient's age, sex, suspicion of intoxication, anticoagulation status (if known), presence of prehospital intubation, presence of distracting injury, suspicion of spinal cord injury, and whether the FAST examination changed the pretest probability assignment they chose. All worksheets were completed before viewing the SCT images or obtaining written SCT results from radiology. Each patient's SCT was performed in the ED using a Philips Brilliance 40 slice CT scanner. For the contrasted portions of the SCT, 150 mL of Optiray 350 was infused at 2.5 mL/s using an automated rapid infuser. An attending radiologist read all CT images and reported the final findings. The radiologists were blinded to which patients were enrolled in the study and to pretest ratings for injury. We reviewed the entire electronic medical record for all patients for at least 4 weeks after the initial injury for death or return visits for injuries missed on SCT.

## 2.4. Data collection and processing

The data collection sheets were placed into a collection box in a secure location and gathered at a later date for review. Information from the worksheets was entered into a spreadsheet using Microsoft Office Excel 2003 (Microsoft, Inc, Seattle, WA).

## 2.5. Outcome measures

Before the initiation of the study, we specifically defined injuries that would be deemed "clinically significant" according to previously published definitions whenever possible (Table 1) [11,24-30]. All final SCT results and available clinical information were reviewed independently by 2 physician investigators to determine whether the injuries on SCT were clinically significant, with the principal investigator adjudicating the final determination based on the study's predetermined criteria. Physicians' pretest rating assignments were compared with the final radiologists' interpretation of the presence or absence of clinically significant injury on SCT.

**Table 1** Injuries deemed clinically significant on CT for each body region before beginning the study

| |
|---|
| Head |
| Substantial epidural or subdural hematoma (1.0 cm in width or with mass effect) |
| Cerebral contusion 1.0 cm in diameter or at >1 site |
| Extensive subarachnoid hemorrhage—mass effect or sulcal effacement |
| Signs of herniation |
| Basal cistern compression or midline shift |
| Hemorrhage to posterior fossa |
| Intraventricular hemorrhage |
| Bilateral hemorrhage |
| Depressed or diastatic skull fracture |
| Pneumocephalus |
| Diffuse cerebral edema |
| Diffuse axonal injury |
| Cervical spine |
| Any fracture (except those deemed not clinically significant per NEXUS criteria) |
| Ligamentous injury |
| Any other injury requiring surgical intervention, causing a neurological deficit, or causing death |
| Chest |
| Contusion requiring oxygen |
| Any pneumothorax |
| Hemothorax |
| Traumatic pericardial effusion |
| Pneumomediastinum |
| Great vessel injury |
| Esophageal injury |
| Multiple rib fractures (only if admitted for IV pain medication or epidural) |
| Flail segment of ribs |
| Any other injury requiring surgical intervention or causing death |
| Abdomen and pelvis |
| Any injury requiring admission or surgical intervention or causing death |
| Thoracic/lumbar spine |
| Any fracture (except isolated transverse process fracture or those not requiring a brace) |
| Any other injury requiring surgical intervention, requiring an orthotic brace, causing a neurological deficit, or causing death |

## 2.6. Primary data analysis

For this study, SCT was considered the gold standard, as clinical decisions were made in real time on the basis of SCT results. Of course, CT is not a true gold standard, as recent results comparing CT to autopsy showed poor diagnostic performance [31]. Results of SCT were binary, positive or negative, for clinically significant injury for each imaged body region. The physicians' pretest ratings were treated as ordinal data. We calculated the sensitivities, specificities, NPVs, and positive predictive values (PPVs) corresponding to various cutoffs for EPs' bedside assessment ratings. For example, when we classified "very low" as negative for injury, "low," "intermediate," "high," and "very high" were considered positive for injury. All the aforementioned accuracy indices were calculated against SCT results at varying cutoffs for what was considered a positive bedside assessment: >very low, >low, >intermediate, and >high (Table 3). Parametric receiver operating characteristic (ROC) curves based on binormal models were estimated for assessment of each body region. The overall accuracy of physicians' bedside assessment was evaluated based on the areas under the ROC curves (AUC) and their 95% confidence intervals (CIs) [32].

We also performed a post hoc analysis after excluding patients intubated either in the prehospital setting or immediately after arrival to the ED. This additional analysis was done after initial data review prompted concern that intubation and the associated sedation and/or paralytics might confound the EP's ability to predict injuries. For statistical analysis, we used R version 2.5.1 (R Development Core Team [2007], Vienna, Austria).

## 3. Results

### 3.1. Characteristics of study subjects

Of 31 eligible attending EPs, 18 (58%) provided informed consent to participate in the study. All participating physicians were board-certified/board-eligible EPs. Participating physicians had a median of 11 years (interquartile range [IQR], 4) of experience compared with a median of 10 years (IQR, 3.5) of experience for all eligible faculty at the time of the study. Of 18 participating physicians, 16 (89%) were men, compared with 25 (81%) of 31 of all faculty at that time.

During the study period, 1476 level 1 trauma alert patients were seen. Of these, a convenience sample of 400 patients had pretest probability worksheets submitted by participating EPs. Seventy-one were excluded, resulting in 329 patients for analysis. Of those excluded, 21 patients were not level 1 acuity; 17 patients had penetrating trauma as the reason for level 1 designation; 14 patients had SCT results from outlying facilities upon arrival; 11 forms were submitted but had no patient identifiers; 7 patients did not receive a complete SCT; and 1 patient was younger than 15 years. Mechanisms of injury were motor vehicle crash (58%), motorcycle crash (13%), fall (10%), pedestrian struck (5%), all-terrain vehicle crash (4%), industrial-related injury (3.5%), assault (3.5%), and miscellaneous (3%).

### 3.2. Main results

Table 2 presents the patient characteristics. Of 329 patients, 224 (68%) had at least 1 clinically significant injury to 1 or more body regions on SCT; 102 (31%) of 329 patients had injuries involving 1 body region; 76 (23%) of 329, to 2 body regions; 38 (12%) of 329, to 3 body regions; 8 (2%) of 329, to 4 body regions; and none (0%), to all 5 body regions. Physicians' pretest rating assignments, combining all 5 body regions, were the following: very low, 207 (13%) of 1645; low, 512 (31%) of 1645; intermediate, 526 (32%) of 1645; high, 227 (14%) of 1645; and very high, 173 (11%) of 1645. There was 98.3% agreement between the 2 chart abstractors for the 329 patients (each patient had 5 body regions, totaling 1645 areas for agreement or disagreement).

**Table 2** Patient characteristics

| Characteristic | No. (%) |
|---|---|
| Age, median (IQR), y | 37 (25-51) |
| Sex (male) | 237 (72) |
| Intoxication | |
| Yes | 72 (21.9) |
| No | 148 (45.0) |
| Unknown | 109 (33.1) |
| Anticoagulation | |
| Yes | 11 (3.3) |
| No | 172 (52.3) |
| Unknown | 146 (44.4) |
| ETT | |
| Yes (prehospital) | 120 (36.5) |
| Yes (immediately in ED) | 37 (11.2) |
| No | 172 (52.3) |
| Distracting injury | |
| Yes | 116 (35.3) |
| No | 210 (63.8) |
| Unknown | 3 (0.9) |
| Spinal cord injury suspected | |
| Yes | 29 (8.8) |
| No | 216 (65.7) |
| Unknown | 84 (25.5) |
| GCS score | |
| 13 | 171 (52.0) |
| 9 | 20 (6.1) |
| 3-8 | 138 (41.9) |
| FAST-affected PTP (yes) | 87 (26.4) |

ETT indicates endotracheal tube; PTP, pretest probability.

Areas under the ROC curve (95% CI) for head, cervical spine, chest, abdominal/pelvic, and thoracic/lumbar spine injuries were 0.87 (0.82-0.92), 0.71 (0.62-0.81), 0.81 (0.76-0.86), 0.77(0.71-0.83), and 0.74 (0.65-0.84), respectively. Using various cutoffs for a positive bedside assessment, the prevalence, sensitivity, specificity, NPV, and PPV for each body region are shown in Table 3.

For our study's purposes, we were more interested in the physicians' ability to rule out serious injuries rather than their ability to predict presence of injury. Therefore, to optimize sensitivity and NPV, we considered a "very low" pretest rating as a negative bedside assessment and any rating greater than that as positive. Emergency physicians had 100% (95% CI, 99%-100%) NPV and sensitivity for predicting clinically significant head injuries using this cutoff; the NPV and sensitivities for the cervical spine, chest, abdomen/pelvis, and thoracic/lumbar spine were lower than for the head, ranging from 90% to 98% (see Table 3). Using this cutoff, sensitivity and NPV were quite high; however,

**Table 3** Diagnostic indices for EP bedside assessment compared with SCT as the gold standard for the presence or absence of clinically significant injury

| | Positive if pretest rating is | Prevalence (95% CI), % | Sensitivity (95% CI), % | Specificity (95% CI), % | NPV (95% CI), % | PPV (95% CI), % |
|---|---|---|---|---|---|---|
| Head | >High | 31.6 (26.7-37) | 61.5 (56.0-66.8) | 89.3 (85.4-92.4) | 83.4 (78.8-87.2) | 72.7 (67.5-77.4) |
| | >Intermed. | | 82.7 (78.1-86.5) | 74.2 (69.1-78.8) | 90.3 (86.4-93.2) | 59.7 (54.2-65.0) |
| | >Low | | 97.1 (94.5-98.6) | 44.0 (38.6-49.6) | 97.1 (94.4-98.5) | 44.5 (39.1-50.0) |
| | >Very low | | 100 (98.6-100) | 18.7 (14.7-23.4) | 100 (98.6-100) | 36.2 (31.1-41.7) |
| C-spine | >High | 11.9 (8.7-16.0) | 15.4 (11.8-19.8) | 98.3 (96.0-99.3) | 89.6 (85.7-92.6) | 54.5 (50.0-60.0) |
| | >Intermed. | | 38.5 (33.2-44.0) | 84.8 (80.4-88.4) | 91.1 (87.4-93.9) | 25.4 (20.9-30.6) |
| | >Low | | 82.1 (77.4-86.0) | 44.8 (39.4-50.4) | 94.9 (91.8-96.9) | 16.7 (12.9-21.2) |
| | >Very low | | 97.4 (94.9-98.8) | 12.4 (9.1-16.6) | 97.3 (94.7-98.7) | 13.0 (9.7-17.2) |
| Chest | >High | 39.0 (33.8-44.6) | 25.8 (21.2-30.9) | 98.5 (96.3-99.5) | 67.5 (62.1-72.5) | 91.7 (88.0-94.3) |
| | >Intermed. | | 50.8 (45.2-56.3) | 92.0 (88.4-94.6) | 74.5 (69.4-79.1) | 80.2 (75.4-84.3) |
| | >Low | | 78.1 (73.2-82.4) | 64.5 (59.0-69.6) | 82.2 (77.5-86.1) | 58.5 (52.9-63.8) |
| | >Very low | | 96.9 (94.2-98.4) | 18.5 (14.5-23.2) | 90.2 (86.4-93.1) | 43.2 (37.8-48.8) |
| Abdomen/pelvis | >High | 29.2 (24.4-34.5) | 18.8 (14.8-23.5) | 97.0 (94.3-98.5) | 74.3 (69.2-78.9) | 72.0 (66.8-76.7) |
| | >Intermed. | | 50.0 (44.5-55.5) | 85.4 (81.0-88.9) | 80.6 (75.8-84.6) | 58.5 (53.0-63.9) |
| | >Low | | 84.4 (79.9-88.0) | 50.6 (45.1-56.2) | 88.7 (84.7-91.8) | 41.3 (36.0-46.9) |
| | >Very low | | 97.9 (95.5-99.1) | 16.3 (12.6-20.9) | 95.0 (91.9-97.0) | 32.5 (27.5-37.9) |
| T/L spine | >High | 10.0 (7.1-14.0) | 21.2 (17.0-26.1) | 98.3 (96.0-99.3) | 91.8 (88.1-94.4) | 58.3 (52.8-63.7) |
| | >Intermed. | | 36.4 (31.2-41.9) | 93.2 (89.8-95.6) | 92.9 (89.4-95.3) | 37.5 (32.3-43.0) |
| | >Low | | 69.7 (64.4-74.6) | 61.0 (55.5-66.3) | 94.7 (91.6-96.8) | 16.7 (12.9-21.2) |
| | >Very low | | 97.0 (94.3-98.5) | 15.6 (11.9-20.1) | 97.9 (95.5-99.1) | 11.4 (8.3-15.5) |

Intermed. indicates intermediate; C-spine, cervical spine; T/L spine, thoracic/lumbar spine.

corresponding specificities were low, ranging from 12% to 19%. Fig. 1 shows the EPs' pretest rating assignments for injury compared with SCT at each level of pretest rating assignment and for each body region.

Very few injuries would have been missed without SCT when physicians rated patients as "very low" for injury (Fig. 2). However, multiple serious injuries would have been missed without SCT when physicians ranked patients as "low" probability for injury (Fig. 2). Patients classified with a "very low" rating for injury would have missed only 8 injuries without SCT (see Fig. 2). Each of these 8 patients had painful distracting injuries (ie, mangled extremities or femur fracture), altered mental status (Glasgow Coma Scale [GCS] score <15), intoxication, presence of intubation, a physical examination that noted tenderness of the area in question, or some combination of these features.

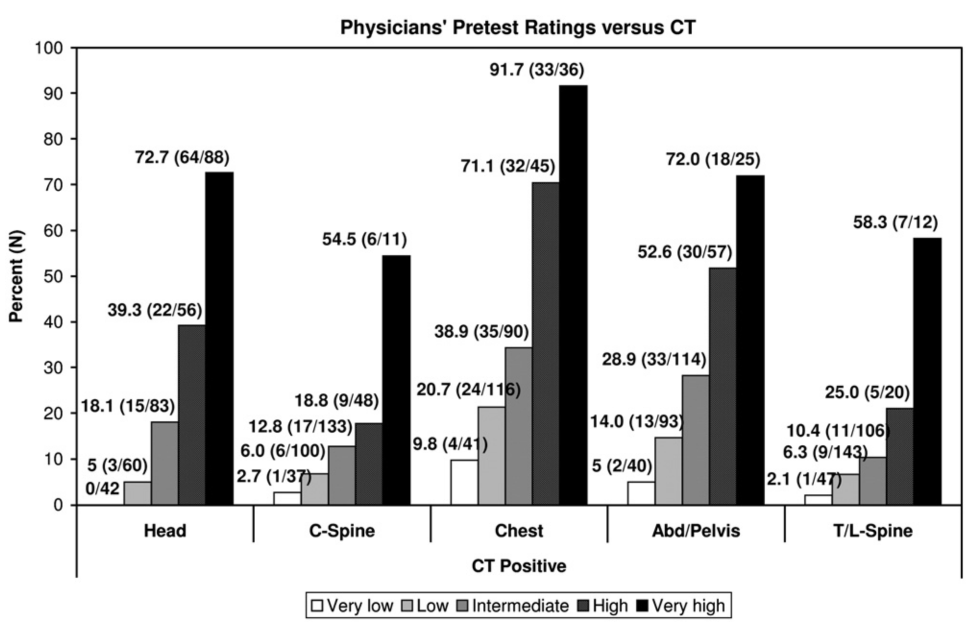


**Fig. 1** Comparison of EPs' pretest ratings for injury with SCT scan results for each body region.

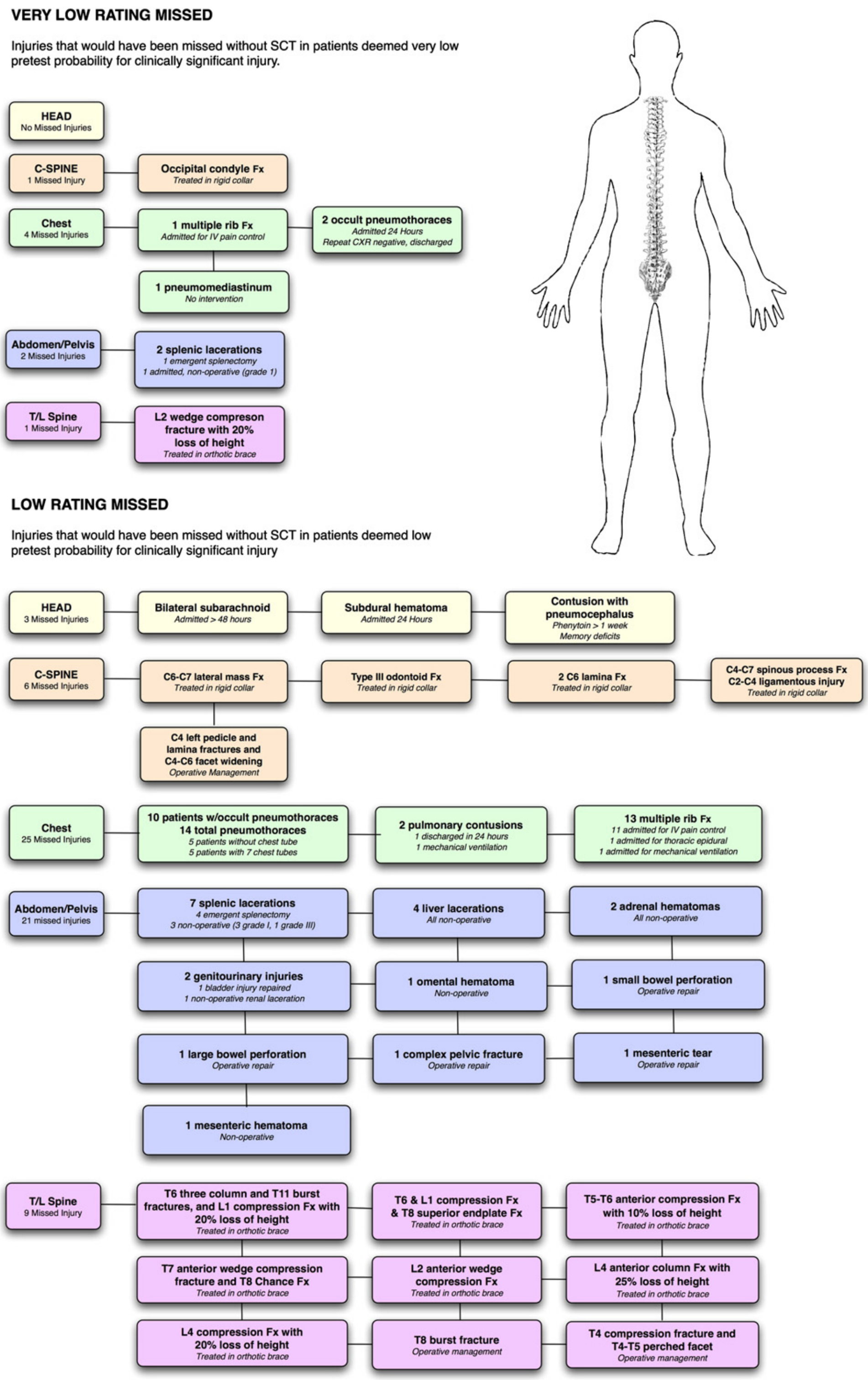


**Fig. 2** Injuries that would have been missed without SCT in patients deemed very low and low pretest probability for clinically significant injury.

A post hoc analysis that measured the same test characteristics in patients who were not intubated yielded 172 patients. In this analysis, AUC (95% CI) in those deemed "very low" pretest rating for injury to the head, cervical spine, chest, abdomen/pelvis, and thoracic/lumbar spine was 0.81 (0.71-0.91), 0.73 (0.57-0.89), 0.82 (0.74-0.89), 0.77 (0.69-0.85), and 0.71 (0.56-0.87), respectively. Sensitivity (95% CI) in those with "very low" rating for injury to the head, cervical spine, chest, abdomen/pelvis, and thoracic/lumbar spine was 100% (97.3%-100%), 93.3%

(88.2%-96.4%), 96.2% (91.8%-98.4%), 97.8 (94.0%-99.3%), and 93.8 (88.7%-96.7%), respectively. In this cohort, 25% were thought to be intoxicated, 12% had unknown intoxication status, 35% had painful distracting injury, and 25% had a GCS score ranging from 10 to 14. Also, more patients in this cohort were rated as "very low" or "low" likelihood for injury when compared with the entire group (19% vs 13% "very low" and 38% vs 31% "low," respectively).

### 3.3. Sensitivity analyses

Table 3 shows how the accuracy indices change when various pretest ratings were considered to be a positive bedside assessment. No dichotomization could lead to both sensitivity and specificity larger than 75% simultaneously.

### 3.4. Limitations

The most important limitation was that this study included only high-acuity trauma patients treated at a single urban trauma center. This patient population was chosen intentionally to address EPs' accuracy in this specific group. However, it greatly affects the ability to generalize our finding to lower acuity populations. This was also a convenience sample, which could have led to selection bias in including sicker patients, as these are the ones physicians might have been most likely to remember to include in the study. This seems probable given the high number of intubated patients, with almost half intubated prehospital or immediately in the ED.

There is, of course, the obvious selection bias in that only patients who were already getting a whole-body SCT as a part of their workup were included. It could be argued that there must have been findings present on assessment that caused the physician to order imaging. However, this was the only ethical way to conduct this type of study, and with the prospective design, we hoped to capture the physicians' candid opinion before imaging as to whether they really thought the patient had injury present. In addition, our trauma department requests whole-body SCT on all level 1 patients with blunt trauma, with very few exceptions. This practice policy often leads to body regions that are scanned despite little initial clinical concern for injury instead of admitting to the hospital for serial examinations and close observation.

Because the study evaluated 1 group of attending emergency medicine physicians, it is possible that other physician groups could have dissimilar prediction ability. However, because all the participating physicians were board certified/board eligible in emergency medicine and had extensive experience (median, 11 years) in caring for trauma patients of all acuity levels, it is likely that our group was reflective of other academic, level 1 trauma centers. It is also important to note that the emergency medicine attending physician was physically present and actively involved in every level 1 trauma resuscitation at our institution. Their clinical assessment was based upon their personal interaction with and examination of the patient. Because this was an unstructured rating system, there may also be considerable heterogeneity among physicians as to what they considered "very low," "low," "intermediate," and so on. However, across all physicians, their candid, subjective impression leads to a graded increase in number of injuries diagnosed on CT as their rating went from very low to very high (Fig. 1).

A FAST examination was not performed in all patients, making it impossible to assess the effect of this on the physicians' assessment of pretest probability of injury. In only 26% of patients did a FAST examination change the pretest probability for injury when it was performed.

The use of SCT as the gold standard could have resulted in missed injuries, as it is known that SCT is less than 100% sensitive for all body regions we studied [31]. Therefore, we reviewed the entire computerized medical record for all patients for at least 4 weeks after the initial injury and did not find any return visits for missed injuries or deaths. Although it is possible that patients may have gone elsewhere for follow-up, it is unlikely, as we are the only level 1 trauma center for the region. Although SCT is short of a true gold standard, in practice, it is treated as such, as clinical decision making regarding treatment and disposition is based on CT results.

We did not include patients based on an injury severity score or other formal measure of acuity but used the hospital's predefined prehospital level 1 acuity criteria (which were based on the American College of Surgeons level 1 and 2 acuity definition) to select the highest acuity population for the study. Of course, some of the level 1 acuity patients were actually not severely ill, as 32% had no injuries at all on CT. However, in practice, the prehospital acuity designation is often a powerful factor in clinical decision making. It seems, however, from the study population that the prehospital acuity designation was accurate and that patients were indeed high acuity, with 36% of patients intubated before arrival and 68% having at least 1 clinically significant injury on SCT.

## 4. Discussion

Despite the advantage of nonselective CT scanning in potentially detecting unsuspected injuries, there are some concerning adverse effects that must be considered. With an attributable risk for cancer mortality of 0.08% for 1 whole-body SCT, and contrast nephropathy developing in up to 13.6% of patients, even when pretreated with saline, emergency and trauma physicians must weigh the risks vs benefits when ordering nonselective SCT imaging [20-22]. There is disagreement, with some physicians advocating liberal CT scanning to avoid occult injury and others very cautious in the use of CT given the above concerns.

The decision to perform SCT imaging in trauma patients is multifactorial. Often, imaging decisions are made on the basis of the trauma surgeon's preference or the reported mechanism of injury instead of on the individual patient's findings on bedside assessment. In our institution, the trauma service that ultimately cares for the patient requests a whole-body SCT on all high-acuity trauma patients, with rare exception, because they think it prevents missed injuries and is more efficient than ordering CT selectively. Selective ordering of SCT may also present problems, as in patients who have received IV contrast and later need a noncontrast study, such as a head CT. It can also pose harm to the patients if they have received a contrast bolus for the abdomen/pelvis, for instance, and it is later determined that contrast SCT imaging of the chest is indicated, necessitating a repeat bolus of IV contrast. Also, the safety and efficiency of having to transport the patient to the CT scanner once for whole-body imaging vs multiple times in a busy ED may factor into the decision making.

Although clinical assessment had 100% sensitivity and NPV for head injury, the lower limit of the 95% CI was 98.5%, suggesting that clinicians proceed with caution when considering omission of head CT until larger studies confirm these findings. The sensitivities for other body regions were 97% to 98% with 95% CI as per Table 3. The question becomes, is a greater than 2% to 3% miss rate acceptable? It is known, according to published guidelines for the workup of subarachnoid hemorrhage, pulmonary embolism, and acute coronary syndrome in a low-risk population (<10% pretest probability), that the current diagnostic workup for each results in a posttest probability of disease of 0%, 0.5%, and 1.1% respectively [33]. From this, it seems that EPs have varying levels of risk tolerance for potentially lethal disease processes but prefer the risk to be 1% or less. Certainly, the potential for missing life-threatening injuries is also present when assessing high-acuity trauma patients. However, other alternatives exist apart from pan-scan CT, such as admission, serial examination, and a selective CT approach.

Given the risks of SCT, our results were encouraging albeit a bit surprising. Our initial hypothesis was that in this population, clinical assessment would fare poorly compared to SCT. Although the size of our study population and its limitations do not allow us to safely recommend abandoning nonselective, whole-body SCT in high-acuity trauma patients, it is encouraging that unstructured clinical assessment performed so well. Had the physicians used validated clinical decision instruments for imaging trauma patients, all the patients rated "very low" likelihood for injury who ultimately had injury present on CT (the false-negatives) would likely have been rated differently [11,24-30]. The rational use of validated clinical decision instruments for trauma imaging in addition to a physician's subjective impression at the bedside could lead to a more selective approach to CT scanning and reduce radiation exposure and cost if future study confirms our findings.

In our post hoc analysis, which excluded intubated patients, accuracy of clinical assessment was similar, but sensitivities and NPVs were worse. We had anticipated that sensitivity and overall accuracy would improve in this cohort. However, 25% were thought to be intoxicated, 12% had unknown intoxication status, 35% had painful distracting injury, and 25% had a GCS score ranging from 10 to 14. Also, more patients in this cohort were rated as "very low" or "low" likelihood for injury when compared with the entire group (19% vs 13% "very low" and 38% vs 31% "low," respectively). This may indicate that when level 1 acuity patients were not intubated upon arrival, the physicians had a false sense of assurance that they were at lower risk for injury. Future study will determine if this holds true in lower acuity, level 2 patients or if prediction improves in this group. We currently have a study underway to address this question.

Although bedside assessment proved to be quite sensitive in patients deemed to have "very low" pretest rating for injury, our study showed that when EPs had any degree of uncertainty about whether a patient was injured, that is, those they considered "low" rating for injury (as opposed to "very low"), their ability to predict injuries decreased significantly. In these high-acuity patients, nonselective whole-body SCT imaging detected many serious, potentially life-threatening injuries that would have been missed with bedside assessment alone (Table 3 and Fig. 2).

In summary, we conclude that unstructured EP bedside assessment had high sensitivity in detecting serious injuries in high-acuity trauma patients in a select cohort of patients with a subjective "very low" pretest rating for injury in our institution. However, in patients assigned a "low" pretest rating for injury, the sensitivity of bedside assessment sharply decreased. Overall diagnostic accuracy (AUC) was low, suggesting that nonselective SCT should be considered in most high-acuity patients to prevent missing injuries.

## Appendix 1. Level 1 acuity criteria at our hospital during the study period

| | |
|---|---|
| Airway/breathing | Unstable airway/unsecure airway |
| | Patients with severe maxillofacial injuries |
| | Patients requiring immediate airway intervention |
| | Facial burns or burns with suspicion of inhalation injury |
| | Moderate-severe respiratory distress, subcutaneous emphysema of face, neck, or chest |
| Circulatory | SBP <90 mm Hg or HR >120 beats/min |
| | Witnessed cardiac arrest from trauma |
| | Arterial bleeding |
| | Spinal shock (hypotension and normal HR with neurological deficits) |
| Central nervous system | GCS score ≤8 |
| | Head injury with LOC >5 min with 1 or more of above (airway/breathing/circulation) |
| | Known spinal cord injury |
| | Neurological deficits with suspected spinal cord injury (any level) |
| Chest/abdomen/pelvis | Cardiac injury |
| | Widened mediastinum |
| | Diagnosed abdominal or pelvic injury with shock (SBP <90 mm Hg or HR >120 beats/min) |
| | Major pelvic injury with shock |
| | Major chest wall injury such as flail chest/sucking chest wound |
| Pregnancy >24 wk with 1 or more of any criteria above | |
| Extremities | Multiple long bone fractures (ie, bilateral femur or femur and humerus with shock) |
| | Amputation of extremity (not digits) |
| | Pulseless extremity with evidence of trauma |
| Mechanism of injury | Penetrating trauma to the head, face, or torso (chest, abdomen, back, or buttocks) |
| | Ejection or thrown from any vehicle with presence of other criteria for trauma activation |
| | Fall from >20 ft with presence of other criteria for trauma activation |
| | High voltage electrical injury |
| | Burns >20% BSA or burns combined with any other injury |
| | Massive crush injury |

SBP indicates systolic blood pressure; HR, heart rate; LOC, loss of consciousness; BSA, body surface area.

## Appendix 2. Physician data collection worksheet

TO BE COMPLETED BY EMERGENCY DEPARTMENT ATTENDING

Based on your history, physical examination, x-ray, and FAST examination, what do you predict will be the likelihood of clinically significant* traumatic injury to the following body areas?

(*Clinically significant traumatic injury defined as that which causes a marked alteration in the patient's immediate management or disposition.)

| For each of the following body areas, make an "X" in the box you think best describes your pretest probability of clinically significant injury. | Very low | Low | Intermediate | High | Very high |
|---|---|---|---|---|---|
| Head | | | | | |
| Cervical spine | | | | | |
| Chest | | | | | |
| Abdomen and pelvis | | | | | |
| Thoracic and lumbar spine | | | | | |

Age: ______ years

Intoxication Suspected? ☐ yes ☐ no ☐ unknown

Plavix or Coumadin? ☐ yes ☐ no ☐ unknown

Pre-hospital intubation? ☐ yes ☐ no

Is there a long bone deformity or other distracting injury? ☐ yes ☐ no

Is there high suspicion for a spinal cord injury? ☐ yes ☐ no ☐ unable to assess

Did the FAST examination change your pretest probability for injury? ☐ yes ☐ no

| | Glasgow Coma Scale | | | | |
|---|---|---|---|---|---|
| Eyes | Eyes | Verbal | Verbal | Motor | Motor |
| | 4. Spontaneous opening | | 5. Oriented | | 6. Obeys commands |
| | 3. To command | | 4. Confused | | 5. Localizes pain |
| | 2. To pain | | 3. Inappropriate | | 4. Withdraws to pain |
| | 1. None | | 2. Incomprehensible | | 3. Flexion to pain |
| | | | 1. None | | 2. Extension to pain |
| | | | T. Intubated | | 1. None |

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