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ORIGINAL ARTICLE

Chest tube output, duration, and length of stay are similar for pneumothorax and hemothorax seen only on computed tomography vs. chest radiograph

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Abstract

Purpose Whole-body computed tomography (CT) for blunt trauma patients is common. Chest CT (CCT) identifies "occult" pneumo- (PTX) and hemothorax (HTX) not seen on chest radiograph (CXR), one-third of whom get chest tubes, while CXR identifies "non-occult" PTX/HTX. To assess chest tube value for occult injury vs. expectant management, we compared output, duration, and length of stay (LOS) for chest tubes placed for occult vs. non-occult (CXR-visible) injury.

Methods We compared chest tube output and duration, and patient length of stay for occult vs. non-occult PTX/HTX. This was a retrospective analysis of 5451 consecutive Level I blunt trauma patients, from 2010 to 2013.

Results Of these blunt trauma patients, 402 patients (7.4%) had PTX, HTX or both, and both CXR and CCT. One third ($n=136$, 33.8%) had chest tubes placed in 163 hemithoraces (27 bilateral). Non-occult chest tube output for all patients was 1558 ± 1919 cc ($n=54$), similar to occult at 1123 ± 1076 cc ($n=109$, $p=0.126$). Outputs were similar for HTX-only patients, with non-occult ($n=34$) at 1917 ± 2130 cc, vs. occult ($n=54$) at 1449 ± 1131 cc ($p=0.24$). Chest tube duration for all patients was 6.3 ± 4.9 days for non-occult vs. 5.0 ± 3.3 for occult ($p=0.096$). LOS was similar between all occult injury patients ($n=46$) and non-occult ($n=90$, 17.0 ± 15.8 vs. 13.7 ± 11.9 days, $p=0.23$).

Conclusion Mature clinical judgment may dictate which patients need chest tubes and explain the similarity between groups.

Keywords Trauma · Thoracic · Tube thoracostomy · Computed tomography

Introduction

Whole-body computed tomography (CT) for blunt injury is becoming standard in well-resourced trauma centers. Previous research has shown that 48% of multiple blunt trauma patients have chest CT for evaluation [1]. In addition, almost all victims of blunt trauma receive a screening chest radiograph (CXR) as part of the secondary survey and resuscitation, according to the American College of Surgeons (ACS) Advanced Trauma Life Support Course [2]. However, CXR misses injuries that are identified on early chest CT in up to 71% of patients [3]. A study from the United Kingdom similarly called attention to the ability of chest CT to identify pneumothorax (PTX) not seen on CXR in 43% of patients [4].

Patients can have PTX and hemothorax (HTX) identified on either CXR or chest CT. Controversy remains whether such patients need tube thoracostomy if "occult" injury is seen only on CT, but not on immediately preceding CXR. Conversely, we defined "non-occult" injury as

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seen on initial CXR with placement of chest tube before CT. A substantial subset of occult injuries, 41% percent of HTX and 29% of PTX, receive chest tubes, but it is unclear whether such injuries require intervention [3]. Placement of chest tubes carries risk (up to 37% complication rate) with an associated ninefold increase in cost [5]. Furthermore, placement of chest tubes increases complication rate from 8 to 20% for occult PTX patients [6].

Two older small randomized trials of chest tube placement for occult PTX ($n = 40$ and 39, respectively) provided conflicting recommendations. Brasel et al. opined that expectant management was safe [7], while Enderson et al., wrote of 21 patients with expectant management, eight of whom had progression of PTX and three developed tension physiology [8].

More recent studies reflect a cautious support for conservative management without chest tube for PTX [6, 9–13], and HTX [10], but some qualify this strategy by size/progression of injury [10–13]. In the largest randomized study to date (2013) of PTX (not HTX) in patients with mechanical ventilation [14], the authors conclude that observation may be appropriate, but also that one-third of patients ultimately get a chest tube, and tension PTX still develops rarely. Furthermore, this paper reports that 60% of occult PTX patients had increasing pleural fluid (blood) as a reason for observation failure but does not report the chest tube outputs to aid in decision making. These two factors, the equivocation regarding chest tube for occult PTX alone, and pleural fluid as a marker of observation failure, prompt this study as the first to quantify and specifically compare output between occult and non-occult injuries of both types.

Few studies have examined occult HTX as a predictor of need for chest tube drainage. Two prospective studies from Mahmood in 2011 and 2015 ($n = 81$ and 56, respectively) concluded that observation of occult HTX was safe [15, 16]. To our knowledge, no recent study has compared both HTX and PTX output and length of stay in a larger population of blunt trauma patients.

This study on output and dwell time provides new information to determine if occult nature of an injury is a valid factor to inform the surgeon's decision to place or forego a chest tube. If occult chest tube output were sparse, and dwell time short, while non-occult were substantial and long, then this factor could, in part, impact the decision.

The primary outcome measure here was total chest tube output for occult HTX alone, and combined HTX and PTX, compared with non-occult injury output. Secondary outcomes were duration of chest tube placement for occult PTX and combined PTX and HTX, compared to non-occult injuries, and total hospital length of stay (LOS) for both groups.

We hypothesized that occult injury chest tubes would have less output, be removed sooner, and result in shorter hospital LOS, than for chest tubes placed for non-occult injury.

Materials and methods

Study design, setting, and population

This is a secondary retrospective analysis of patients from one of 10 ACS verified Level I Trauma Centers in the U.S., which developed and validated a decision instrument for blunt chest trauma [1]. At this one center, 5451 patients were initially recruited. Figure 1 shows the progression toward the final 136 patients, with 163 hemithoraces with chest tubes, analyzed in this paper. We obtained institutional review board approval for this study.

Study protocol

We included all blunt trauma activations from 2010 to 2013, who had both CXR and immediately following chest CT. Our unit of analysis for output and duration of chest tube was each hemithorax. Our unit of analysis for hospital LOS was each patient. We included patients with any size PTX or HTX that received a chest tube. Placement of a chest tube was at the discretion of the treating trauma surgeon either before or after chest CT. There was no institutional protocol for chest tube placement or duration of treatment at the time this study was performed.

We excluded patients who had chest tube placed more than 5 days after chest CT, those placed during resuscitative thoracotomy, those that died in the operating room after emergency department (ED) resuscitation, PTX identified only on CT of the cervical spine, and chest tubes placed without apparent CT-identified injury.

Injuries were categorized as occult vs. non-occult from the attending radiologist's report, based on whether the chest tube was present (non-occult) vs. absent (occult) on initial CT. For this study, we operationalized and extrapolated the definition of occult injury (either PTX or HTX) from Ball's study [17]: "… PTX that was not suspected on the basis of clinical examination or plain radiography, but is ultimately detected with CT." For non-occult injury, the presence of the chest tube on CT meant that the treating physician used clinical judgement and CXR findings of visible PTX or HTX to decide to place the chest tube. Conversely, occult injury was defined as chest tube absent on CT, with subsequent placement, indicating the CT contributed to the decision to place a chest tube.

A senior investigator (MIL) abstracted paper ($n = 10$) and electronic medical records (EMR, $n = 142$ [16 patients excluded, see Fig. 1]) of flow sheets by ED and intensive care unit (ICU) nurses for chest tube output over the duration

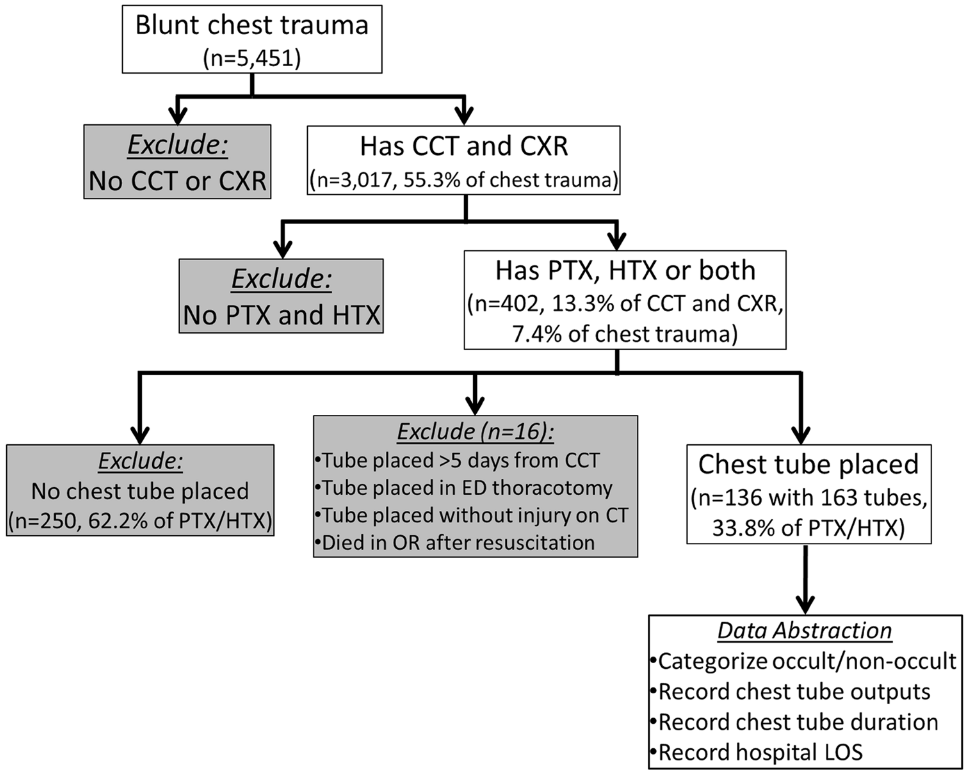

Fig. 1 Patient selection beginning with total blunt trauma patients ($n=5451$) through study subjects ($n=136$), with major inclusion and exclusion criteria. *CCT* chest computed tomography, *CXR* chest radiograph, *PTX* pneumothorax, *HTX* hemothorax, *LOS* length of stay, *ED* emergency department, *OR* operating room, *CT* computed tomography

of drainage. If a patient had two chest tubes placed on the same side, the outputs were summed; if bilateral tubes were placed, the outputs were considered separately. If two chest tubes were placed on the same side, we report the duration of the tube which remained longer.

Research students identified which patients had chest tubes placed, and on which hospital day, from the EMR, as well as total hospital length of stay. Data abstraction followed recommendations to minimize bias in retrospective chart review [18]. Chart abstractors were trained, we used explicit criteria to select study subjects, defined key variables specifically, used a standard abstraction recording format (Research Electronic Data Capture, RedCap), and held periodic meetings with chart abstractors to review coding rules. We did not formally monitor performance of chart abstractors, who were not blinded to study hypothesis, and did not calculate inter-rater agreement. Per additional retrospective chart review quality factors identified by Worster and Bledsoe [19], we established procedures for missing data (only one chart had output missing for 2 days, included in analysis) and conflicting data. Chest tube outputs on the flowsheets did not sum to shift or daily totals approximately 20% of the time, so we used daily totals.

Data analysis

Data were entered into a spreadsheet (Excel, Microsoft, Redmond, WA) and analyzed with Stata (version 14.2, StataCorp, College Station, TX). For comparisons of chest tube output and other continuous variables, we used Welch's *t* test to account for unequal variances between the occult and non-occult hemithoraces. We report all outcomes (fluid outputs, LOS, duration of chest tube placement) as mean values ± standard deviations (SD). We also explored a generalized-linear model with log link function and normal error term but found that the log-normal distribution did not improve fit. The distribution of the total chest tube output was illustrated with histograms using 500 cc bins. Proportions were compared using the Chi-square test for independence.

Results and discussion

Primary outcome

We identified 136 patients who met inclusion criteria (33.8% of 402 with injury) who had 163 chest tubes placed on one ($n=109$) or both sides ($n=27$). The injuries for which chest tubes were placed are shown in Table 1. These injuries sum to more than 136 patients and 163 hemithoraces because some patients had both PTX and HTX.

Table 2 shows the Injury Severity Score (ISS) and Abbreviated Injury Scale (AIS) for the thoracic region for all patients, and for occult and non-occult groups.

Table 1 Distribution of thoracic injuries that received chest tubes ($n=163$ hemithoraces in 136 patients)

Thoracic injury	*n*	% of injured hemithoraces
Total	163	100
Any PTX (isolated PTX or both PTX and HTX)	151	92.6
Any HTX (isolated HTX or both PTX and HTX)	88	64.7
Both PTX and HTX	77	47.2
HTX only	11	6.7
PTX only	74	45.3

Injuries sum to more than these totals as some patients had both PTX and HTX

PTX pneumothorax, *HTX* hemothorax

Primary outcome comparison was total mean chest tube fluid/blood output throughout the duration of placement, between patients with occult (109 chest tubes in 90 patients, 66.9%) and non-occult injury (54 chest tubes in 46 patients, 33.1%).

Non-occult chest tube output was 1558 ± 1919 cc, similar to occult output at 1123 ± 1076 cc ($p=0.126$). Shown graphically in Fig. 2, it is evident that the distribution of outputs is not clinically different. The initial and first-24-h chest tube output for all patients, and HTX patients alone, did not differ between groups.

For patients with isolated HTX only ($n=11$), total chest tube output was similar to output for all hemithoraces ($n=163$), and did not differ between occult and non-occult. For patients with any HTX (isolated HTX or both PTX and HTX, $n=34$), output for non-occult was 1917 ± 2130 cc vs. occult ($n=54$) at 1449 ± 1131 cc ($p=0.24$). This is shown graphically in Fig. 3.

Three-quarters (75.6%) of patients with occult HTX and 73.3% of patients with occult PTX had chest tube placed on day 0 or 1, vs. 100% of patients with non-occult injury (by definition). This subset of occult HTX and PTX is important to analyze separately, as CT would more likely be a contributing factor in the decision to place the chest tube.

Chest tube outputs for this subset ($n=31$) were statistically and clinically similar. For occult HTX patients, output was 1537 ± 1226 cc vs. non-occult at 1917 ± 2130 cc ($p=0.38$).

Table 2 Injury Severity Score (ISS) and Abbreviated Injury Scale (AIS) for the thoracic region (median [interquartile range]) for the entire patient cohort and for occult and non-occult groups

Injury measure	All patients ($n=136$)	Non-occult injury ($n=90$)	Occult injury ($n=46$)
Injury Severity Score	29 (20–38)	29 (20–38)	27 (19–35)
Abbreviated Injury Scale (thorax, 1–6)	4 (4–5)	4 (4–4)	4 (4–5)

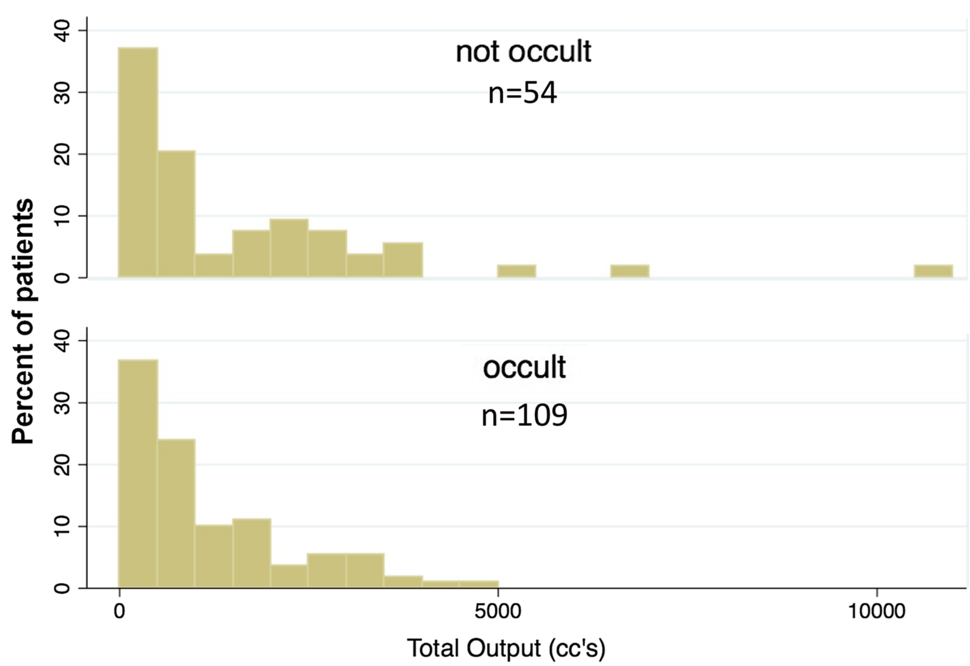

Fig. 2 Histogram of chest tube total outputs for non-occult (top) vs. occult (bottom) injury for hemothorax and pneumothorax combined ($p=0.126$). *Y* axis is proportion of patients with fluid output of amounts by 500 cc increments (*X* axis)

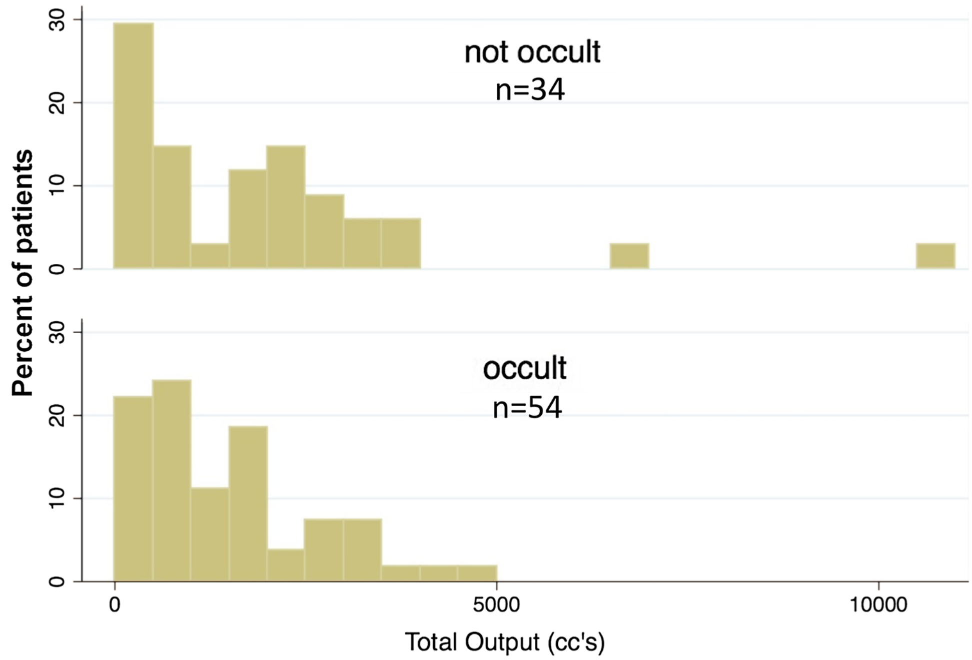

Fig. 3 Histogram of chest tube total outputs for non-occult (top) vs. occult (bottom) injury for hemothorax only chest tube patients ($p=0.24$). *Y* axis is proportion of patients with fluid output of amounts by 500 cc increments (*X* axis)

While all these patients with occult injuries had chest tubes placed by virtue of inclusion in the study, Table 3 reports the relative size of hemithoraces with HTX, PTX, and both, according to descriptions in the final radiology reports. Non-occult patients would have already had a chest tube in place, so the size of residual PTX or HTX seen on CT is irrelevant for this analysis.

Secondary outcomes

The duration of chest tubes placed for all patients was 6.3 ± 4.9 days for non-occult patient chest tubes vs. 5.0 ± 3.3 days for occult patient chest tubes ($p=0.096$).

For the subset of patients with PTX only who had chest tubes placed on day 0 or 1 ($n=107$), they remained on average 1.5 days shorter, 4.8 ± 3.9 for occult injury vs. 6.3 ± 4.9 for non-occult injury ($p=0.058$). These last two results could be considered marginally clinically different.

We found no significant difference between hospital LOS between occult injury patients ($n=90$) and non-occult ($n=46$, 17.0 ± 15.8 vs. 13.7 ± 11.9 days, $p=0.23$). There was also no difference in LOS if patients who died on day of admission ($n=2$, $p=0.14$) or on hospital day 1 ($n=4$, $p=0.08$) were excluded.

Please see Table 4 for summary of comparisons between groups.

As occult HTX patients with small effusions on CT might ultimately be found to have scant outputs, we compared the proportions of occult vs. non-occult HTX with less than 500 and 1000 cc total output. Twenty-two percent of HTX hemithoraces had less than 500 cc, and 46% had less than 1000 cc. These proportions were not different from those in the non-occult group.

Analogously, we found similar proportions of short duration of chest tube placement between occult and

Table 3 Size of occult injury seen on computed tomography (CT) per radiologist final interpretation ($n=109$ hemithoraces in 90 patients)

Qualitative size of injury on CT	PTX (*n*, % of hemithoraces with occult PTX)	HTX (*n*, % of hemithoraces with occult HTX)	PTX + HTX (*n*, % of all occult injuries)
Trace/tiny/"questionable"/very small	17 (20.2)	11 (23.9)	28 (21.5)
Small/mild/"small to moderate"	40 (47.6)	25 (54.3)	65 (50.0)
Medium/moderate	21 (25.0)	9 (19.6)	30 (23.1)
Large/"moderate to large"	6 (7.2)	1 (2.2)	7 (5.4)
Total injuries	84	46	130

Numbers add to more than 109 occult injury chest tubes, as some patients had both pneumothorax (PTX) and hemothorax (HTX)

Table 4 Comparisons of primary and secondary outcomes for non-occult vs. occult injury

Comparison	Subset	Non-occult ($n=54$)	Occult ($n=109$)	*p* value
Primary outcome				
Total output	All patients	1558 ± 1919 cc $n=54$	1123 ± 1076 cc $n=109$	0.126
	HTX only	1917 ± 2130 cc $n=34$	1449 ± 1131 cc $n=54$	0.24
	HTX only, with chest tube placed day 0 or 1	1917 ± 2130 cc $n=34$	1537 ± 1226 cc $n=31$	0.38
Secondary outcomes				
Chest tube duration	All patients	6.3 ± 4.9 days $n=54$	5.0 ± 3.3 days $n=109$	0.096
	PTX only with chest tube placed day 0 or 1	6.3 ± 4.9 days $n=52$	4.8 ± 3.9 days $n=55$	0.058
LOS	All patients	17.0 ± 15.8 days $n=46$	13.7 ± 11.9 days $n=90$	0.23

HTX hemothorax, *PTX* pneumothorax, *LOS* length of stay

non-occult groups: 26% of patients in the occult PTX group had chest tubes for ≤ 2 days, 43% ≤ 3, and 57% ≤ 4.

Physicians were four times more likely to place a chest tube for occult PTX alone than for occult HTX alone. Among 88 hemithoraces with any occult HTX, only 12.5% ($n=11$) received a chest tube when the HTX was isolated (no PTX). Conversely, among 151 hemithoraces with any occult PTX, almost half (49.1%, $n=74$) received a chest tube when the PTX was isolated (no HTX).

By comparison, if a patient had both occult PTX and HTX, a similar proportion, 77/163 hemithoraces (47.2%), got chest tubes, indicating that the presence of additional occult HTX did not trigger a chest tube; occult PTX was the primary driver of intervention.

Discussion

While multiple clinical and imaging factors inform the clinician's decision to place a chest tube, there is paucity of literature regarding the likely outcome of chest tube placement for fluid, as well as any direct comparison between chest tubes placed for occult and non-occult injury.

We found no clinically important difference between chest tubes placed for occult and non-occult PTX or HTX. There is general agreement that injuries seen on CXR need chest tubes, yet we found no difference in output and LOS whether the injury was seen on CXR, and the chest tube placed before CT, or the injury was identified on CT alone, and the chest tube was placed after CT. These findings do not support current recommendations that there are small degrees of injury (seen on CT only) where avoidance of chest tubes is warranted.

These data were drawn from the largest prospective study on thoracic trauma to date [1]. This retrospective analysis from the greatest enroller of the 10 sites, reports 163 chest tubes. To our knowledge, this is the largest in the literature to report, for both HTX and PTX, fluid output, duration of placement and LOS, and to compare occult to non-occult chest tubes. Chung et al. recently reported their experience with 84 patients with HTX, 42 (50%) of whom got chest tubes [20]. They found a mean total output of 860 ± 600 cc. This is approximately two-thirds the output described here in a fourfold larger sample (1123 ± 1076 cc for occult injury and 1558 ± 1919 cc for non-occult). Possible reasons for this apparent discrepancy are: (1) patients in this study were more severely injured than Chung's, where he excluded patients with other organ system AIS ≥ 2, resulting in median ISS of 29 here vs. 13 for Chung, (2) duration of chest tube placement here was likely longer (median 5 days, not reported by Chung), as was hospital stay (15 vs 7 days for Chung), allowing more time for chest tube output, and (3) thoracic trauma management in Taiwan may differ from the US, including timing of removal of chest tubes.

This study's novel primary outcome comparison of chest tube output between occult and non-occult injury is more quantifiable than hospital LOS or chest tube duration (secondary outcomes here). Given that multiple other factors determine LOS, we studied an outcome more specific to the chest tube itself, rather than the whole patient, whose other injuries clearly affect LOS. We noted that output determined duration of chest tube placement, as tubes were removed routinely when daily outputs dropped below 30 cc. Our secondary outcome, duration of placement of chest tubes for occult injuries, has not previously been reported.

We found no difference in output between chest tubes placed for occult and non-occult HTX or PTX, and therefore analyzed whether output was different for HTX-only hemithoraces, and whether chest tube duration was different for PTX-only patients. These subgroups also did not show clinically important differences. Exclusion of one outlier for chest tube output for non-occult injury (> 10,000 cc) did not change the significance of our comparisons.

We found two comparisons between occult and non-occult thoracic injury which neared statistical significance: 1 day shorter duration of chest tubes placed for all patients (5.0 vs. 6.3 days, $p = 0.096$), and shorter duration of chest tube placement for PTX-only patients whose tubes were placed on the day 0 or 1 (4.8 vs. 6.3 days, $p = 0.058$). These marginal statistical differences also have questionable clinical importance, though one less day of tube placement may be important for patient comfort.

An American Association for the Surgery of Trauma multicenter study from 16 sites (2011) recommends that most trauma patients can be carefully monitored without chest tube. However, 6% of patients failed observation and required tube thoracostomy for occult PTX progression, respiratory distress, or subsequent HTX. Specifically, HTX was associated with failure of observation, at least doubling the risk of requiring a chest tube, but the actual chest tube outputs were not reported [21].

Given the risk of chest tube complications for HTX and PTX, various authors have attempted to provide guidance regarding which patients require chest-tube placement after CT. If expectant management were deemed safe, complications, some serious, could be avoided. Rates of empyema had been significant, but have diminished over time, from 10% in pre-2000 cohorts, to as little as 1% more recently, due to enhancements in sterile technique [22–24]. Risk factors include prolonged dwell time, length of intensive care unit stay, pulmonary contusion, laparotomy and retained hemothorax [25]. Furthermore, one study showed that up to 30% of tubes are placed incorrectly, including extrapleural location, kinking, inadequate advancement or misplacement apart from the posterior apex [26]. Rates for all complications, including empyema, misplacement, recurrent PTX upon removal and wound infections have been reported at 11% [27], 21% [28], and up to 36–37% [5, 29].

For HTX, Mowery, in the EAST Practice guidelines, writes that surgeons debate regarding how large a HTX can be safely observed [30]. Billelo reported on 78 patients, and recommended foregoing chest tube placement with ≤ 300 cc [31]. This approach to HTX observation was also used by Demetri, who reported on a cohort of 340 trauma patients over 12 years [23]. He concluded that "small" HTX < 300 cc were safe to observe, as 98% of the 121 successfully observed patients had such small HTX. However, only 50.6% of all small HTX (129/255 from Demetri's Table 1), were successfully treated without a chest tube. Conversely, he found that only 3% (2/85) of large HTX were successfully observed.

In support of this approach for selective chest tube placement, other authors report substantially higher rates of empyema in HTX. Karmy-Jones reported a 33% incidence without quantifying size of HTX [32]. Dubose reported a 26.8% empyema rate overall (for patients with retained HTX after first chest tube) [33]. This study reported a 34.7% empyema rate with larger HTX (> 300 cc per estimation formula of Mergo) [34] vs. 22.6% for small HTX (< 300 cc, Chi square derived from Table 1 of Dubose data, $p < 0.02$) [33]. This significant empyema rate, even for small HTX, supports this paper's finding that mature clinical judgment, rather than HTX size alone, should determine the need for chest tube placement.

For PTX, de Moya developed an objective scoring system for size on chest CT [35]. Unfortunately, he did not provide recommendations regarding which patients need chest tubes. A randomized trial of selective chest tube placement in 40 patients reported that 8/21 patients with expectant management had progression of PTX, and three developed tension physiology [8]. We were unable to find studies that validated a selective approach to chest tube placement for small PTX. Recent ATLS guidelines advise chest tube placement for all PTX unless as "qualified physician" elects expectant management [2]. Despite no clear evidence for safety, de Moya stated that it may be reasonable to closely observe occult PTX [35]. Furthermore, Moore did not find PTX size to be an independent predictor of failure of conservative management/observation when respiratory distress and PTX progression on serial CT were considered [21]. He did, however, report that larger PTX was associated with failed observation (15.9 mm vs. 8.6 mm per de Moya calculation [35]), and alluded to an ongoing prospective study, which has yet to be published. As these reports question whether size of PTX is important in the decision to place a chest tube, we did not estimate PTX size from CT images, and, instead report qualitative sizes of PTX from radiologist interpretations.

Since the early 1990s, multiple small series of patients ($n = 27$–103) with occult PTX or HTX have been published [6, 7, 9–14, 16, 17, 29, 34–39]. Most have documented safety of expectant management of mostly PTX [6, 7, 9–14, 17, 34–39] and, to a lesser degree HTX [15, 16, 31, 40]. Three of these publications (1992, 2008, and 2010) have come from the trauma surgery group at this center, reflecting an evidence-based culture of avoiding chest tubes in subtle or CT-only occult injury [36, 39, 40]. Two of these describe only PTX patients [36, 39], and the third describes both HTX and PTX [40]. Hence it is not surprising that the majority of patients in this study, cared for by the same trauma group, did not have chest tube placement (250/402, 62.2%, see Fig. 1).

We found essentially equipoise between occult and non-occult groups regarding primary and secondary outcomes. Chest tube output, duration and hospital LOS, as well as injury severity measured by AIS and ISS, were similar. These findings do not add evidence for an expectant management strategy, nor do they favor necessity of chest tube placement. We interpret these results as validation of clinical judgment in this single trauma center, as placement of chest tubes for some occult injuries had similar outcomes as those placed for obvious injuries visible on initial CXR.

Of 402 patients with HTX or PTX, 136 received chest tubes for occult or non-occult injury, and 16 were excluded (Fig. 1), leaving 250 patients (about two-thirds) who never received a chest tube. This suggests that experienced clinicians at a Level I Trauma Center with 24-h in-hospital trauma team may be able to safely distinguish which occult injuries require intervention, and perhaps forego chest tube placement. Such injured patients without a chest tube were routinely monitored in the intensive care or surgical step-down unit. Further study should compare clinical outcomes of occult HTX and PTX who had chest tube placement with those that did not, both in trauma centers and less high-resource settings.

In this first study to compare LOS for all patients who did get a chest tube, either for occult or non-occult injury, we found no important difference. Previous literature on chest tubes for occult injury reported some LOS data [8, 16, 36, 41]. These reports have all compared LOS for patients with occult injuries that received a chest tube vs. those without, also showing no clinically important difference. So whether one compares patients with occult injury who do or do not get chest tubes (previous literature), or all patients with chest tubes (this study) placed after CXR or chest CT, there does not appear to be an important difference in LOS.

Limitations

Although the study comparisons were of marginal statistical significance and clinical importance, we did not correct for multiple (seven) comparisons. Therefore, even marginal clinical significance may be due to chance.

While we report qualitative degrees of occult injury, we did not quantify size of HTX or PTX, nor did we extract complications of chest tube or expectant management.

We acknowledge that many other factors inform a clinician's decision to place a chest tube, including O_2 saturation, other injuries, need for mechanical ventilation, rib fractures, subcutaneous air, and subjective respiratory distress. Hence, the CT result may not have been the, or even an important, determinant of the decision to place a chest tube for occult injury.

We did not include patients who never had a chest tube, regardless of whether injury was seen on CXR or CT. This includes patients whose PTX or HTX was seen on CXR prior to CT. It is possible that a small degree of injury might have been seen on the CXR, and CT was used to better determine severity. It is also possible that CT identified a PTX or HTX, but if such a patient did not get a chest tube, they are not reported here.

LOS is only a gross marker of seriousness of chest injury. Given the retrospective nature of the study, we did not abstract data from the medical record on a myriad of confounders that would influence the LOS, including thoracic and other organ injuries, their severity, procedures, need for artificial ventilation, comorbid conditions, and traumatic and iatrogenic complications. LOS may not reflect the outcomes of chest tube placement at all.

This was a moderate sample size from a single site which already has studied this issue, and foregoes chest tube placement on 2/3 of occult thoracic injuries. Results may not therefore be generalizable to other trauma centers, or community settings.

We did not perform a power calculation in this retrospective study, as sample size was determined by the database. This does not exclude a Type II error, but obvious overlap of histograms of chest tube outputs makes the chance of type II error small.

Conclusions

In this retrospective observational study, chest tubes placed for PTX or HTX seen only on CT (not preceding CXR) were not associated with clinically important decreased output, or shorter duration of chest tube or hospital stay vs. non-occult injury identified on immediately previous CXR. At a Level I trauma center with close monitoring of expectant management, mature clinical judgment may already dictate which patients need chest tubes and explain the similarity between groups.

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Compliance with ethical standards

Conflict of interest Bhavesh H. Patel, Christopher O. Lew, Tanya Dall, Craig L. Anderson, Robert Rodriguez, and Mark I. Langdorf declare that they have no conflicts of interest.

Ethical approval The study was approved by the Institutional Review Board (IRB) at the University of California, Irvine and is in accordance with the ethical standards of the 1964 Helsinki Declaration and its later amendments or comparable ethical standards. The IRB granted a waiver of informed consent for this study.

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