Pneumothorax and Hemothorax in the Era of Frequent Chest Computed Tomography for the Evaluation of Adult Patients With Blunt Trauma

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Study objective: Although traditional teachings in regard to pneumothorax and hemothorax generally recommend chest tube placement and hospital admission, the increasing use of chest computed tomography (CT) in blunt trauma evaluation may detect more minor pneumothorax and hemothorax that might indicate a need to modify these traditional practices. We determine the incidence of pneumothorax and hemothorax observed on CT only and the incidence of isolated pneumothorax and hemothorax (pneumothorax and hemothorax occurring without other thoracic injuries), and describe the clinical implications of these injuries.

Methods: This was a planned secondary analysis of 2 prospective, observational studies of adult patients with blunt trauma, NEXUS Chest (January 2009 to December 2012) and NEXUS Chest CT (August 2011 to May 2014), set in 10 Level I US trauma centers. Participants' inclusion criteria were older than 14 years, presentation to the emergency department (ED) within 6 hours of blunt trauma, and receipt of chest imaging (chest radiograph, chest CT, or both) during their ED evaluation. Exposure(s) (for observational studies) were that patients had trauma and chest imaging. Primary measures and outcomes included the incidence of pneumothorax and hemothorax observed on CT only versus on both chest radiograph and chest CT, the incidence of isolated pneumothorax and hemothorax (pneumothorax and hemothorax occurring without other thoracic injuries), and admission rates, hospital length of stay, mortality, and frequency of chest tube placement for these injuries.

Results: Of 21,382 enrolled subjects, 1,064 (5%) had a pneumothorax and 384 (1.8%) had a hemothorax. Of the 8,661 patients who received both a chest radiograph and a chest CT, 910 (10.5%) had a pneumothorax, with 609 (67%) observed on CT only; 319 (3.7%) had a hemothorax, with 254 (80%) observed on CT only. Of 1,117 patients with pneumothorax, hemothorax, or both, 108 (10%) had isolated pneumothorax or hemothorax. Patients with pneumothorax observed on CT only had a lower chest tube placement rate (30% versus 65%; difference in proportions [Δ] -35%; 95% confidence interval [CI] –28% to 42%), admission rate (94% versus 99%; Δ 5%; 95% CI 3% to 8%), and median length of stay (5 versus 6 days; difference 1 day; 95% CI 0 to 2 days) but similar mortality compared with patients with pneumothorax observed on chest radiograph and CT. Patients with hemothorax observed on CT had only a lower chest tube placement rate (49% versus 68%; Δ -19%; 95% CI –31% to -5%) but similar admission rate, mortality, and median length of stay compared with patients with hemothorax observed on chest radiograph and CT. Compared with patients with other thoracic injury, those with isolated pneumothorax or hemothorax had a lower chest tube placement rate (20% versus 43%; Δ -22%; 95% CI –30% to -13%), median length of stay (4 versus 5 days; difference -1 day; 95% CI –3 to 1 days), and admission rate (44% versus 97%; Δ -53%; 95% CI –62% to -43%), with an admission rate comparable to that of patients without pneumothorax or hemothorax (49%).

Conclusion: Under current imaging protocols for adult blunt trauma evaluation, most pneumothoraces and hemothoraces are observed on CT only and few occur as isolated thoracic injury. The clinical implications (admission rates and frequency of chest tube placement) of pneumothorax and hemothorax observed on CT only and isolated pneumothorax or hemothorax are lower than those of patients with pneumothorax and hemothorax observed on chest radiograph and CT and of those who have other thoracic injury, respectively. [Ann Emerg Med. 2019;73:58-65.]

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INTRODUCTION

Trauma centers are increasingly using protocols that incorporate head-to-pelvis computed tomography (CT) (often referred to as pan-scan) for evaluation of adult patients with blunt trauma.[1-4] In previously reported analyses of large cohorts of adult patients with blunt trauma who received chest imaging in the NEXUS Chest studies, the management, morbidity, and mortality associated with

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Editor's Capsule Summary

What is already known on this topic

Chest computed tomography (CT) will detect more injuries than chest radiographs in trauma patients.

What question this study addressed

What is the incidence and clinical relevance of pneumothoraces and hemothoraces evident on CT but not observed on chest radiograph?

What this study adds to our knowledge

The authors combined 2 multicenter observational cohorts totaling 8,661 patients with both CT and chest radiographs and found that pneumothoraces and hemothoraces observed only on CT were of lesser importance.

How this is relevant to clinical practice

Within the limitations of an observational study, these data suggest that care and disposition of patients with CT-only findings should be determined by the patients' condition and associated injuries.

sternal fractures, pulmonary contusions, rib fractures, and scapular fractures have been clarified and updated, given the current era of frequent pan-scan and chest CT.[5-8] Compared with chest radiographs, chest CT detects many more of these injuries, but often these are trivial and do not change patient management.[5-8]

In this study, we sought to use NEXUS Chest study data to similarly describe and update the clinical implications of pneumothorax and hemothorax in the current era of frequent chest CT imaging for blunt trauma.[9,10] Specifically, we sought to determine the incidence of pneumothorax and hemothorax observed on CT only versus on both chest radiograph and chest CT; the incidence of isolated (no other thoracic injuries) pneumothorax and hemothorax; and admission rates, length of hospital stay, mortality, and frequency of chest tube placement in patients with pneumothorax and hemothorax, with a focus on when pneumothorax and hemothorax are observed on CT only and when they occur as isolated thoracic injuries. Extrapolating from our previous studies in this realm, we hypothesized that most pneumothorax and hemothorax would be observed on CT only and that the clinical implications of pneumothorax and hemothorax observed on CT only and isolated pneumothorax or hemothorax would be less than those of patients with pneumothorax and hemothorax observed on chest radiograph and CT and of patients with pneumothorax and hemothorax with other thoracic injuries.

MATERIALS AND METHODS

Study Design

We conducted this planned secondary analysis of data from 2 prospective, observational studies of adult patients with blunt trauma: NEXUS Chest (conducted from January 2009 to December 2012) and NEXUS Chest CT (conducted from August 2011 to May 2014).[9,10] We obtained institutional review board approval at all study sites before these studies.

Setting and Selection of Participants

The specifics of these parent studies have been previously published, but briefly, both studies were conducted at 10 urban, US, Level I trauma centers prospectively enrolling patients with blunt trauma, with the following inclusion criteria: older than 14 years, presenting to the emergency department (ED) within 6 hours of blunt trauma, and receiving chest imaging (chest radiograph, chest CT, or both, ordered at the discretion of providers) during their ED evaluation. All imaging in this analysis occurred within 6 hours of arrival to the ED, with the index chest radiograph preceding chest CT in all cases. We used the entire cohort (21,382 patients) for some analyses and a subgroup from within that cohort (8661 patients who had both chest radiograph and chest CT) for other analyses that involved comparisons of these 2 types of imaging.

Outcome Measures

Our primary measures, using the cohort of 8661 patients who had both CXR and chest CT, for this analysis were the incidence of pneumothorax and hemothorax observed on CT only versus on both chest radiograph and chest CT and the incidence of isolated pneumothorax and hemothorax (pneumothorax and hemothorax occurring without other thoracic injuries).

Our secondary measures and outcomes were hospital admission (full admission not including ED observation), hospital length of stay, inhospital mortality, and frequency of chest tube placement, comparing 4 pairs of patient groups: (1) patients with pneumothorax and hemothorax versus no hemothorax or pneumothorax (entire cohort); (2) patients with pneumothorax and hemothorax observed on CT only versus pneumothorax and hemothorax observed on both chest radiograph and CT (had both chest radiograph and chest CT cohort); (3) patients with isolated (as defined above) pneumothorax and hemothorax versus pneumothorax and hemothorax with other thoracic injuries (had both chest radiograph and chest CT cohort); and (4) patients with isolated pneumothorax and hemothorax (had both chest radiograph and chest CT cohort) versus no hemothorax or pneumothorax (entire cohort). We chose these as the first comparison groups to provide general perspective in regard to the broad population (entire cohort) of trauma patients with and without pneumothorax and hemothorax. Our second comparison groups focused on the clinical differences between pneumothorax and hemothorax observed on CT only and pneumothorax and hemothorax observed on both chest radiograph and CT. In our third and fourth comparisons, we sought to assess the clinical effect of other thoracic injuries on outcomes in patients with pneumothorax and hemothorax.

We defined pneumothorax and hemothorax according to chest radiograph and chest CT reports. When chest radiograph and chest CT readings were discordant, we used the chest CT interpretation as the referent standard. We included injuries that were discovered on initial imaging and excluded pneumothorax, hemothorax, and other thoracic injuries that were discovered on imaging greater than 24 hours after ED presentation. We defined observed on CT only patients as those who had pneumothorax and hemothorax observed on chest CT but not on chest radiograph, and isolated pneumothorax and hemothorax patients as those who had no other thoracic injuries (besides the pneumothorax or hemothorax). Research staff, who were blinded to imaging results, reviewed inpatient records to determine the following clinical outcomes: admission, hospital mortality, length of stay, and placement of chest tube (or other evacuation procedure). We included only chest tubes that were placed within 24 hours of ED presentation. Injury Severity Scores (ISSs) and size of pneumothorax and hemothorax were not collected during the first study (NEXUS Chest), and therefore we used data only from the second study (NEXUS Chest CT) for these particular analyses. The parent study included interabstractor agreement assessments that found it perfect (100%; κ=1.0) for the study outcomes included in this analysis.

Primary Data Analysis

We managed input data with Research Electronic Data Capture, hosted by the University of California, San Francisco,[11] blinded for peer review, and exported completed data to Excel (version 2016; Microsoft, Redmond, WA) for sorting and simple analyses. For age, ISS, and length of stay, we determined medians and interquartile ranges. The prevalence of pneumothorax and hemothorax observed on CT only, isolated pneumothorax or hemothorax, admission, inhospital mortality, and chest tube placement was calculated as proportions with 95% confidence intervals (CIs). To assess differences between groups in regard to ISS and length of stay, we calculated median differences and 95% CIs around those differences. To compare prevalence of admission, inhospital mortality, and chest tube placement rates between groups, we calculated difference in proportions with 95% CIs. We adhered to conventional Strengthening the Reporting of Observational Studies in Epidemiology guidelines for reporting all findings.[12]

RESULTS

Of the total 21,382 enrolled subjects (entire cohort) in the 2 primary NEXUS Chest studies, 1,064 (5%) had a pneumothorax and 384 (1.8%) had a hemothorax. Compared with patients without pneumothorax or hemothorax, those with either one had higher admission rates (96% versus 49%; difference in proportions [Δ] 47%; 95% CI 45% to 48%), hospital mortality (7% versus 2%; Δ 5%; 95% CI 4% to 6%), and median length of hospital stay (5 versus 3 days; Δ 2 days; 95% CI 1.9 to 2.1 days) (Table 1). Patients with pneumothorax or hemothorax also had higher median ISS (19 versus 4; Δ 15; 95% CI 14.8 to 15.2) and were more likely to also have had abdominal or pelvis CT performed with their index chest CT (85% versus 45%; Δ 40%; 95% CI 37% to 43%).

Of the 8,661 patients in the cohort who had both chest radiograph and chest CT, 798 (9.2%) had a pneumothorax, 207 (2.4%) had a hemothorax, and 112 had both pneumothorax and hemothorax (1.3%). Pneumothorax was the third most common thoracic injury behind rib fracture (24%) and pulmonary contusion (12%), and hemothorax was the fifth most common injury additionally behind sternal fracture (3%).

Of the 910 patients with a pneumothorax, 609 had pneumothorax observed on CT only (67%; 95% CI 64% to 70%) (Figure). Compared with patients with

Table 1. Hemothorax or pneumothorax versus no hemothorax or pneumothorax among all 21,382 patients enrolled.

Characteristic	HTX or PTX (n=1,448)	No HTX or PTX (n=19,934)	Difference, % (95% CI)
Median age, y	46	45	1
Male sex, %	62	62	0
Admitted, No. (%)	1,389 (95.9)	9,847 (49.4)	46.5 (45.2–47.7)
Hospital mortality, No. (%)	96 (6.6)	339 (1.7)	4.9 (3.7–6.3)
Median LOS, days (IQR)	5 (2–10)	3 (1–6)	2 (1.9–2.1)
Median ISS (IQR)	19 (11–28)	4 (1–9)	15 (14.8–15.2)

HTX, Hemothorax; *PTX*, pneumothorax; *LOS*, length of stay; *IQR*, interquartile range.

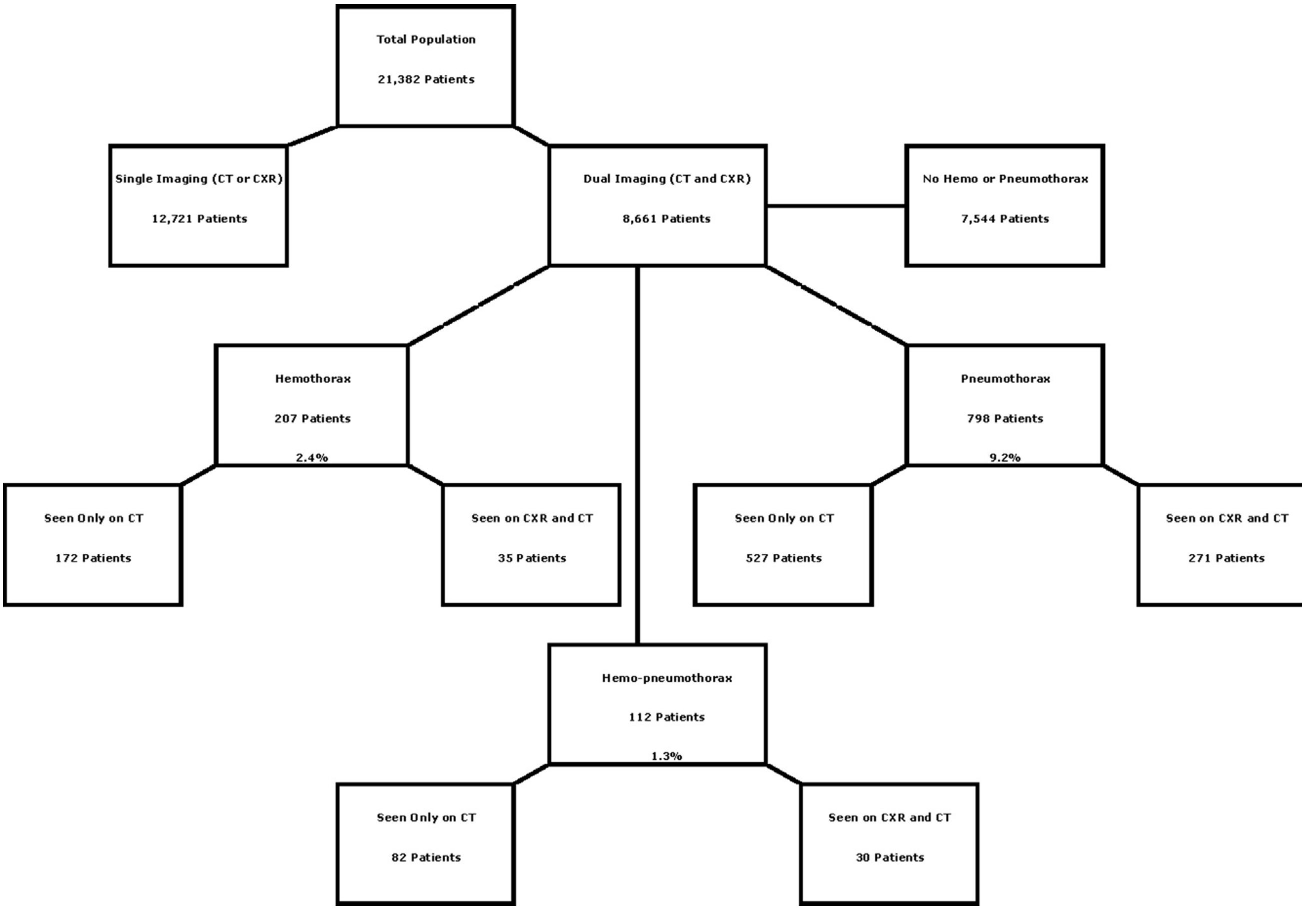

Figure. Enrollment, inclusion, and categorization: Seen Only on CT versus Seen on CXR and CT. *CXR*, Chest radiograph.

pneumothorax observed on chest radiograph and CT (n=910), those with pneumothorax observed on CT only (n=609) had lower admission rates (94% versus 99%; Δ –5%; 95% CI –3% to –8%), length of stay (5 versus 6 days; difference 1 day; 95% CI –0.4 to 2.4 days), and frequency of chest tube placement (30% versus 65%; Δ –35%; 95% CI –28% to –41%). However, hospital mortality and median ISS did not differ in these 2 groups (Table 2). Compared with patients with pneumothorax observed on CT only who did not have chest tubes, those with pneumothorax observed on CT only who had chest tubes had higher median ISSs (25 versus 18; Δ 7; 95% CI 5.6 to 8.5) and higher likelihood of other thoracic injuries (93% versus 82%; Δ 11%; 95% CI 2% to 18%).

Of the 319 patients with hemothorax, 254 had hemothorax observed on CT only (80%; 95% CI 75% to 84%). Pneumothorax and hemothorax observed on CT only were more likely to be "trace," "tiny," or "small" on CT readings than pneumothorax and hemothorax observed on chest radiograph and chest CT (36% versus 25%; Δ 11%; 95% CI 3% to 19%). The frequency of chest tube placement in patients with hemothorax observed on CT only was lower than in those who had hemothorax observed on chest radiograph and CT (49% versus 68%; Δ –19%; 95% CI –31% to –5%). However, admission rates, hospital mortality, median length of stay, and median ISS did not differ in these 2 groups (Table 3). Compared with patients with hemothorax observed on CT only who did not have chest tubes, those with hemothorax observed on CT only who had chest tubes had higher median ISSs (29 versus 20; difference 9; 95% CI 7.7 to 10.4) and higher likelihood of other thoracic injuries (100% versus 91%; Δ 9%; 95% CI 0.1% to 19%).

Of the 8,661 patients who had chest radiograph and chest CT, only 108 had isolated pneumothorax, hemothorax, or both, representing 10% (95% CI 8% to 12%) of the 1,117 total patients with pneumothorax, hemothorax, or both. The most common injuries associated with pneumothorax or hemothorax were rib fractures (60%), pulmonary contusions (40%), thoracic spine fractures (3%), and sternal fractures (1%). Compared with patients who had pneumothorax or hemothorax with other concurrent thoracic injury, those with isolated pneumothorax or hemothorax had lower admission rates

Table 2. Patients with pneumothorax observed on CT only versus observed on chest radiograph and CT among the 910 patients who had pneumothorax.

Characteristic	PTX on CXR and CT (n=301)	PTX SOCTO (n=609)	Difference, % (95% CI)
Admitted, No. (%)	299 (99.3)	572 (93.9)	5.4 (3.1 to 7.7)
Hospital mortality, No. (%)	18 (6.0)	32 (5.3)	0.7 (–2.7 to 4.1)
Median LOS, days (IQR)	6 (4 to 13)	5 (2 to 10)	1 (–0.4 to 2.4)
Median ISS (IQR)	21 (14 to 29)	19 (13 to 27)	2 (–1.3 to 5.3)
Had chest tube, No. (%)	196 (65.1)	185 (30.4)	34.7 (28.0 to 41.5)

SOCTO, Observed on CT only.

(44% versus 97%; Δ –53%; 95% CI –62% to –43%), median length of stay (4 versus 5 days; difference 1 day; 95% CI –0.6 to 2.6 days), frequency of chest tube placement (20% versus 43%; Δ –22%; 95% CI –30% to –13%), and median ISS (10 versus 21; difference 11; 95% CI 7.4 to 14.6). Hospital mortality did not differ between these 2 groups (Table 4). All deaths in the isolated pneumothorax or hemothorax group occurred in patients who had ISS greater than 9. Despite higher median ISS, the isolated pneumothorax and hemothorax group did not differ from the no pneumothorax or hemothorax group in terms of admission rates, mortality, or length of stay (Table 5).

LIMITATIONS

Although to our knowledge this is the largest published cohort of adult patients with blunt trauma and with pneumothorax and hemothorax, the relatively few numbers of deaths may have precluded detecting true significant differences in mortality, especially in the isolated pneumothorax or hemothorax versus pneumothorax or hemothorax with other concurrent thoracic injury analysis. We conducted this study at high-volume Level I trauma centers, which introduces spectrum bias that may limit generalization of our findings to lower-acuity trauma centers. Other causes of spectrum bias, especially the intersite variations in chest CT use, may have affected our findings. Sites with higher CT use would likely have had greater absolute numbers of pneumothorax and hemothorax detected (more observed on CT only), but lower percentages of patients who received chest tubes.

We did not account for certain confounding factors, such as injury to other organ systems, that likely affected our primary outcomes of admission rates, length of stay, and mortality. Similarly, we did not discern reasons for admission and chest tube placement and cannot make conclusions about whether they were necessary. Finally, although we had incomplete data on ISS, this was not

Table 3. Patients with hemothorax observed on CT only versus observed on chest radiograph and CT among the 319 patients who had hemothorax.

Characteristic	HTX on CXR and CT (n=65)	HTX SOCTO (n=254)	Difference, % (95% CI)
Admitted, No. (%)	64 (98.5)	248 (97.6)	0.8 (–3.8 to 6.0)
Hospital mortality, No. (%)	5 (7.7)	20 (7.9)	–0.2 (–9.3 to 6.1)
Median LOS, days (IQR)	7 (4 to 12)	7 (3 to 14)	0 (–3.1 to 3.1)
Median ISS (IQR)	25 (17 to 36)	24 (16 to 34)	1 (–5.3 to 7.3)
Had chest tube, No. (%)	44 (67.7)	124 (48.8)	18.9 (5.3 to 30.7)

Table 4. Isolated pneumothorax or hemothorax versus pneumothorax or hemothorax with other concurrent thoracic injuries among the 1,117 patients who had pneumothorax, hemothorax, or both.

Characteristic	PTX or HTX With Other Thoracic Injuries (n=1,009)	Isolated PTX or HTX (n=108)	Difference, % (95% CI)
Admitted, No. (%)	980 (97.1)	48 (44.4)	52.7 (43.2 to 61.7)
Hospital mortality, No. (%)	63 (6.2)	3 (2.8)	3.4 (–1.8 to 5.9)
Median LOS, days (IQR)	5 (2 to 11)	4 (2 to 6)	1 (–0.6 to 2.6)
Median ISS (IQR)	21 (14 to 29)	10 (5 to 22)	11 (7.4 to 14.6)
Had chest tube, No. (%)	430 (42.6)	22 (20.4)	22.3 (13.2 to 29.5)

Table 5. Isolated pneumothorax or hemothorax versus no pneumothorax or hemothorax.

Characteristic	Isolated PTX or HTX (n=108)	No HTX or PTX (n=19,934)	Difference, % (95% CI)
Admitted, No. (%)	48 (44.4)	9,847 (49.4)	–5.0 (–14.0 to 4.5)
Hospital mortality, No. (%)	3 (2.8)	339 (1.7)	1.1 (–0.8 to 6.2)
Median LOS, days (IQR)	4 (2 to 6)	3 (1 to 6)	1 (0.9 to 1.1)
Median ISS (IQR)	10 (5 to 22)	4 (1 to 9)	6 (5.9 to 6.1)

In this table we compare 2 groups whose total N is not the sum total of all patients in the study.

one of our primary or secondary measures and outcomes.

DISCUSSION

The sensitivity of injury detection in patients with blunt trauma has significantly increased during the past 2 decades.[1,2] Increased availability of advanced diagnostic imaging, particularly CT, has played a large role, as has the desire to achieve a zero miss rate of traumatic injuries to avoid potential legal liability.[13-20] Although a portion of these identified injuries will directly affect patient care, others may not require interventions or alter outcomes and could lead to unnecessary hospital admissions and interventions.[21-23] In this analysis of 2 large, prospectively enrolled, multicenter cohorts of adult patients with blunt trauma, we found that most pneumothoraces and hemothoraces are observed on CT only, an expected finding, given our previous study results showing that most rib fractures, pulmonary contusions, sternal fractures, and scapular fractures are also observed on CT only.[5-8] Also as expected, we found that isolated pneumothorax or hemothorax was unusual; most pneumothoraces and hemothoraces were diagnosed along with other thoracic injuries.

Additionally, we found that the clinical implications of pneumothorax and hemothorax observed on CT only and of isolated pneumothorax or hemothorax are less significant than that of their respective comparison groups (pneumothorax or hemothorax observed on chest radiograph and pneumothorax or hemothorax with other thoracic injury). Both of the observed on CT only groups had much lower rates of chest tube placement, which may partially be explained by the fact that these groups more often had trace or small pneumothorax and hemothorax. The pneumothorax observed on CT only group had lower rates of admission than the pneumothorax observed on chest radiograph and CT group, but mortality was similar and median length of stay was only 1 day shorter. These findings suggest that once admitted, these groups of patients had similar hospital courses.

Our findings in regard to isolated pneumothorax or hemothorax are particularly notable. This group had much lower rates of admission and chest tube placement than the group with other thoracic injuries, as well as shorter length of stay. Furthermore, compared with patients without pneumothorax or hemothorax (Table 5), those with isolated pneumothorax or hemothorax were similar in all outcome measures despite having higher ISSs. These results, along with our finding that all deaths in this group occurred in patients with ISS greater than 9, suggest that in the current age of frequent chest CT, isolated pneumothorax or hemothorax may be of relatively minor significance and that clinical outcomes in trauma patients with pneumothorax or hemothorax may be driven by other associated injuries.

Our rates of pneumothorax observed on CT only are much higher than the rates of what are called "occult" pneumothorax by other investigators in other small cohorts.[14-16] Spectrum bias and other differences in study methods may account for this difference. These other series were conducted 5 to 8 years before our study, when chest CT was less commonly used, and most of the patients in these studies experienced penetrating mechanisms of injury rather than blunt trauma.

Management of occult pneumothorax and hemothorax has been controversial. With complication rates reported to be as high as 22%, tube thoracostomy is not a trivial procedure, and observation of small, occult pneumothorax without thoracostomy tube is acceptable according to the Eastern Association for the Surgery of Trauma consensus guidelines.[24-31] Although recent consensus guidelines suggest that all hemothorax be considered for drainage, regardless of size, Mahmood et al[32] were able to successfully manage 83% of trauma patients without tube thoracostomy. Our findings confirm that clinicians are commonly forgoing chest tube placement in favor of observation for both pneumothorax and hemothorax, especially when they are observed on CT only.

Under current imaging protocols that frequently use chest CT for adult blunt trauma evaluation, we have found that most pneumothoraces and hemothoraces are observed on CT only. Like other thoracic injuries observed on CT only that we have studied, the clinical implications of pneumothorax or hemothorax observed on CT only are lower than when pneumothorax and hemothorax are observed on chest radiograph, especially in terms of rates of chest tube placement. Isolated pneumothorax or hemothorax is uncommon. Patients with isolated pneumothorax or hemothorax have much lower rates of chest tube placement and admission than those whose pneumothorax or hemothorax is associated with other thoracic injuries, suggesting that these aspects of clinical management may be related to these other thoracic injuries.

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Author contributions: RMR, BMB, WRM, MIL, AJM, DRA, GWH, DN, and ASR were responsible for study design. RMR, KC, BMB, WRM, MIL, AJM, DRA, GWH, DN, and ASR were responsible for study implementation and data acquisition. RMR, KC, and WRM were responsible for data analysis. RMR, KC, BMB, WRM, MIL, AJM, DRA, GWH, and ASR were responsible for article preparation. All authors were responsible for article revision. RMR takes responsibility for the paper as a whole.

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