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Review

Selective chest imaging for blunt trauma patients: The national emergency X-ray utilization studies (NEXUS-chest algorithm)

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ABSTRACT

Chest imaging plays a prominent role in blunt trauma patient evaluation, but indiscriminate imaging is expensive, may delay care, and unnecessarily exposes patients to potentially harmful ionizing radiation. To improve diagnostic chest imaging utilization, we conducted 3 prospective multicenter studies over 12 years to derive and validate decision instruments (DIs) to guide the use of chest x-ray (CXR) and chest computed tomography (CT). The first DI, NEXUS Chest x-ray, consists of seven criteria (Age >60 years; rapid deceleration mechanism; chest pain; intoxication; altered mental status; distracting painful injury; and chest wall tenderness) and exhibits a sensitivity of 99.0% (95% confidence interval [CI] 98.2–99.4%) and a specificity of 13.3% (95% CI, 12.6%–14.0%) for detecting clinically significant injuries.

We developed two NEXUS Chest CT DIs, which are both highly reliable in detecting clinically major injuries (sensitivity of 99.2%; 95% CI 95.4–100%). Designed primarily to focus on detecting major injuries, the NEXUS Chest CT-Major DI consists of six criteria (abnormal CXR; distracting injury; chest wall tenderness; sternal tenderness; thoracic spine tenderness; and scapular tenderness) and exhibits higher specificity (37.9%; 95% CI 35.8–40.1%). Designed to reliability detect both major and minor injuries (sensitivity 95.4%; 95% CI 93.6–96.9%) with resulting lower specificity (25.5%; 95% CI 23.5–27.5%), the NEXUS CT-All rule consists of seven elements (the six NEXUS CT-Major criteria plus rapid deceleration mechanism).

The purpose of this review is to synthesize the three DIs into a novel, cohesive summary algorithm with practical implementation recommendations to guide selective chest imaging in adult blunt trauma patients.

1. Background

Chest imaging is currently recommended in the evaluation of all blunt trauma patients who present with a concerning mechanism of injury. As a consequence, chest x-ray (CXR) imaging has become a reflexive test, often ordered regardless of clinical signs of injury [1-2]. In fact, the CXR is the most common imaging study performed in blunt trauma patients [3].

The use of chest computed tomography (CT) has increased in spite of stable injury prevalence rates [4-6]. The push for head-to-pelvis CT (pan-scan) has similarly fueled an increased in utilization of CT in adult blunt trauma diagnostic protocols [7-10]. Such routine ordering, however, may lead to expensive, low-yield, inefficient care and expose patients to unnecessary radiation exposure [11-17]. For example, when performed after a normal CXR, chest CT diagnoses only one major injury for every 67 studies [13]. This practice generates approximately $220,000 in radiographic charges and may induce as many as one lethal malignancy for every 11 major injury diagnoses [12-19].

Order sets that include indiscriminate imaging have been shown to increase the costs, and in some cases, risk to patients [20]. Median charges for chest x-ray in 2013 are $298 per examination, while median charges for chest CT are $3294 per patient [13,21]. Potential risks include harmful effects from ionizing radiation exposure, as well as potential renal injury and allergic reactions from intravenous contrast [22]. While CXR delivers negligible amounts of radiation, chest CT exposes the patient to a considerable effective radiation dose (ERD) and cancer induction risk, especially for women. Chest CT delivers approximately 8.9 mSv, which is estimated to induce one lethal cancer among every 650 exposed 40 year old women [12]. Although newer CT scan protocols may deliver lower ERD (approximately 5 mSv), lethal malignant transformation rates are higher among younger patients who comprise trauma populations [15,18,19].

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With these principles of cancer induction risk, expense, and resource utilization in mind, we have examined the issue of blunt trauma chest imaging in 5 prospective studies conducted over the past 12 years [3,13,23-26]. With the ultimate goals of reducing unnecessary imaging and producing more efficient protocols for blunt trauma chest imaging, we prospectively enrolled over 24 000 adult blunt trauma victims at 10 Level 1 trauma centers. The purpose of this review of our previously published work is to synthesize the three resulting decision instruments into a cohesive summary algorithm with practical implementation recommendations to guide selective imaging in adult blunt chest trauma patients.

2. Methods

We began our chest imaging DI work in 2003, when chest CT was less commonly utilized. We therefore initially directed our efforts at reducing unnecessary CXR in a manner similar to the original NEXUS and Canadian cervical spine studies, which looked primarily at patients with plain radiography of the cervical spine [27,28]. While deriving and validating a rule for selective CXR, we recognized the movement toward greater use of chest CT [7-10], and later sought to develop a rule for selective use of chest CT [3].

Our DIs were developed as one-way directive instruments intended to reduce the reflexive, nearly universal use of chest imaging in blunt trauma patients. Adhering to the principles for clinical decision rule development put forth by Stiell, et al. [29], we employed consistent core methodology in all of our pilot, derivation and validation studies [29,30]. After our pilot study at 3 trauma centers, we conducted our 4 primary studies at 10 urban Level 1 trauma centers, prospectively enrolling patients with the following inclusion criteria: 1) age over 14 years, 2) presentation to the ED for blunt trauma that occurred within 6 h of arrival, and 3) consistent with our objective to derive one-way rules–having chest imaging (either CXR or chest CT) ordered in the ED as part of their trauma evaluation [3,23,24]. We focused our enrollment primarily to daytime hours according to research personnel availability.

2.1. Candidate Criteria

By reviewing literature and investigator consensus, we generated lists of DI candidate criteria and refined these lists into DIs through prospectively conducted derivation studies. We checked all criteria for inter-rater reliability using dual, independent assessments, ensuring that they met pre-defined kappa thresholds for agreement [3,23].

2.2. Outcomes

We defined all injuries according to official radiologist interpretations. In order to assess the clinical impact of injuries, we convened a priori expert trauma clinician panels to classify injuries seen on chest and thoracic imaging into major, minor and no clinical significance categories. See Table 1 for this classification. We followed enrolled patients through their hospital course, abstracting outcome data by recommended chart abstraction guidelines and checked subsets of data to confirm inter-abstractor consistency and agreement [3,23,24,30].

2.3. Controls for bias

Systematically enrolling groups of patients who did not receive imaging or who were not admitted to the hospital, we controlled and checked our work extensively for the introduction of spectrum bias and follow-up bias. We also followed patients whose initial ED imaging was negative to see if they were later diagnosed with injury [3,24].

2.4. Analyses

Considering that clinicians prefer directive rules over rating scales, we primarily focused on the development of DIs that rule out injury and eliminate the need for imaging (identification of patients who are at very low risk for injury seen on imaging). In terms of statistical analyses, we therefore used classification tree (binary recursive partitioning) techniques to derive our primary DIs [3,23]. When

Table 1
Trauma expert panel determination of clinical significance of injuries seen on chest imaging.

Category	Injury
Major clinical significance	Aortic or great vessel injury (all considered major)
	Ruptured diaphragm (all considered major)
	Pneumothorax: received evacuation procedure (chest tube or other procedure)
	Hemothorax: received drainage procedure (chest tube or other procedure)
	Sternal fracture: received surgical intervention
	Multiple rib fracture: received surgical intervention or epidural nerve block
	Pulmonary contusion: received mechanical ventilation (including non-invasive ventilation) primarily for respiratory failure within 24 h for management
	Thoracic spine fracture: received surgical intervention
	Scapular fracture: received surgical intervention
	Mediastinal or pericardial hematoma: received drainage procedure
	Esophageal injury: received surgical intervention
	Tracheal or bronchial injury: received surgical intervention
Minor clinical significance	Pneumothorax: no evacuation procedure but observed as inpatient >24 h
	Hemothorax: no drainage procedure but observed as inpatient for >24 h
	Sternal fracture: no surgical intervention
	Multiple rib fracture: no surgical intervention or epidural nerve block
	Pulmonary contusion or laceration: no mechanical ventilation but observed >24 h
	Thoracic spine fracture: no surgical intervention
	Scapular fracture: no surgical intervention
	Mediastinal or pericardial hematoma: no surgical intervention
	Esophageal injury: no surgical intervention
	Tracheal or bronchial injury: no surgical intervention
No clinical significance*	Hemothorax: no surgical intervention, no inpatient observation
	Pneumothorax: no surgical intervention, no inpatient observation
	Pneumomediastinum without pneumothorax: no inpatient observation
	Pulmonary contusion or laceration: no mechanical ventilation, no surgical intervention, no inpatient observation

* This category was generated to account for those instances in which CT visualizes minute abnormalities that result in no changes in management.