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Pulmonary contusion in the pan-scan era

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ABSTRACT

Background: Although pulmonary contusion (PC) is traditionally considered a major injury requiring intensive monitoring, more frequent detection by chest CT in blunt trauma evaluation may diagnose clinically irrelevant PC.

Objectives: We sought to determine (1) the frequency of PC diagnosis by chest CT versus chest X-ray (CXR), (2) the frequency of PC-associated thoracic injuries, and (3) PC patient clinical outcomes (mortality, length of stay [LOS], and need for mechanical ventilation), considering patients with PC seen on chest CT only (SOCTO) and isolated PC (PC without other thoracic injury).

Methods: Focusing primarily on patients who had both CXR and chest CT, we conducted a pre-planned analysis of two prospectively enrolled cohorts with the following inclusion criteria: age >14 years, blunt trauma within 24 h of emergency department presentation, and receiving CXR or chest CT during trauma evaluation. We defined PC and other thoracic injuries according to CT reports and followed patients through their hospital course to determine clinical outcomes.

Results: Of 21,382 enrolled subjects, 8661 (40.5%) had both CXR and chest CT and 1012 (11.7%) of these had PC, making it the second most common injury after rib fracture. PC was SOCTO in 739 (73.0%). Most (73.5%) PC patients had other thoracic injury. PC patients had higher admission rates (91.9% versus 61.7%; mean difference 30.2%; 95% confidence interval [CI] 28.1–32.1%) and mortality (4.7% versus 2.0%: mean difference 2.8%; 95% CI 1.6–4.3%) than non-PC patients, but mortality was restricted to patients with other injuries (injury severity scores > 10). Patients with PC SOCTO had low rates of associated mechanical ventilation (4.6%)

and patients with isolated PC SOCTO had low mortality (2.6%), comparable to that of patients without PC.

Conclusions: PC is commonly diagnosed under current blunt trauma imaging protocols and most PC are SOCTO with other thoracic injury. Given that they are associated with low mortality and uncommon need for mechanical ventilation, isolated PC and PC SOCTO may be of limited clinical significance.

Introduction

Current surgical and emergency medicine texts, including the Advanced Trauma Life Support Manual, suggest that pulmonary contusion (PC) is a high morbidity injury associated with serious complications that mandate close monitoring and observation for the development of respiratory failure [1–6]. These principles may largely reflect older experience when PC was mostly diagnosed by plain chest X-ray (CXR).

As more centres adopt head-to-pelvis computed tomography (CT) (pan-scan) protocols for blunt trauma evaluation, chest CT utilisation is increasing substantially [7–11]. Given that chest CT has much greater sensitivity for pulmonary and thoracic injury than plain CXR [11–15], minor pulmonary contusions are likely being diagnosed with greater frequency, and standard teaching regarding high morbidity and observation for PC may no longer be relevant.

Examining a large, prospectively observed cohort of adult blunt trauma victims, we sought to update PC diagnosis principles to reflect current trauma diagnostic protocols that incorporate the increased use of chest CT. Specifically, our objectives were to determine: (1) the frequency of PC diagnosis, comparing frequency seen on chest CT and chest X-ray, (2) the frequency of PC associated thoracic injuries, and (3) clinical outcome measures (mortality, hospital length of stay [LOS], and need for mechanical ventilation) of PC patients, with special emphasis on patients with PC seen on chest CT only (SOCTO) and isolated PC (PC without other thoracic injury). We hypothesized that most PC are currently SOCTO and that these PC are associated with low mortality and infrequent need for mechanical ventilation, rendering former teachings about intense monitoring for PC obsolete.

Methods

We conducted this pre-planned analysis of data collected during two prospective, observational studies of blunt trauma patients: NEXUS Chest (from January 2009 to December 2012) [16,17] and NEXUS Chest CT (from August 2011 to May 2014). We followed standard STROBE guidelines and had identical inclusion/ exclusion criteria, enrolment procedures and PC outcome assessments for these two studies, enrolling patients between 07:00 and 23:00 daily at 10 urban Level 1 trauma centres [18]. Our inclusion criteria were age >14 years, blunt trauma occurring within 24 h of emergency department (ED) presentation, and receiving CXR or chest CT in the ED during trauma evaluation. We did not influence imaging decisions, leaving CXR and chest CT choices up to trauma providers.

We defined PC according to official readings of chest CT by board-certified radiologists, who were blinded to patient enrolment in these studies. When imaging interpretations were indeterminate (‘‘possible pulmonary contusion’’), we deemed PC to be present. If CXR and chest CT readings were discrepant with regard to the diagnosis of PC, we used the chest CT interpretation as the referent standard. We defined other thoracic injuries as any of the following noted on ED-derived chest imaging: rib fractures, pneumothorax, hemothorax, pneumomediastinum, mediastinal or pericardial hematoma, aortic or great vessel injury, diaphragmatic rupture, tracheobronchial injury, oesophageal injury, scapula fracture, and thoracic spine fracture.

Because we sought to characterize injuries that were identified on initial trauma evaluation and imaging, we excluded PC and other thoracic injuries that were discovered on imaging >24 h after ED presentation. We defined SOCTO as PC seen on chest CT but not on CXR and isolated PC as PC without other thoracic injury.

To determine outcomes of patients with PC, we followed admitted patients through their hospital course and reviewed charts according to standardized chart review techniques [19]. We defined PC associated mechanical ventilation as any type of mechanical ventilatory assistance (including non-invasive ventilation) that occurred within 24 h of ED presentation and that was primarily directed at pulmonary aspects of respiratory compromise. By this definition, endotracheal intubation and ventilation that occurred for altered mental status or for operative procedures, for example, did not qualify as being PC associated. To check chart abstraction and outcome determination consistency, we con-ducted dual independent chart abstraction in 80 patients and calculated a kappa statistic for agreement for the main outcome measures.

All sample size calculations were directed toward the selective chest imaging decision rule validation (not this PC analysis specifically). We managed data using REDcap hosted by the University of California San Francisco [20] and analysed data using STATA v12 (College Station, TX). We obtained institutional board approval at the ten study sites prior to study implementation.

Results

Of the 21,382 enrolled subjects in these two NEXUS studies, 11,784 (55.1%) had CXR alone, 937 (4.4%) had chest CT alone, and 8661 (40.5%) had both CXR and chest CT. PC was diagnosed by ED imaging in 1229 (5.7%) of all patients, in 1058 (11.0%) of patients who had chest CT, and in 69 (0.6%) of patients who had CXR without CT. See Fig. 1 for stratification by imaging type. We had high inter- abstractor agreement for all outcomes (radiologic diagnosis of PC— 99% agreement, kappa = 0.97; hospital admission and PC associated mechanical ventilation—100% agreement, kappa = 1.0).

In our primary analysis group of the 8661 patients with CXR and chest CT, 739 (73.0%) of the 1012 patients with PC were SOCTO. The diagnosis of PC was suggested on CXR but ruled out by chest CT imaging in 89 (1.0%) patients. The overall screening performance characteristics of single view anterior-posterior CXR for PC were: sensitivity 27.0% (95% confidence interval [CI] 25.3–28.5%), specificity 98.8% (95% CI 98.6–99.0%), positive predictive value 75.4% (95% CI 70.8–79.5%) and negative predictive value 91.1% (95% CI 90.9–91.3%).

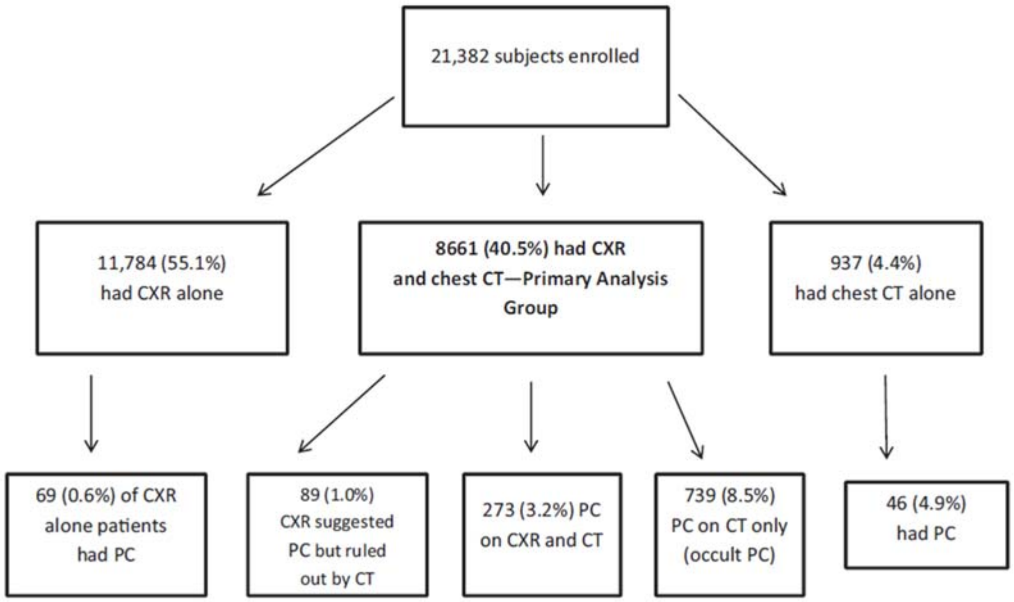

Fig. 1. Subjects stratified by imaging and PC diagnosis. CXR = Chest X-ray; PC = pulmonary contusion; CT = computed tomography.

Most PC patients (73.5%) had other thoracic injuries—most commonly rib fractures (55.8%), pneumothorax (44.9%), hemothorax (17.3%) and sternal fracture (9.7%). The admission rate of PC patients with other thoracic injury was 95.4% and their mortality was 5.1%. Of the 57 (4.8%) of PC patients who had PC associated mechanical ventilation, 47 (82.4%) had other thoracic injuries.

Patients with PC had higher injury severity scores (ISS) [median 18 versus 5], were more commonly admitted to the hospital (91.9% versus 61.7%; mean difference 30.2%; 95% CI 28.1–32.1%), had longer median hospital LOS (4 days versus 3 days), and higher mortality (4.7% versus 2.0%: mean difference 2.8%; 95% CI 1.6–4.3%) than non-PC patients. All PC patients with an ISS < 11 survived to hospital discharge.

Patients with isolated PC SOCTO had higher rates of admission (81.6% versus 61.9%; mean difference 19.7%; 95% CI 14.4–24.5%) but similar mortality rates (2.6% versus 3.2%; mean difference 0.5%; 95% CI - 2.2% to 2.8%) compared to patients without PC. Compared to patients with PC seen on CXR and CT, patients with PC SOCTO had less than the half the rate of PC associated mechanical ventilation (4.3% versus 9.2%; mean difference 4.8%; 95% CI 1.5–9.0%). See Table 1 for characteristics of PC SOCTO, PC on CXR and CT, and no PC patients.

Discussion

Widespread utilisation of CT (and pan-scan in particular) has dramatically altered the spectrum of blunt trauma diagnostic evaluation [7–11,13,21]. With the exponentially greater diagnostic detail that CT provides, trauma providers are diagnosing many more injuries than they did in the pre-CT era [7–14]. In some cases, clarification of injuries allows for better risk stratification and management of the poly-trauma patient. However, identification of minor injuries that would otherwise go undetected and have no clinically important implications may paradoxically lead to more costly care with excessive monitoring or admission [21]. With these principles in mind, we sought to characterize PC and its clinical implications in the current era of pan-scan and frequent chest CT for blunt trauma. Prospectively examining a large cohort of adult patients who had chest imaging for blunt trauma evaluation, we found that that the vast majority of PC were SOCTO and that patients who had chest CT were over 18 times more likely to be diagnosed with PC than patients who only had CXR. Overall, CXR had low sensitivity and high specificity for PC on CT.

Table 1
Characteristics of PC SOCTO, PC on CT and CXR, and No PC patients.

	PC SOCTO *N* = 739	PC on CT and CXR *N* = 273	No PC *N* = 7649
Median age (IQR)	42 (27–56)	39 (25–55)	42 (29–60)
Male gender	542 (73.3%)	214 (78.4%)	4805 (62.8%)
Injury mechanism			
MVA	304 (41.1%)	105 (38.5%)	3350 (43.8%)
MCA	130 (17.6%)	55 (20.1%)	919 (12.0%)
Fall	125 (16.9%)	49 (17.9%)	1514 (19.8%)
PVA	84 (11.4%)	30 (11.0%)	908 (11.9%)
Admitted	668 (90.4%)	262 (96.0%)	4718 (61.7%)
LOS (days)	4 (2–8)	4 (2–11)	3 (2–7)
Mortality	32 (4.3%)	16 (5.9%)	151 (2.0%)
Median ISS (IQR)	17 (10–24)	22 (14–29)	5 (1–10)
PC attributed mech Ventilation	32 (4.3%)	25 (9.2%)	N/A

PC = Pulmonary contusion; SOCTO = seen on CT only; CT = computed tomography; IQR = interquartile range; MVA = motorized vehicle accident; MCA = motorcycle accident; PVA = pedestrian struck by vehicle; LOS = length of stay; ISS = injury severity scale.

We found that chest CT so commonly diagnoses PC (second only to rib fracture in frequency of diagnosis), that it may be considered an expected co-finding in trauma patients with other thoracic injury. PC patients had much higher ISS and commonly had other thoracic injuries that likely contributed to their higher hospital admission rates and mortality. All PC patient deaths occurred in patients with ISS > 10, which corresponded to the 75th percentile ISS of non-PC patients.

Several investigators have suggested that CT volumetric mea- surements of PC may be used to risk stratify blunt trauma patients. Larger PCs were associated with higher risk of adult respiratory distress syndrome, greater need for mechanical ventilation, and longer intensive care unit stay [22–25]. However, the incremental value in terms of isolated PC (and other thoracic injury) diagnosis by chest CT is unclear [26,27]. Kaiser et al. reported that thoracic injuries seen on CT only are of limited clinical significance [28]. Moore et al. reported that pneumothorax seen on CT only can be managed without tube thoracostomy [29]. Our findings of low rates of

PC SOCTO associated mortality and mechanical ventilation support these studies and those of others who have demonstrated that small, PCs SOCTO may be clinically insignificant [26,27].

Admission and monitoring for clinically insignificant PC and other occult thoracic injuries may potentially lead to escalations in costs of care. We could not ascertain the exact reason(s) for hospital admission in our cohorts, but PC patients had much higher hospital admission rates than non-PC patients, even when PC was the sole thoracic injury diagnosis.

Limitations

Given that less than half of patients received CT, it is likely that some patients receiving only CXR had undiagnosed PC. Spectrum bias likely accounts for part of the higher PC detection rate in patients who had chest CT—patients with more severe mecha- nisms of injury or who appeared to be more injured on ED presentation would be more likely to have CT ordered by providers.

Although, we used accepted criteria to define PC and other thoracic injuries, there are no standard criteria to define the outcome of PC associated mechanical ventilation. Our abstractor agreement on this outcome, however, was high, demonstrating high likelihood of reproducibility. We limited our review of clinical outcomes to mortality, LOS, and mechanical ventilation. PC patients may receive other respiratory support beyond mechanical ventilation, such as high flow oxygen, and it is possible that the diagnosis of PC confers other clinical outcome benefits

This study was conducted at urban, Level 1 trauma centres— trauma evaluation protocols and ordering of CT may differ at dissimilar hospitals. Institutions with higher rates of trauma CT utilisation (more CT for less acutely injured patients) would likely have lower rates of overall PC diagnosis, but higher rates of occult PC. Practice patterns also likely affect decisions to institute mechanical ventilation and admission decisions—it is likely that patients were admitted and monitored for reasons other than solely their PC.

Although we did not enrol patients between 23:00 and 07:00, we found no meaningful differences in patient characteristics presenting during these times. It is unlikely that our daytime enrolment produced significant selection or outcome bias [16].

Although radiologists were unaware of patient enrolment, they were not blinded to the different imaging studies and it is possible that their interpretations of CXR and chest CT studies may have been influenced by their viewing of the other modality. It is unclear whether this would artificially inflate or deflate the percentage of PC SOCTO patients.

Overall, we believe that traditional teaching about PC should be changed to reflect how commonly it is diagnosed with highly sensitive chest CT in the pan-scan era. Our findings suggest that PC has only minor clinical implications of itself. We recommend viewing PC more broadly as part of a thoracic injury complex and in this context, former teachings about intense monitoring and respiratory care for isolated PC and PC SOCTO should be tempered.

Conclusions

In this prospective cohort of adult blunt trauma patients, we found that chest CT commonly diagnoses PC that is not seen on CXR. Patients with PC SOCTO and isolated PC had low associated mortality and mechanical ventilation rates. Former teachings should be updated to reflect the commonality of PC diagnosis with chest CT and the fact that it has minimal clinical implications of itself.

Conflict of interest

This study was funded by the Centers for Disease Control and the University of California Center for Health Quality and Innovation (CHQI). Beyond this funding, the authors have no conflicts of interest to declare regarding this research.

Author contributions

Study design—R.M.R., B.F., M.I.L., B.M.B., D.N., G.W.H., A.J.M., A.S.R., W.R.M. Study implementation/data acquisition—R.M.R., M.I.L., B.M.B., D.N., G.W.H., A.J.M., A.S.R., W.R.M. Data analysis— R.M.R., B.F., W.R.M. Manuscript preparation—R.M.R., B.F., M.I.L., B.M.B., D.N., G.W.H., A.J.M., A.S.R., W.R.M. Manuscript revision— R.M.R., B.F., D.N., W.R.M.

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