Minor Blunt Thoracic Trauma in the Emergency Department: Sensitivity and Specificity of Chest Ultralow-Dose Computed Tomography Compared With Conventional Radiography

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Study objective: To evaluate the diagnostic performance of chest ultralow-dose computed tomography (CT) compared with chest radiograph for minor blunt thoracic trauma.

Methods: One hundred sixty patients with minor blunt thoracic trauma were evaluated first by chest radiograph and subsequently with a double-acquisition nonenhanced chest CT protocol: reference CT and ultralow-dose CT with iterative reconstruction. Two study radiologists independently assessed injuries with a structured report and subjective image quality and calculated certainty of diagnostic confidence level.

Results: Ultralow-dose CT had a sensitivity and specificity of 100% compared with reference CT in the detection of injuries (187 lesions) in 104 patients. Chest radiograph detected abnormalities in 82 patients (79% of the population), with lower sensitivity and specificity compared with ultralow-dose CT ($P<.05$). Despite an only fair interobserver agreement for ultralow-dose CT image quality ($\kappa=0.26$), the diagnostic confidence level was certain for 95.6% of patients (chest radiograph=79.3%). Ultralow-dose CT effective dose (0.203 mSv [SD 0.029 mSv]) was similar ($P=.14$) to that of chest radiograph (0.175 mSv [SD 0.155 mSv]) and significantly less ($P<.001$) than that of reference CT (1.193 mSv [SD 0.459 mSv]).

Conclusion: Ultralow-dose CT with iterative reconstruction conveyed a radiation dose similar to that of chest radiograph and was more reliable than a radiographic study for minor blunt thoracic trauma assessment. Radiologists, regardless of experience with ultralow-dose CT, were more confident with chest ultralow-dose CT than chest radiograph. [Ann Emerg Med. 2019;73:665-670.]

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INTRODUCTION

Background

Thoracic injuries are frequent, with significant morbidity and mortality. Management of patients mostly depends on the mechanism of the injury, age of the patient, and gravity of the symptoms.[1,2] The Vittel criteria[3] are part of a triage algorithm used by first-response crews in France for managing trauma patients before admission. The diagnosis of severe trauma is based on the presence of one criterion (other than predisposition), which results in directing the most critical patients to a specialized traumatology center. A patient with severe trauma, according to the Vittel criteria, corresponds to one with at least one potentially life-threatening or disabling injury, or who sustained trauma whose mechanism or severity suggests that such lesions may exist. When no criterion is present, chest radiograph is the first-line imaging for suspicion of chest lesion in thoracic trauma. Although computed tomography (CT) has a higher sensitivity and specificity than chest radiograph in the evaluation of these patients,[2,4] it is usually used as second-line imaging because of its higher irradiation.

Importance

Recently, technologic improvements such as iterative reconstruction have become available and have improved the radiation safety of patients undergoing CT. The iterative reconstruction reduces the noise of a CT image generated with a decreased radiation dose.[5] The iterative reconstruction allows ultralow-dose CT with a dose in

Editor's Capsule Summary

What is already known on this topic

Thoracic chest computed tomography (CT) has higher diagnostic accuracy than chest radiograph for patients with thoracic injuries, but this accuracy comes at the expense of increased radiation doses.

What question this study addressed

Does ultralow-dose chest CT provide advantages in accuracy similar to those of standard-dose chest CT but at lower radiation doses?

What this study adds to our knowledge

This prospective observational pilot study of 160 patients with blunt thoracic trauma found that ultralow-dose CT produced acceptable image quality, was highly sensitive and specific for injuries compared with standard chest CT, and was more diagnostically reliable than radiograph.

How this is relevant to clinical practice

Ultralow-dose chest CT may be a reasonable alternative to standard CT for evaluating trauma patients. Outcome studies are needed to determine the cost-benefit ratio of widespread implementation.

the range of a chest radiograph while preserving diagnostic image quality despite a noisier image.[6] Hence, ultralow-dose CT can obviate the excessive radiation dose exposure of a standard CT for the evaluation of patients with minor blunt thoracic trauma.

Goals of This Investigation

The primary objective of this study was to compare the sensitivity and specificity (globally and per lesion type) of chest ultralow-dose CT with that of chest radiograph for patients with minor blunt thoracic trauma in the emergency department (ED), with diagnostic performances evaluated against a reference CT.

MATERIALS AND METHODS

Study Design

This was a cross-sectional single-center diagnostic study. Patients were prospectively recruited from October 2016 to March 2017. The institutional review board of our institution (Level I trauma center) approved this study, provided that total irradiation per patient (chest radiograph+CTs) did not exceed the national diagnostic reference level of a chest CT.[7]

Selection of Participants

Participants were identified in our ED and were included in the availability periods (convenience sample) of the ultralow-dose CT scan (8 AM to 6 PM from Monday to Friday). Inclusion criteria were hemodynamically stable patients older than 18 years who sustained a kinetic energy trauma (motor vehicle crash, fall downstairs, etc). The exclusion criteria were patients with unstable hemodynamic conditions (decrease of blood pressure >30% or systemic pressure <110 mm Hg), dyspnea, loss of consciousness, or at least one Vittel criterion.[3]

Setting

Patients systematically underwent chest radiograph as a first step, with rib series when rib fractures were suspected by emergency physicians or radiologists (125 and 70 kVp, respectively) (Digital Diagnost X-ray room; Philips, Amsterdam, the Netherlands), immediately (<30 minutes later) followed by a CT examination as a second step. Chest CT images were obtained with a 64-multidetector CT scanner (Definition AS+; Siemens Healthineers, Forcheim, Germany). Patients lay supine for a reference CT (100 kVp, 60 mA, CareDose-4D activated, and pitch 1.5) and an ultralow-dose CT (100 kVp, 10 mA fixed, and pitch 1.5). Both acquisitions were acquired consecutively without intravenous injection of contrast media. The tube current parameters were fixed for ultralow-dose CT to be below the national dose reference level for a chest radiograph (effective dose 0.225 mSv).[7] Ultralow-dose CT images were reconstructed with sinogram-affirmed iterative reconstruction.

Data Collection and Processing

Two independent study radiologists, with 9 (F.M. [study radiologist 1]) and 6 (E.K. [study radiologist 2]) years of experience as board-certified radiologists, independently randomly assessed anonymized chest radiograph and ultralow-dose CT data sets on clinical workstations with a picture archiving and communication system viewer (Centricity; GE Healthcare, WI), with at least 2 weeks between each data-reading session. Study radiologists were not aware of patients' clinical data. Study radiologist 1 had 3 years of experience with ultralow-dose CT images, whereas study radiologist 2 had no experience in chest ultralow-dose CT (undergoing only a 2-week training period before this study). Reference CT images were read by the scheduled radiologists during regular shifts (excluding study radiologists 1 and 2), who were informed of the final diagnosis. Study radiologists evaluated the images to detect the presence of pneumothorax, subcutaneous emphysema, pneumomediastinum, pulmonary contusion, fractures of the thoracic skeleton (thoracic spine, rib cage, clavicles, and sternum), pleural effusion, and pericardial (>2-mm thickness) and pleuropericardial effusions. The primary outcome was the presence of at least one lesion. Number of rib fractures or severity of effusions was not evaluated.

The subjective image quality of the chest radiograph and ultralow-dose CT was evaluated with a 5-point Likert scale: 1, excellent; 2, good; 3, fair; 4, poor; and 5, unacceptable.[6] Study radiologists expressed for each patient and for the 2 modalities a diagnostic confidence level as certain or uncertain.

The radiation dose was evaluated by calculation of the effective doses. Dose-area product for the chest radiograph and the dose-length product for the ultralow-dose CT and the reference CT were recorded from the dose report of each patient and converted to effective dose. Effective dose was calculated by multiplying the dose-length product and the dose-area product by the normalized effective dose conversion coefficient for the chest: 0.014 $mSv \times mGy^{-1} \times cm^{-1}$ for the CT and 0.00018 $mSv \times mGy^{-1} \times cm^{-2}$ for the radiography.

Primary Data Analysis

The sensitivity and specificity of ultralow-dose CT and chest radiograph were estimated, with 95% confidence intervals, against the reference CT (reference standard) globally and per lesion type. Study radiologist 1 results were used for diagnostic performance estimations. Concordance between study radiologists (interobserver agreement) was assessed with κ and weighted κ statistics (with their 95% confidence intervals) globally and per lesion type. Hodges-Lehmann estimator was computed to test the effective dose differences between ultralow-dose CT versus chest radiograph and ultralow-dose CT versus reference CT. All analyses were performed with R software using a 2-sided type I error rate of 5% as a threshold for statistical significance. The sample size was calculated on the expected difference between the sensitivities of ultralow-dose CT and chest radiograph. With a hypothesis that 60% of the study population would present with at least one lesion, 154 patients were necessary to show a sensitivity increase from 80% to 95% (with a 2-sided type I error rate of 5% and 90% power). To be conservative, we planned to include 160 patients.

RESULTS

Characteristics of Study Subjects

A total of 160 patients were included, all evaluated by chest radiograph and CTs (14-minute average time lapse between the 2 examinations; range 5 to 30 minutes) to detect chest lesion. Patients were aged a mean 65 years (SD 21 years), with a mean body mass index (BMI) of 23.9 kg/m^2 (SD 5.4 kg/m^2). Of 160 patients, 98 (61%) were men (61 years [SD 20 years]; BMI 23.8 kg/m^2 [SD 5.8 kg/m^2]), whereas 62 (39%) were women (69 years [SD 22 years]; BMI 24.0 kg/m^2 [SD 5.0 kg/m^2]).

Among these 160 patients, reference CT showed pathologic findings in 104 (65%), with 187 lesions. A single lesion was found in 52 of the patients (50%). Two lesions were found in 32 patients (31%). A total of 16 patients (15%) presented with 3 lesions and 4 patients (4%) had at least 4 lesions. The Figure describes all the lesions and whether they were detected by each study radiologist for each index test.

All patients with at least one injury related to the minor blunt thoracic trauma had injury detected on ultralow-dose CT (100% sensitivity [95% CI 97 to 100]), but only 82 patients' injuries (79% sensitivity [95% CI 70 to 86]) were observed on chest radiograph. Ultralow-dose CT had no false-positive results (100% specificity [95% CI 94 to 100]), whereas chest radiograph yielded false-positive results for 8 patients (86% specificity [95% CI 74 to 94]) with respect to the pleural effusion, which was overestimated, being confused with pulmonary contusions. Table 1 presents the results of sensitivities and specificities globally and per lesion type. Ultralow-dose CT resulted in 100% sensitivity and specificity for all considered abnormalities. In contrast, sensitivity of chest radiograph was low, specifically for pulmonary contusion (4/17; 24%). Chest radiograph specificities were 100% except for effusion (89% [95% CI 80 to 94]) because of one false-positive result. Pericardial effusions could be diagnosed only on CT (36 patients [26 pleuropericardial effusion and 10 pericaridial effusion], 23% of the population). Subjective image quality per study radiologist is reported in Table 2. Images from cases demonstrating image quality are available in Appendix E1, available at http://www.annemergmed.com. The interobserver agreement for image quality was moderate (κ=0.26 [95% CI 0.17 to 0.35]) for ultralow-dose CT and good (κ=0.85 [95% CI 0.74 to 0.96]) for chest radiograph (Table E1, available online at http://www.annemergmed.com). The diagnostic confidence level on chest radiograph images was rated certain in 81.8% (95% CI 75.9 to 87.9) and 79.3% (95% CI 73.1 to 85.7) of cases, respectively, for study radiologists 1 and 2. The diagnostic confidence level for ultralow-dose CT was certain in 96.8% (95% CI 94.2 to 99.6) and 95.6% (95% CI 92.4 to 98.8) of cases for study radiologists 1 and 2, respectively. Finally, the interobserver agreement for diagnostic confidence level was certain for

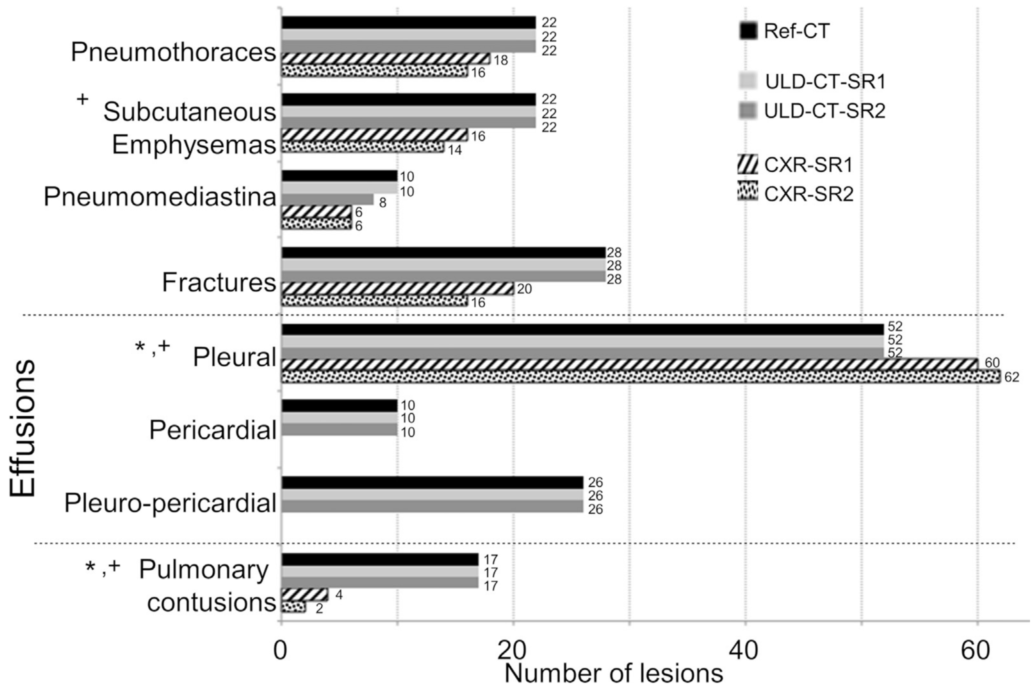

Figure. Lesions detected on chest reference CT (reference standard), chest ultralow-dose CT, and chest radiograph (2 index tests) by study radiologists 1 and 2. Asterisk corresponds to *P*<.05 for study radiologist 1 between CXR and ULD. Plus sign corresponds to *P*<.05 for study radiologist 2 between CXR and ULD. *Ref*, Reference.

chest radiograph and ultralow-dose CT (chest radiograph κ=0.92 [95% CI 0.84 to 1.00]; ultralow-dose CT κ=0.83 [95% CI 0.59 to 1.00]).

In regard to the dose level, that for ultralow-dose CT was significantly lower than that for reference CT ($\Delta^{\wedge} = 0.93$ [0.86 to 1.00]) but not significantly different from that for chest radiograph ($\Delta^{\wedge} = 0.06$ [0.10 to 0.20]).

LIMITATIONS

The first limitation of the study concerns practices that differ between centers in terms of trauma management. Our population, older and with a low BMI, might not reflect the population from other centers. The definition of pleural or pericardial effusions could be assessed differently, depending on the size of the effusion and the influence for the

Table 1. Sensitivity and specificity (and their respective 95% confidence intervals) for chest radiograph and chest ultralow-dose CT compared with the reference CT.

	CXR		ULD CT	
	Sensitivity	Specificity	Sensitivity	Specificity
≥1 lesion, n/N, %	82/104	48/56	104/104	56/56
	78.8 (69.7–86.2)	85.7 (73.8–93.6)	100.0 (96.5–100.0)	100.0 (93.6–100.0)
By lesion type				
Pneumothorax (n=22)	81.8 (61.5–92.7)	100.0 (97.3–100.0)	100.0 (85.1–100.0)	100.0 (97.3–100.0)
Subcutaneous emphysema (n=22)	72.7 (51.9–86.9)	100.0 (97.3–100.0)	100.0 (85.1–100.0)	100.0 (97.3–100.0)
Pneumomediastinum (n=10)	60.0 (31.3–83.2)	100.0 (97.5–100.0)	100.0 (72.3–100.0)	100.0 (97.5–100.0)
Fractures of the thoracic skeleton (n=28)	71.4 (52.9–84.8)	100.0 (97.2–100.0)	100.0 (87.9–100.0)	100.0 (97.2–100.0)
Effusions (n=88)	59.1 (48.7–68.8)	88.9 (79.6–94.3)	100.0 (95.8–100.0)	100.0 (94.9–100.0)
Pulmonary contusion (n=17)	23.5 (9.5–47.3)	100 (97.4 –100.0)	100.0 (81.6–100.0)	100.0 (97.4–100.0)

ULD, Ultralow dose; *CXR*, chest radiograph.
Study radiologist 1 results were compared with the reference standard results (reference CT reports made by shift radiologists) for the sensitivity and specificity analyses.

Table 2. Subjective image quality of chest radiograph and chest ultralow-dose CT.

	CXR			ULD CT		
Image Quality	**SR1**	**SR2**	**κ**	**SR1**	**SR2**	**κ**
Excellent	140	135		132	59	
Good	9	14		21	94	
Fair	5	6	0.85	7	7	0.26
Poor	6	5	(0.74–0.96)	0	0	(0.17–0.35)
Unacceptable	0	0		0	0	

SR, Study radiologist.
SRs 1 and 2 with interobserver agreement (weighted κ estimations with 95% confidence interval).

management of the patient. The difference between small or extensive effusion, number of rib fractures, or clinical effect on patients was not recorded. Ultralow-dose CT cost is higher than that of chest radiograph. A comparison with standard chest CT (5 to 7 mSv) was not conducted because for 4 years we have been routinely performing low-dose chest CT (1 to 2 mSv), whose diagnostic reliability is promoted by vast literature. Despite the rigorous method of analysis between the 2 study radiologists, data were anonymized rather than deidentified, which might have influenced study radiologists' reviewing.

DISCUSSION

This study demonstrated that chest ultralow-dose CT with iterative reconstruction allows a more detailed assessment than chest radiograph for patients with minor blunt thoracic trauma, delivering a radiation dose lower than the national chest radiograph diagnostic reference level. Moreover, the radiologist with a short training period (study radiologist 2) in ultralow-dose CT imaging was more confident with such CT imaging, despite the modification of the image quality because of the decreased dose and iterative reconstruction application, than with standard chest radiograph.

The study radiologists found more injuries related to minor blunt thoracic trauma on ultralow-dose CT than on chest radiograph. Small pneumothorax and pneumomediastinum should not be underestimated because of the incidence of aggravation and potential bronchodigestive damage,[8] respectively. Ultralow-dose CT compared with chest radiograph had a very high sensitivity and specificity in detecting pulmonary contusions. The ultralow-dose CT allowed a thorough study of the rib cage, thoracic spine, and, occasionally, the shoulder girdle. The versatility of 2- and 3-dimensional CT images and their multiplanar reconstructions avoided the inconvenience of structure superimposition generated by radiographs, with their misleading interpretations. Rib fractures are extremely painful during regular breathing, and if overlooked they are a critical factor in mortality increase in elderly patients, especially with comorbidity.[9] Overall, study radiologists counted more pleural effusions on ultralow-dose CT than on chest radiograph. The pericardial effusions were observed only on ultralow-dose CT because low volumes made them invisible with chest radiograph. Pleural and pericardial effusions were frequent in this study because of the conservative cutoff for effusion (definition >2 mm), with unpredictable clinical course.[10] Effusions are not necessarily hemorrhages and could have been present before the trauma. Also, elderly individuals with low BMI form a particular population that is more fragile in traumas involving minor mechanisms of injury. Sensitivity and specificity values of the ultralow-dose CT were higher than those of chest radiograph, in keeping with the published literature for standard CT.[4]

The major issue of CT radiation dose reduction is reduction in image quality because of increased noise. Sinogram-affirmed iterative reconstruction decreases the noise, but when high strengths are applied, a smoothing effect can occur, which can initially confuse an unaccustomed radiologist. Study radiologists had fair interobserver agreement for ultralow-dose CT. Study radiologist 1 scored the majority of cases excellent for image quality, whereas study radiologist 2 rated them good. Study radiologist 2 was trained for ultralow-dose imaging specifically for this study, whereas study radiologist 1 had dealt with ultralow-dose imaging for 3 years. Study radiologists never considered the image quality poor or unacceptable for ultralow-dose CT. Study radiologists 2 and 1 had a higher diagnostic confidence level with ultralow-dose CT than with chest radiograph (96% versus 80%, respectively). This result highlights that even though study radiologist 2 was new and less satisfied with the image quality of ultralow-dose CT, they finally proved more confident with ultralow-dose CT than with standard radiographs.

In conclusion, ultralow-dose CT with iterative reconstruction allows a thorough study of patients with minor blunt thoracic trauma, with lower radiation-induced cancer risks, suggesting a new approach for the minor blunt thoracic trauma evaluation. Other studies should be conducted to define whether this initial major expense, which allows a more reliable and quick assessment, avoids further elevated health costs in the management of patients with minor blunt thoracic trauma.

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