Original Article

Occult pneumothorax in patients with blunt chest trauma: key findings on supine chest radiography

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Background: In patients with multiple trauma, a supine chest radiography [chest X-ray (CXR)] is preferred over a erect CXR. However, this method has limitations in detecting post-traumatic pneumothorax. The use of chest computed tomography (CT) to detect traumatic pneumothorax is well known. However, pneumothorax that is not detected before a chest CT scan is known as an occult pneumothorax (OP), and it can cause serious complications in the patient. This study sought to evaluate the frequency and risk factors for OP in trauma patients.

Methods: Patients who suffered thoracic trauma at the Level 1 Regional Trauma Center of Wonju Severance Christian Hospital between 2015 and 2022 were included in this study. All patients were at least 18 years old. The study reviewed all patients' supine CXR and chest CT images and classified them into five radiographic diagnoses: pneumothorax, rib fracture, subcutaneous emphysema, lung contusion, and pneumomediastinum.

Results: The study included 1,284 patients, all with diagnoses of pneumothorax, rib fracture, subcutaneous emphysema, lung contusion, and pneumomediastinum following supine CXR and chest CT. The patient's average age was 58.3±15.2 years. Pneumothorax diagnosis on supine CXR had the lowest accuracy, at 46.7%, and the lowest sensitivity, at 12.7%. In univariate analysis, rib fracture, lung contusion, and subcutaneous emphysema on supine CXR were all found to be statistically significant regarding traumatic OP. In multivariate analysis, the risk factors for OP were lung contusion [odds ratio (OR), 1.440; 95% confidence interval (CI): 1.115–1.860; P=0.005] and subcutaneous emphysema (OR, 25.883; 95% CI: 13.155–50.928; P<0.001) on supine CXR.

Conclusions: The lung contusion and subcutaneous emphysema in supine CXR of trauma patients indicate the presence of OP. Therefore, if chest CT cannot be performed immediately due to unstable vital signs or other circumstances, recognizing the above radiological findings of traumatic pneumothorax may be necessary.

Keywords: Chest radiography; pneumothorax; blunt trauma; computed tomography (CT)

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Introduction

Blunt trauma to the chest is the second leading cause of mortality among all blunt trauma-related deaths, accounting for up to 20% of all deaths (1). Traumatic pneumothorax and rib fractures are common injuries found in chest trauma patients, and they can lead to severe complications like tension pneumothorax, which requires immediate treatment (2). In multiple trauma patients, a supine chest radiography [chest X-ray (CXR)] is preferred over an erect CXR due to inconsistent vital signs or devices such as pelvic fixations. However, this method has limitations in diagnosis because blood and air may overlap with normal lung markings, making pneumothorax or hemothorax difficult to detect (3). The use of multidetector chest computed tomography (CT) has been shown to increase the likelihood of detecting traumatic pneumothorax or hemothorax that may have been missed when conducting a supine CXR by 20–30%. However, the precise data on the frequency and subsequent treatment of traumatic occult pneumothorax (OP) is currently limited and under investigation (4,5).

Generally, traumatic pneumothorax can be quickly treated with a closed drainage technique (3). Radiologically, this is described as intrapleural gas or air between the parietal and visceral pleural layers on a CXR or chest CT (4). However, a subsequent chest CT may be delayed or not conducted in patients with major trauma due to unstable vital signs, ongoing resuscitation, or emergent procedures. A pneumothorax that is not detected before a chest CT scan is performed is known as an OP. Therefore, detecting an OP early on is critical because it can progress into a tension pneumothorax over time, especially in situations where positive ventilation is required.

The aim of this study was to investigate the frequency and risk factors of OP in blunt chest trauma patients when a chest CT scan is difficult to achieve. We also investigated the supine CXR-based diagnosis of injuries seen in trauma patients. The findings may help clinicians improve the primary survey and management of patients with blunt chest trauma. We present this article in accordance with the STARD reporting checklist (available at https://jtd.amegroups.com/article/view/10.21037/jtd-23-541/rc).

Highlight box

Key findings

- Lung contusion and subcutaneous emphysema in supine chest radiograph of trauma patients suggest the presence of traumatic occult pneumothorax.

What is known and what is new?

- It is well known that traumatic occult pneumothorax can progress to a tension pneumothorax, putting the patient in a critical situation.
- This paper shows that subcutaneous emphysema and lung contusion on supine chest radiography represent risk factors for occult pneumothorax.

What is the implication, and what should change now?

- When CT cannot be performed immediately due to unstable vital signs, it may be necessary to recognize the chest radiography finding of traumatic occult pneumothorax.

Methods

Study cohort and data collection

The patients included in this study were who suffered thoracic trauma at the Level 1 Regional Trauma Center of Wonju Severance Christian Hospital between 2015 and 2022. All patients were at least 18 years old. The study acquired clinical information from electronic medical records, including age, gender, mechanism of injury, Injury Severity Score (ISS), chest Abbreviated Injury Scale (AIS), image study, time of imaging, and procedural interventions (6,7). An AIS score of 3 or higher was characterized as severe trauma. The study excluded certain patients, including those with cut or penetrating injuries, as well as patients who did not undergo a supine CXR or chest CT during the study period. Additionally, subjects for whom data acquisition and analysis could not be obtained due to insufficient medical records were also excluded from the study. The researchers examined all the patients' supine CXR and chest CT images and classified them into five radiographic diagnoses: pneumothorax, rib fracture, subcutaneous emphysema, lung contusion, and pneumomediastinum. One out of three thoracic surgeons with Trauma specialty immediately confirmed CXR at the patient's Trauma Center visit, and at Trauma rounding the next day, two of thoracic surgeons and one radiologist checked the images together and made a diagnosis. *Figure 1* shows the numerous radiographic findings of OP in supine CXR and chest CT. The researchers calculated the sensitivity, specificity, positive predictive value, and negative predictive value for pneumothorax diagnosis on supine CXR versus chest CT. The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). The study was approved by the institutional review board of

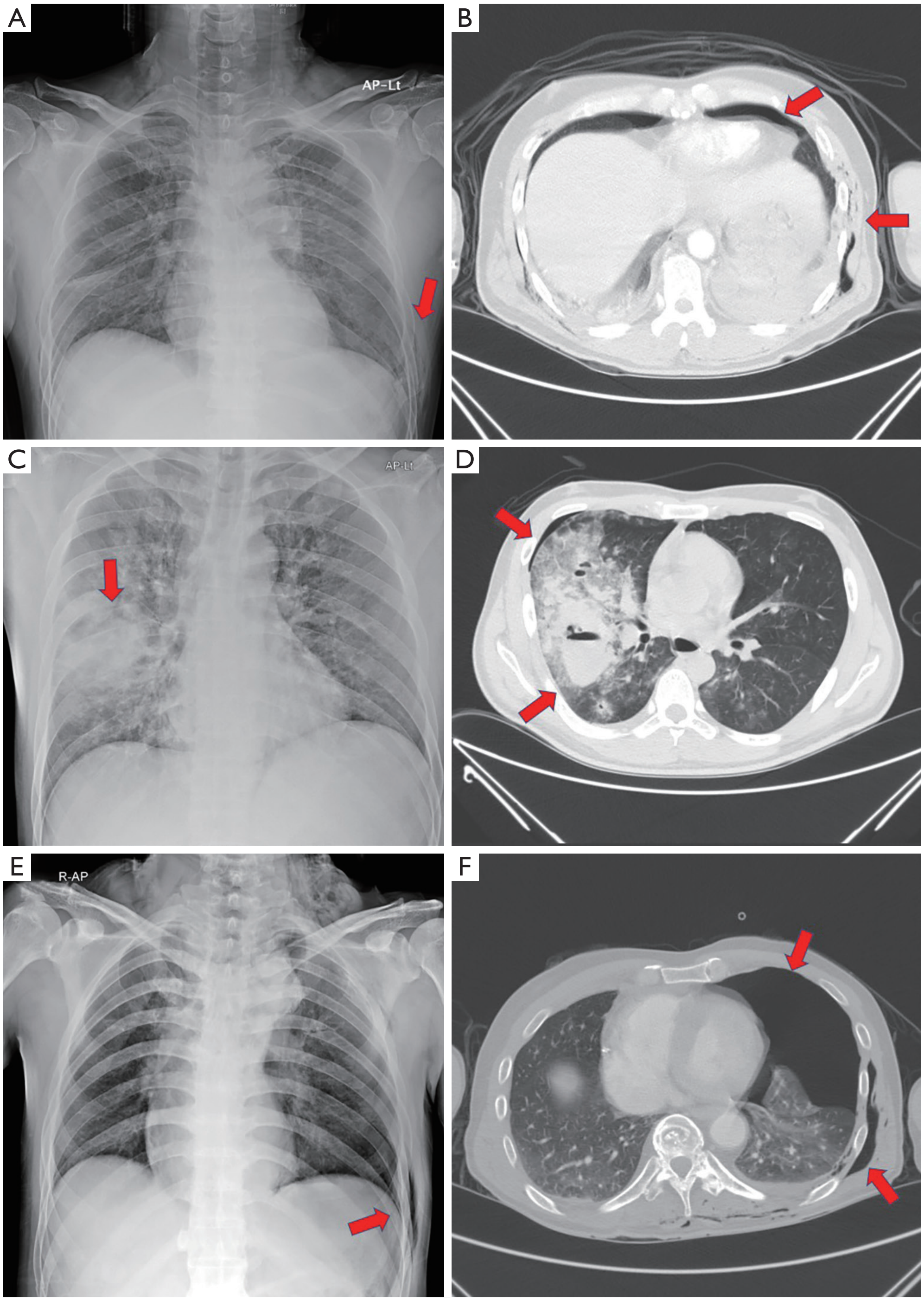

Figure 1 Various supine chest radiography and chest computed tomography findings of occult pneumothorax in Blunt chest trauma. (A,C,E) Arrows show the subcutaneous emphysema, rib fracture and lung contusion in supine chest radiography. (B,D,F) Arrows show the subcutaneous emphysema, rib fracture, lung contusion and traumatic pneumothorax in same patient. AP, anterior-posterior; Lt, left; R, right.

Table 1 Baseline characteristics of study subjects (n=1,284)

Characteristics	Number (%) or mean ± SD
Age (years)	58.3±15.2
Sex, male	967 (75.3)
Type of injury	
Traffic accidents	690 (53.7)
Fall down	344 (26.8)
Slip down	77 (6.0)
Object collision	126 (9.8)
Machine crash	26 (2.0)
Assault	21 (1.6)
ISS	18.9±9.5
ISS <9	535 (41.7)
ISS ≥9	749 (58.3)
Chest AIS	3.04±0.50
1	1 (0.1)
2	113 (8.8)
3	1,021 (79.5)
4	129 (10.0)
5	20 (1.6)

SD, standard deviation; ISS, injury severity score; AIS, abbreviated injury score.

Wonju Severance Christian Hospital (No. CR322100) and individual consent for this retrospective analysis was waived.

Statistical analysis

The *t*-test was employed to evaluate continuous variables, while categorical variables were evaluated using the chi-squared test. Means, proportions, and associated standard deviations were computed where applicable. For descriptive statistics, Pearson χ^2 tests were used to evaluate related factors between the two groups, and binary logistic regression analysis was employed to assess risk factors. In univariate analysis, factors that would have affected pneumothorax were analyzed, and in multivariate analysis, factors that affected pneumothorax were analyzed and significant results were presented in a table. All significance tests were two-sided, with a P value <0.05 deemed significant. All statistical analyses were carried out using SPSS ver. 26 (SPSS, Chicago, IL, USA), SAS statistical software version 9.4 (SAS Institute, Cary, North Carolina, USA), and R version 4.2.1 (R core Team, Vienna, Austria).

Results

Of a total of 1,836 patients originally included in the analysis, 552 cases were then excluded due to penetrating injuries, a lack of supine CXR or chest CT, drowning, or burns. The study included 1,284 patients, with confirmed diagnoses of lung contusion, rib fracture, pneumothorax, subcutaneous emphysema, and pneumomediastinum on supine CXR and chest CT. *Table 1* shows the general characteristics of the included patients. The average age was 58.3±15.2 years, and the average ISS was 18.9±9.5. Traffic accidents were the most common cause of injury (690 cases), followed by falls (344 cases), collisions with objects (126 cases), slips (77 cases), mechanical press accidents (26 cases), and assaults (21 cases). Most Chest AIS score were 3, accounting for 79.5% of the total cases.

On supine CXR, rib fractures were diagnosed in 863 cases, lung contusions in 497 cases, subcutaneous emphysema in 270 cases, traumatic pneumothorax in 100 cases, and pneumomediastinum in 13 cases, according to *Table 2*. On chest CT scans, 1,184 cases had rib fractures, 1,130 had lung contusions, 478 had subcutaneous emphysema, 783 had traumatic pneumothorax, and 66 had pneumomediastinum. The total number of OP cases was 683. Compared to chest CT scan, the accuracy and sensitivity of pneumothorax diagnosis on supine CXR were lower with 46.7% and 12.7%, respectively. Accuracy, sensitivity, specificity, positive predictive value, and negative predictive value of CXR diagnoses are presented in Table S1.

Table 3 shows the results of univariate analysis. Rib fracture, lung contusion, and subcutaneous emphysema on supine CXR were all statistically significant concerning traumatic OP with a P<0.05. Although, when the AIS was clustered into two groups by score, there was no significant finding in supine CXR for OP for in the group with an AIS score of 2 or less. In contrast, in the group with AIS of 3 or higher, rib fracture, lung contusion, and subcutaneous emphysema on supine CXR were all determined to be statistically significant (P<0.05) in OP. In multivariate analysis, the risk factors for OP were lung contusion [odds ratio (OR), 1.440; 95% confidential interval (CI): 1.115–1.860; P=0.005] and subcutaneous emphysema [OR, 25.883; 95% CI: 13.155–50.928; P<0.001] on CXR which were expressed in *Table 4*. Furthermore, there was no risk factor in the low AIS group, but as expressed in *Table 4*, in the high

Table 2 Number of thoracic trauma diagnoses according to supine chest radiography and chest computed tomography

Variables	Rib fracture	Lung contusion	Subcutaneous emphysema	Pneumothorax	Pneumomediastinum
Chest radiography	863	497	270	100	13
Chest CT	1,184	1,130	478	783	66

Data are presented as numbers. CT, computed tomography.

Table 3 Univariate analysis of risk factors for occult pneumothorax in supine chest radiography according to injury score

Chest radiography	All (n=1,284)			AIS <2 (n=114)			AIS ≥3 (n=1,170)		
	OP−	OP+	P	OP−	OP+	P	OP−	OP+	P
Rib fracture			<0.001			0.512			<0.001
Negative	233	188		25	56		208	132	
Positive	368	495		13	20		355	475	
Subcutaneous emphysema			<0.001			1.000			<0.001
Negative	549	465		34	67		515	398	
Positive	52	218		4	9		48	209	
Lung contusion			<0.001			0.454			<0.001
Negative	399	388		29	63		370	325	
Positive	202	295		9	13		193	282	
Pneumomediastinum			0.099			–			0.093
Negative	598	673		38	76		560	597	
Positive	3	10		0	0		3	10	

Data are presented as numbers. AIS, abbreviated injury score; OP, occult pneumothorax.

Table 4 Multivariate analysis of occult pneumothorax risk factor in supine chest radiography in blunt trauma patients

Chest radiography	All patient		AIS ≥3	
	P value	OR (95% CI)	P value	OR (95% CI)
Rib fracture	N/S	N/S	0.002	1.544 (1.173–2.033)
Lung contusion	0.005	1.440 (1.115–1.860)	0.001	1.580 (1.208–2.066)
Subcutaneous emphysema	<0.001	25.883 (13.155–50.928)	<0.001	24.930 (12.612–49.282)

AIS, abbreviated injury score; OR, odds ratio; CI, confidence interval; N/S, not significant.

AIS group, rib fracture was P=0.002 (OR, 1.544; 95% CI: 1.173–2.033) and lung contusion was P=0.001 (OR, 1.580; 95% CI: 1.208–2.066), with subcutaneous emphysema P<0.001 (OR, 24.930; 95% CI: 12.612–49.282).

Discussion

Trauma patients who visit the emergency department are usually studied with CXR before having a torso CT scan. However, CT scans are frequently avoided when the patient's vital signs are unstable. The most common injuries identified on a supine CXR include pneumothorax, rib fracture, subcutaneous emphysema, lung contusion, and pneumomediastinum. However, OP's situation differs slightly. If a pneumothorax is not detected on a supine CXR, decompression may not be essential, especially if the pneumothorax is small or positive pressure ventilation is not required. Nevertheless, in critical situations, an undetected pneumothorax on CXR may progress to a delayed pneumothorax while the patient is being transported to another procedure or admission. OP is especially dangerous in trauma patients with compromised cardiorespiratory reserve or those requiring positive-pressure mechanical ventilation. It frequently delays life-threatening signs and increases the risk of tension pneumothorax (8-10). Therefore, identifying risk factors for OP based on supine CXR results is essential.

Based on these identified risk factors, treatment decisions can be made for patients at significant risk of developing OP. These risk factors can also help achieving early treatment decisions during resuscitation in critically injured patients because supine CXR has low diagnostic sensitivity (2). In the phase 3 retrospective study of 338 patients with severe injuries, subcutaneous emphysema (OR, 5.47), lung contusion (OR, 3.25), and rib fracture (OR, 2.65) were recognized as clinical risk factors for OP (11). However, in a following prospective level-II study by the same group, only subcutaneous emphysema stayed independently predictive of OP (12). It should be known that while 15% of patients with OP have concurrent subcutaneous emphysema, nearly all subcutaneous emphysema patients have an underlying overt or OP.

Risk factor of OP in blunt trauma

In our study, univariate analysis revealed that all injuries found on supine CXR were associated with pneumothorax, but this is not considered statistically significant because chest injuries are typically complexly associated. However, in multivariate analysis, lung contusion, and subcutaneous emphysema were determined as statistically significant risk factors for OP in all patients. Furthermore, rib fracture was discovered to be a risk factor for OP in the group with an AIS of 3 or severe chest injury. According to the findings of this study, if the parietal pleura ruptures due to rib fracture, it can lacerate the visceral pleura of the lung, leading to the accumulation of air in the thoracic cavity. The air in the thoracic cavity then passes through the injured parietal pleura, resulting in subcutaneous emphysema. Additionally, severe lung injury caused by inertial deceleration appears as lung contusion on a supine CXR and causes air leakage from the lung parenchyma. All these findings observed on a supine CXR strongly indicate the presence of OP. Further research is needed to develop an improved diagnostic method for OP, potentially utilizing a scoring system or artificial intelligence analysis of supine CXRs. This research should consider factors such as the quantity of rib fractures, lung contusion, and subcutaneous emphysema.

Clinical values of supine CXR in blunt chest trauma

The increased use of CT scans and chest ultrasounds in the investigation of thoracoabdominal blunt trauma results in the detection of pneumothorax, which cannot be diagnosed using traditional supine CXR (2,13,14). In polytrauma patients, initial evaluation is often performed with focused assessment with sonography for trauma (FAST). Recently, ultrasound has been widely used in trauma patients, with reported sensitivity of 92–100% for pneumothorax diagnosis. However, there may be rare cases where ultrasound cannot be used for any situation of emergency room. And although using ultrasound, the presence of subcutaneous emphysema can limit the field of view, making it challenging to diagnose pneumothorax using ultrasound. Paradoxically, subcutaneous emphysema can be considered an overt predictor of pneumothorax. This evidence is unsurprising given that supine CXR is the least sensitive of all commonly used radiographic techniques for detecting pneumothorax (8). Furthermore, the percentage of OP in the supine CXR ranged from 29% to 72% (2,8,13,15-17).

In our study, 261 out of 270 patients (96.7%) with subcutaneous emphysema on CXR were diagnosed with pneumothorax on CT, whereas 522 out of 1,014 patients (51.5%) without subcutaneous emphysema on CXR were diagnosed with pneumothorax on CT in all included patients. Also, among 1,184 patients without pneumothorax on CXR, 218 out of 227 patients (96.0%) with subcutaneous emphysema on CXR were diagnosed with pneumothorax on CT, while 465 out of 957 patients (48.6%) without subcutaneous emphysema on CXR were diagnosed with pneumothorax on CT. According to the findings, the absence of subcutaneous emphysema cannot rule out an OP. Inspecting the 9 patients with subcutaneous emphysema in CXR but no pneumothorax in chest CT from the above paragraph, all patients had lung diseases such as tuberculosis, bronchiectasis, and emphysema. These lung diseases cause severe pleural adhesions on the entire pleura and can be attributed to the inhibition of pneumothorax in chest CT. The specificity of CXR in detecting thoracic trauma was confirmed to be almost 100% in all chest trauma diagnoses. In other words, most findings that were not visible on CT did not appear on CXR. Pneumomediastinum was found in 66 patients on chest CT, but in 13 patients in CXR, the detection rate was very low. CXR had the highest sensitivity in detecting rib fractures, at 72.9%.

Consequently, an OP cannot be detected using CXR but can be identified using a CT scan. Although CT scans are widely used nowadays, identifying OP using plain CXR is critical when multiple trauma patients require mechanical ventilation or when CT scans are difficult to perform due to poor vital signs, time constraints, or the need for immediate emergency surgery. Failure to promptly detect and treat an OP can result in the development of tension pneumothorax, which can be fatal.

This study has a significant limitation in that it only represents the experience of a single institution. Furthermore, the study was conducted retrospectively and relied on accurate and complete electronic medical records. And this study only involved patients with blunt trauma. Cases where pneumothorax was fully evident on initial CXR, were immediately treated with chest tube insertion before a CT scan. Therefore, the included pneumothorax cases in this study may not presentative. Lastly, in cases where vital signs remained unstable despite vigorous resuscitation, these patients were unable to undergo a chest CT scan due to the immediate need for a procedure or operation. Therefore, the included pneumothorax cases in this study may not be representative of critically injured patients. The decision to insert a chest tube should not depend solely on the size of the pneumothorax.

Conclusions

The presence of lung contusion and subcutaneous emphysema in trauma patients underwent CXR, indicates the existence of OP. Therefore, if chest CT scan cannot be performed, it may be necessary to recognize the above clinical signs of OP and consider performing preventive procedures.

Acknowledgments

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Footnote

Reporting Checklist: The authors have completed the STARD reporting checklist. Available at https://jtd.amegroups.com/article/view/10.21037/jtd-23-541/rc

Data Sharing Statement: Available at https://jtd.amegroups.com/article/view/10.21037/jtd-23-541/dss

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Conflicts of Interest: All authors have completed the ICMJE uniform disclosure form (available at https://jtd.amegroups.com/article/view/10.21037/jtd-23-541/coif). The authors have no conflicts of interest to declare.

Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). The study was approved by the institutional board of Wonju Severance Christian Hospital (No. CR322100) and individual consent for this retrospective analysis was waived.

References

1. Tocino IM, Miller MH, Frederick PR, et al. CT detection of occult pneumothorax in head trauma. AJR Am J Roentgenol 1984;143:987-90.
2. Rowan KR, Kirkpatrick AW, Liu D, et al. Traumatic pneumothorax detection with thoracic US: correlation with chest radiography and CT--initial experience. Radiology 2002;225:210-4.
3. Livingston DH, Haurer CJ. Trauma to the chest wall and lung. In: Moore EE, Feliciano DV, Mattox KL, editors. Trauma. 5th ed. New York: McGraw-Hill; 1995:507-37.
4. Stocchetti N, Pagliarini G, Gennari M, et al. Trauma care in Italy: evidence of in-hospital preventable deaths. J Trauma 1994;36:401-5.
5. Di Bartolomeo S, Sanson G, Nardi G, et al. A population-based study on pneumothorax in severely traumatized patients. J Trauma 2001;51:677-82.
6. Rating the severity of tissue damage. I. The abbreviated scale. JAMA 1971;215:277-80.

7. Baker SP, O'Neill B, Haddon W Jr, et al. The injury severity score: a method for describing patients with multiple injuries and evaluating emergency care. J Trauma 1974;14:187-96.
8. Neff MA, Monk JS Jr, Peters K, et al. Detection of occult pneumothoraces on abdominal computed tomographic scans in trauma patients. J Trauma 2000;49:281-5.
9. Harkness MK, Hashim A, Spence D. The "hidden" pneumothorax. Emerg Med J 2004;21:386-7.
10. Plewa MC, Ledrick D, Sferra JJ. Delayed tension pneumothorax complicating central venous catheterization and positive pressure ventilation. Am J Emerg Med 1995;13:532-5.
11. Ball CG, Kirkpatrick AW, Laupland KB, et al. Incidence, risk factors, and outcomes for occult pneumothoraces in victims of major trauma. J Trauma 2005;59:917-24; discussion 924-5.
12. Ball CG, Ranson K, Dente CJ, et al. Clinical predictors of occult pneumothoraces in severely injured blunt polytrauma patients: A prospective observational study. Injury 2009;40:44-7.
13. Ball CG, Hameed SM, Evans D, et al. Occult pneumothorax in the mechanically ventilated trauma patient. Can J Surg 2003;46:373-9.
14. Kirkpatrick AW, Ng AK, Dulchavsky SA, et al. Sonographic diagnosis of a pneumothorax inapparent on plain radiography: confirmation by computed tomography. J Trauma 2001;50:750-2.
15. Kirkpatrick AW, Sirois M, Laupland KB, et al. Hand-held thoracic sonography for detecting post-traumatic pneumothoraces: the Extended Focused Assessment with Sonography for Trauma (EFAST). J Trauma 2004;57:288-95.
16. Holmes JF, Brant WE, Bogren HG, et al. Prevalence and importance of pneumothoraces visualized on abdominal computed tomographic scan in children with blunt trauma. J Trauma 2001;50:516-20.
17. Guerrero-López F, Vázquez-Mata G, Alcázar-Romero PP, et al. Evaluation of the utility of computed tomography in the initial assessment of the critical care patient with chest trauma. Crit Care Med 2000;28:1370-5.

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Supplementary

Table S1 The ratio of positive findings on supine chest radiography when the chest computed tomography scan is positive

Chest radiography	Accuracy	Sensitivity	Specificity	PPV	NPV	F-score
Rib fracture	75.0%	72.9%	100.0%	100.0%	23.6%	84.3%
Lung contusion	50.5%	43.9%	99.4%	99.8%	19.4%	61.0%
Subcutaneous emphysema	83.6%	56.2%	99.9%	99.6%	79.4%	71.9%
Pneumothorax	46.7%	12.7%	100.0%	100.0%	42.3%	22.7%
pneumomediastinum	95.9%	19.7%	100.0%	100.0%	95.8%	32.9%

PPV, positive predictive value; NPV, negative predictive value.

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