World J Surg (2018) 42:2054–2060
https://doi.org/10.1007/s00268-017-4417-5

ORIGINAL SCIENTIFIC REPORT

The Benefit of Ultrasound in Deciding Between Tube Thoracostomy and Observative Management in Hemothorax Resulting from Blunt Chest Trauma

Meng-Hsuan Chung[1] · Chen-Yuan Hsiao[3] · Nai-Shin Nian[2] · Yen-Chia Chen[1,3] · Chien-Ying Wang[1,3] · Yi-Szu Wen[1,3] · Hsin-Chin Shih[1,4] · David Hung-Tsang Yen[1,4]

Published online: 5 January 2018

Abstract

Background Hemothorax is most commonly resulted from a closed chest trauma, while a tube thoracostomy (TT) is usually the first procedure attempted to treat it. However, TT may lead to unexpected results and complications in some cases. The advantage of thoracic ultrasound (TUS) over a physical examination combined with chest radiograph (CXR) for diagnosing hemothorax[1] has been proposed previously. However, its benefits in terms of avoiding non-therapeutic TT have not yet been confirmed. Therefore, this study is aimed to evaluate the severity of hemothorax in blunt chest trauma patients by using TUS in order to avoid non-therapeutic TT in stable cases.

Methods The data from 46,036 consecutive patient visits to our trauma center over a four-year period were collected, and those with blunt chest trauma were identified. Patients who met any of the following criteria were excluded: transferred from another facility, with an abbreviated injury scale (AIS) score ≥ 2 for any region except the chest region, with a documented finding of tension pneumothorax or pneumothorax >10%, younger than 16 years old and with indications requiring any non-thoracic major operation. The decision to perform TT for those patients in the non-TUS group was made on the basis of CXR findings and clinical symptoms. The continuous data were analyzed by using the two-tailed Student's *t* test, and the discrete data were analyzed by Chi-square test.

Results A total of 84 patients met the criteria for inclusion in the final analysis, with TT having been performed on 42 (50%) of those patients. The mean volume of the drainage amount was 860 ml after TT. The TT drainage was less than 500 ml in 12 patients in the non-TUS group (40%), while none was less than 500 ml in the TUS group ($p = 0.036$, Fisher's exact test). In terms of the positive rate of subsequent effective TT, the sensitivity of TUS was 90% and the specificity was 100%. There were 3 patients with delayed hemothorax: 2 of the 58 (3.6%) in the non-TUS group and 1 of 26 (4.5%) in the TUS group ($p > 0.05$, Fisher's exact test). The hospital length of stay in the non-TUS group with non-therapeutic TT was significantly longer than in the TUS group without TT (8.2 vs. 5.4 days, $p = 0.018$). There were no other major complications or deaths in either group during the 90-day follow-up period.

Conclusion In the case of blunt trauma, TUS can rapidly and accurately evaluate hemothorax to avoid TT in patients who may not benefit much from it. As a result, the rate of non-therapeutic TT can be decreased, and the influence on shortening hospital length of stay may be further evaluated with prospective controlled study.

✉ Chien-Ying Wang
wangcy@vghtpe.gov.tw

[1] Division of Trauma, Emergency Department, Taipei-Veterans General Hospital, No. 201, Sec. 2, Shih-Pai Road, Taipei 112, Taiwan

[2] Department of Nursing, Taipei Veterans General Hospital, Taipei, Taiwan

[3] School of Medicine, National Yang-Ming University, Taipei, Taiwan

[4] Institute of Emergency and Critical Care Medicine, National Yang-Ming University, Taipei, Taiwan

Abbreviations

AIS Abbreviated injury scale
MAP Mean arterial pressure
WBC White blood cell
TT Tube thoracostomy
TUS Thoracic ultrasound
CT Computed tomography
CXR Chest radiograph

Introduction

Emergency medicine ultrasound (US) was first promoted by the American College of Surgeons in 1993 as part of the Advanced Trauma Life Support (ATLS) course's standard algorithm for the detection of hemoperitoneum [1]. In order to ensure the rapid application of appropriate interventions in blunt chest trauma patients, the initial assessment and resuscitation are always key importance, while chest radiograph (CXR), US, computed tomography (CT) scan and laboratory examinations are the applicable adjuncts. Generally, a CXR can be performed rapidly for the early diagnosis of potentially life-threatening injuries in chest trauma patients, but this procedure has certain limitations, such as low sensitivity and specificity in the detection of small to moderate hemothorax or pneumothorax. Moreover, differentiating this condition from lung contusion can be difficult with a CXR, because mostly such patients undergo a portable supine CXR in the emergency department (ED).

In addition, the epidemiology of minor chest wall injuries (e.g., muscle contusions and strains) is largely unknown because many patients with such injuries do not present to the medical system at the time of injury. This may lead to a bias in the literature insofar as most studies use data from trauma registries primarily involving patients admitted to hospital with significant injuries. That is, the available information on chest trauma patients is largely retrospective and obtained from patients with more serious injuries.

Some studies have proposed that thoracic ultrasound (TUS) is superior to the combination of a CXR with physical examination for diagnosing hemothorax at the bedside [2]. However, the proportion of traumatic hemopneumothorax cases in which a decision to apply TT is appropriate remains controversial, because thoracentesis and tube thoracostomy (TT) drainage are associated with complications. Therefore, it is beneficial to decide whether drainage is required by quantifying effusion volume initially as well as reevaluating the amount regularly. Furthermore, those patients who do not undergo TT can recover relatively rapidly and thus have a shorter hospital stay [3–7]. Therefore, we reviewed available data at Taipei Veterans General Hospital in order to clarify if it is an appropriate management of hemothorax in blunt chest trauma patients by using TUS to avoid non-therapeutic TT in stable cases.

Patients and methods

The data analyzed in this study came from patients retrospectively identified as blunt chest trauma cases through registry data collected at the trauma center of Taipei Veterans General Hospital over a 4-year period beginning in December 2012. The medical records of adult patients with blunt chest trauma whose chest AIS score $\geq$ 3 during this period were reviewed. Of those, patients meeting any of the following criteria were then excluded from further analysis: those who were transferred from another facility, those with an AIS score $\geq$ 2 for any region except the chest region, those with a documented finding of tension pneumothorax or pneumothorax >10%, those younger than 16 years old and those with indications requiring any non-thoracic major operation.

Among the 84 patients who met the criteria for inclusion in the final analysis, all of the patients had received CXR examination during the primary survey. We have promoted the use of TUS after performing focused assessment with sonography in trauma (FAST) as a set of extended FAST. However, the decision of performing TUS during FAST examination depends on different trauma surgeons' confidence to CXR and patients' clinical presentation. Therefore, the patients were then divided into a non-thoracic ultrasound (non-TUS) group and a TUS group according to whether a TUS survey was performed during the examination of FAST. In the non-TUS group, the decision to perform TT was made on the basis of X-ray image findings and clinical symptoms, with the relevant criteria including dyspnea and decreased saturation of peripheral oxygen (SpO_2) levels under 92%. To estimate the volume of pleural fluid in the TUS group, the examination was performed in a sitting position and the US probe moved in a cranial direction along the mid-scapular line. As the visceral layer moved during each respiratory cycle with a decrease in interpleural separation during inspiration, the lung behind the pleural effusion appeared either ventilated or consolidated. Then, the effusion volume could be detected clearly between the diaphragm and visceral pleura as stated in a previous report by Usta et al. [8]. The amount of fluid drained after TT in both TUS and non-TUS groups was recorded for data measurement.

Patients who had a thoracic CT scan in the emergency room were excluded, because the arrangement of a CT scan implies the suspicion of more severe injury by physical examination, CXR and US findings. For those patients who had TT, the chest tube was always inserted by open method as recommended by ATLS® and other expert authorities. In this study, a non-therapeutic TT was defined as one in which the total drainage amount was less than 500 ml; this definition was chosen according to previous studies [9–12] that showed the benefits of drainage after the prediction of >500 ml of pleural fluid via ultrasonography. A routine CXR inspection was performed in all patients after TT or chest tube removal, and there was no mortality in the overall study group.

Statistical analysis

Results were expressed as mean ± standard deviation (S.D.) or median. Continuous data were analyzed by using a two-tailed Student's *t*-test, and discrete data were analyzed by using the Chi-square test when appropriate. Comparisons associated with a p value <0.05 were defined as significance. All numerical analyses were performed using SPSS 21.0 for Windows (SPSS, Chicago, IL, USA).

Ethics approval

This retrospective study was approved by the hospital's ethics committee with no requirement for informed consent.

Results

A total of 84 patients were analyzed: 62 (74%) were male and 22 were female. The mean age was 60 years. The median chest AIS was 4, and the median injury severity score was 16. The hemodynamic conditions in all patients remained stable without obvious active bleeding during their stays in the emergency department, with a mean heart rate of 84/min, a mean arterial pressure of 102 mmHg and a mean hemoglobin of 12.97 g/dl. All of the patients received X-ray examinations, and 26 (31%) of them received US examination. TT was performed in 42 (50%) patients in total. The mean volume of the drainage amount was 860 ml after TT, and the mean of hospital stay was 7.2 days.

Overall, 26 patients received a TUS examination after CXR, and only nine of those patients needed TT (Fig. 1). The other 17 patients received conservative treatment, and only one of them (6%) did not recover well due to a delayed massive hemothorax. That patient then received TT on the third day post-trauma after a positive finding via follow-up TUS. In terms of the rate of subsequent effective TT, the sensitivity of TUS was 90%, the specificity was 100%, the positive predictive value was 100%, and the negative predictive value was 94%. In contrast, for the non-TUS group, the sensitivity was 90%, the specificity was 68%, the positive predictive value was 60%, and the negative predictive value was 93%. Of the 58 patients who only received CXR, 28 did not undergo TT and still improved well, with the mean length of hospital stay for this subgroup being 5.3 days. On the other hand, 12 (40%) of the 30 patients who received TT after CXR examination without TUS had non-therapeutic TT due to a total tube drainage amount of <500 ml and these 12 patients had a mean hospital stay of 8.17 days.

After dividing the patients into the TUS group and the non-TUS group, there was no significant difference between the two groups in terms of all clinical variables mentioned above (Table 1), with the exception of the number of patients who underwent non-therapeutic drainage and the mean length of hospital stay. Specifically, 12 patients in the non-TUS group (40%) had drainage of less than 500 ml compared with 0 patient in TUS group ($p = 0.036$, Fisher's exact test), and the mean length of hospital stay among those 12 patients (7.86 ± 2.88) was significantly longer ($p = 0.018$) than that of the 16 patients without TT in TUS group (5.38 ± 2.7), despite the mean length of hospital stay for the entire non-TUS group

Fig. 1 Flow diagram of the progress through the treatment

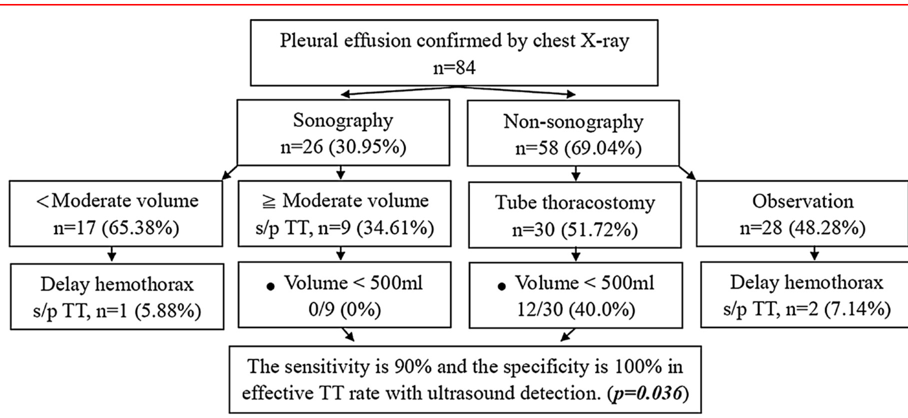

Table 1 Clinical characteristics of thoracic ultrasound and non-thoracic ultrasound group

	TUS ($n = 26$)		Non-TUS ($n = 58$)		Statistical significance
	Mean/SD	Median	Mean/SD	Median	
Gender (% men)	53.85		82.76		0.012
Age (years)	58.73/13.41	56	60.40/19.03	60	0.40
ISS	13.77/3.93	16	13.05/4.21	13	0.54
AIS chest	3.58/0.50	4	3.47/0.54	3	0.318
No. of rib fractures	3.92/1.57	4	3.57/1.90	3	0.214
Heart rate (beats/min)	88/22	83	82/14	82	0.12
MAP (mmHg)	102/19	102	102/18	104	0.606
WBC ($\times 10^9$/l)	10,204/2990	9700	10,523/4318	9400	0.14
Hemoglobin (g/dl)	12.50/2.28	12.85	13.18/1.71	13.00	0.105
Serum glucose (mg/dl)	149/56	139	151/78	127	0.458
CK (U/l)	1102/1621	183	287/193	212	0.053
Volume (ml)	1018/604	900	810/635	690	0.795
Hospital length of stay (days)	6.92/3.79	6	7.26/2.88	7	0.30

TUS thoracic ultrasound, *ISS* injury severity score, *AIS* abbreviated injury scale, *MAP* mean arterial pressure, *CK* creatine kinase, *TT* tube thoracostomy

(7.26 ± 2.88) not being significantly different from the overall mean length of hospital stay for the entire TUS group (6.92 ± 3.79). There were 3 patients with delayed hemothorax: two of the 58 patients (3.6%) in the non-TUS group versus one of the 26 patients (4.5%) in the TUS group ($p > 0.05$, Fisher's exact test). According to a univariate analysis, the absence of US was the only factor that influenced the rate of non-therapeutic TT (Table 2). There were no major complications that required surgical intervention nor any deaths in either group during the 90-day follow-up period.

Table 2 Clinical variables correlated with non-therapeutic tube thoracostomy

Variable	Univariate analysis		
	Odds ratio	95.0% CI	*P* value
Gender (%men)	0.90	0.27–2.98	0.56
Age (≥65 years)	1.2	0.46–1.02	0.10
ISS ≥16	0.4	0.43–1.48	0.367
AIS chest ≥4	0.78	2.1–72.3	0.367
No. of rib fractures ≥2	0.8	0.52–1.23	0.216
Ultrasound	1.5	1.17–1.93	**0.02**
Heart rate ≥100 or ≤50	4.9	0.72–1.15	0.44
MAP ≤70 (mm Hg)	23.5	0.91–1.03	0.71
Serum glucose ≥140 (mg/dl)	11.1	0.53–1.64	0.57

Bold value indicates the statistical significance level of $p = 0.05$

ISS injury severity score, *CI* confidence interval; see footnote in Table 1

Discussion

Trauma-related hemothorax has been known to lead to subsequent post-traumatic retained hemothorax and empyema, while rib fractures also have been documented as an independent risk factor for empyema [13]. TT drainage has been regarded as the primary mode of treatment on decreasing the potential complications of hemothorax since the continuous chest drainage via an intercostal tube was first described by Hewett in 1876 [14]. However, potential complications and relative contraindications are associated with the procedure, and they are categorized as insertional (e.g., hemorrhage, laceration), positional (e.g., extrathoracic placement, placement in the lung fissure, dislodgement) and infective (e.g., wound infection, empyema). The overall rate of complications associated with TT placement quoted in the literature ranges from 6 to 38% [4–6] and may markedly increase hospitalization costs [15]. Therefore, it is now generally agreed that TT is necessary in cases of massive hemothorax or hemothorax combined with severe clinical symptom and signs. Nevertheless, use of TT in relatively stable patients with blunt chest trauma is controversial. As such, TUS may play a role in determining the best course of action in such situations.

Nowadays, US examination is very popular and easily accessible. The focused assessment with sonography for trauma (FAST), which can be performed by trained non-radiologists, has been shown to provide an accurate and rapid evaluation of the trauma patient for hemoperitoneum, thereby augmenting clinical decision making [16–18]. Despite current widespread use of the TUS approach in many contexts [19–22], it is not yet used on blunt chest trauma patients with the frequency and regularity that would be expected. In a 2003 study, Abbound and Kendall [23] proposed that emergency medicine US examinations do not effectively detect small-volume hemothoraces that could be identified by CT scan, but they also noted that none of these "small" or "tiny" hemothoraces seen on CT scans subsequently developed into clinically significant lesions.

According to the latest literature, it is widely accepted that ultrasonography of the anterior and lateral chest can identify pneumothorax and hemothorax with greater sensitivity and specificity than supine chest radiography [24–26]. However, the diagnostic accuracy of ultrasonography in the acute assessment of common thoracic lesions after trauma was not yet confirmed with respect to hemothorax [27]. Since the image quality has improved and the methods and accuracy of quantifying pleural effusion via TUS have been well established over the past few decades [9, 19, 28], it is time to re-inspect the role of TUS in making decisions regarding first-line use of TT for hemothorax.

According to our results regarding patients in stable condition after blunt chest trauma, the effective rate of TT was 100% in patients who received both CXR and TUS examinations compared with only 60% in patients who received only a CXR examination. Furthermore, the success rate of conservative treatment was 94.1% in patients who received both CXR and TUS examinations. The reason for these results may be that for trauma patients who suffer from blunt chest injury, even if presented with stable vital signs, the CXR examination is usually performed via the anteroposterior (AP) view instead of posteroanterior (PA) view. This may cause some misjudgment in the amount of pleural effusion. In addition, TUS is more accurate than CXR in the evaluation of pleural fluid volume and thus facilitates a more precise detection of the amount of hemothorax. In turn, TUS may enhance the likelihood of making the most suitable treatment decision.

Although CT scans are regarded as the "gold standard" for the detection and evaluation of severe blunt trauma chest injuries and may detect some hemothoraces not seen on US, CT scans have various limitations, including higher cost and higher dose of radiation, longer time to perform and the need to transport patient from one place to another. In contrast, TUS is comparable to the initial CXR in terms of accuracy in the detection of hemothorax [3, 29] and can be repeated serially at bedside without radiation or contrast exposure. Therefore, we propose that TUS may play a major role in any initial assessment, as well as in follow-up imaging due to the advantages of quick and easy bedside access, and the near-to-none radiation exposure compared to CT scan. Consequently, this method of TUS use will reduce the incidences of non-therapeutic TT. Moreover, by avoiding unnecessary TT, the length of hospital stay may also decrease.

For a long time, surgeons have debated how large of a hemothorax can be observed safely. Visualization quantity of 500 ml of blood on chest radiography was the generally agreed limit [11]. This implies that occult hemothoraces of less than 500 ml may be safe and insignificant. In the past literatures, authors have used an estimated volume of 500 ml as the entry point in studies for evacuation of retained hemothorax [12] and for occult hemothorax under plain chest radiograph that can be managed successfully without tube thoracostomy [30]. Therefore, we adopted 500 ml as the cutoff value of non-therapeutic TT. Since there were no complications of empyema in our study group, we believe that the rationale of taking conservative treatment in patients with less than 500 ml of hemothorax after blunt chest trauma is applicable.

There are several limitations to our study, particularly with respect to the small sample size and how the patients in the sample were selected. Sometimes, during emergent rescue efforts, deciding not to perform TT in a highly suspicious hemothorax patient is difficult. This was also not a randomized study. Randomizing patients with blunt chest trauma is very challenging. With these issues in mind, larger number of patients should be included into future studies to assess the benefits of US in stable cases of blunt chest trauma with rib fractures.

Reviewing the past literature, we found one study in which postoperative pleural effusion in cardiac surgery patients was estimated by ultrasound. The authors established a practical and simplified formula to facilitate the management of pleural effusion, and thoracentesis was performed in those patients with pleural effusion of more than 500 ml. The outcomes of the study were obvious: Postoperative respiration and recovery were improved, and postoperative stay was shortened [31]. These results were consistent with the result of our study. One potential source of error for volume underestimation is in cases of lower lobe atelectasis with large effusions of over 1000 ml. In addition, layer measurements performed via US may cause underestimation of the actual volume of pleural fluid in large thoraxes. The situations mentioned above were noted in our study. Another important limitation affecting our study was the examination technique: The transducer must not be angled or tilted, as any angle or tilt may result in a scan that is oblique to the transverse plane. Such a measurement may overestimate the width of the effusion.

In another study, Blackmore et al. [32] devised and validated a prediction rule for estimating pleural effusion volume on the basis of chest radiographic appearance. Blackmore et al. stated that pleural fluid becomes visible on the upright lateral radiograph at approximately 50 ml at the meniscus in the posterior costophrenic sulcus. Furthermore, the meniscus becomes visible on the posteroanterior projection at about 200 ml and will obliterate the hemidiaphragm at approximately 500 ml. However, the assessments of the patients in this study were based on standing posteroanterior and lateral CXRs. The situation was not consistent with the patients in our study who had suffered from blunt chest trauma and generally could not stand-up well. Considering the limitation of CXRs, we can understand that it takes effort to accurately estimate the fluid amount in chest trauma patients with US and chest X-ray only. This may lead to additional imaging (via CT scans) or a procedure (e.g., placement of a thoracostomy tube) depending on clinical circumstance.

According to our result, the comparison of hospital length of stay (LOS) between the non-TUS patients who received "non-therapeutic" TT and the TUS patients who did not receive TT indicates that TT may extend hospital LOS. Considering that we did not find significant difference in the LOS between all TUS and non-TUS patients under our current dataset after multivariate analysis, which was not shown in table, we cannot conclude the influence of TUS on hospital LOS. However, we believe the decision of conservative treatment without TT after TUS survey will decrease the LOS in patients with non-therapeutic TT and that the complications relating to tube insertion could be avoided. Therefore, further prospective study on cost-effectiveness and hospital LOS may be conducted to evaluate the value of performing TUS in blunt chest trauma.

Conclusion

In selected blunt chest trauma patients, TUS can rapidly and accurately evaluate hemothorax to avoid the application of TT in patients who may not benefit from it. As a result, the use of non-therapeutic TT can be decreased, and the influence on shortening hospital length of stay may be further evaluated with prospective controlled study.

Compliance with ethical standards

Conflict of interest We declare that there is no conflict of interest in relation to this article.

References

1. Herbert JP, Raymond HA et al (1993) Advanced trauma life support. American College of Surgeons, Chicago
2. Leblanc D, Bouvet C, Degiovanni F, Nedelcu C, Bouhours G, Rineau E et al (2014) Early lung ultrasonography predicts the occurrence of acute respiratory distress syndrome in blunt trauma patients. Intensive Care Med 40:1468–1474
3. Johnson G (1996) Traumatic pneumothorax: is a chest drain always necessary? J Accid Emerg Med 13:173–174
4. Fartoukh M, Azoulay E, Galliot R, Le Gall JR, Baud F, Chevret S et al (2002) Clinically documented pleural effusions in medical ICU patients: how useful is routine thoracocentesis? Chest 121:178–184
5. Colt HG, Brewer N, Barbur E (1999) Evaluation of patient-related and procedure-related factors contributing to pneumothorax following thoracocentesis. Chest 116:134–138
6. Collop NA, Kim S, Sahn SA (1997) Analysis of tube thoracostomy performed by pulmonologists at a teaching hospital. Chest 112:709–713
7. Resnick DK (1993) Delayed pulmonary perforation: a rare complication of tube thoracostomy. Chest 103:311–313
8. Usta E, Mustafi M, Ziemer G (2010) Ultrasound estimation of volume of postoperative pleural effusion in cardiac surgery patients. Interact CardioVasc Thorac Surg 10:204–207
9. Roch A, Bojan M, Michelet P, Romain F, Bregeon F, Papazian L et al (2005) Usefulness of ultrasonography in predicting pleural effusions >500 ml in patients receiving mechanical ventilation. Chest 127:224–232
10. Razazi K, Thille AW, Carteaux G, Beji O, Brun-Buisson C, Brochard L et al (2014) Effects of pleural effusion drainage on oxygenation, respiratory mechanics, and hemodynamics in mechanically ventilated patients. Ann Am Thorac Soc 11(7):1018–1024
11. Mowery NT, Gunter OL, Collier BR, Diaz JJ Jr., Haut E, Hildreth A et al (2011) Practice management guidelines for management of hemothorax and occult pneumothorax. Trauma 70(2):510–518
12. Vassiliu P, Velmahos GC, Toutouzas KG (2001) Timing, safety, and efficacy of thoracoscopic evacuation of undrained post-traumatic hemothorax. Am Surg 67:1165–1169
13. DuBose J, Inaba K, Okoye O, Demetriades D, Scalea T, O'Connor J et al (2012) Development of posttraumatic empyema in patients with retained hemothorax: results of a prospective, observational AAST study. J Trauma Acute Care Surg 73:752–757
14. Hewett FC (1876) Thoracentesis: the plan of continuous aspiration. Br Med J 1:317
15. Hernandez MC, Zeb MH, Heller SF, Zielinski MD, Aho JM (2017) Tube thoracostomy complications increase cost. World J Surg 41(6):1482–1487. https://doi.org/10.1007/s00268-017-3897-7
16. Rozycki GS, Ochsner MG, Schmidt JA, Frankel HL, Davis TP, Wang D et al (1995) A prospective study of surgeon-performed ultrasound as the primary adjuvant modality for injured patient assessment. J Trauma 39:492–498 **(discussion 498–500)**
17. Dolich MO, McKenney MG, Varela JE, Compton RP, McKenney KL, Cohn SM (2001) 2576 ultrasound for blunt abdominal trauma. J Trauma 50:108–112
18. Boulanger BR, Brenneman FD, McLellan BA, Rizoli SB, Culhane J, Hamilton P (1995) A prospective study of emergent abdominal sonography after blunt abdominal trauma. J Trauma 39:325–330
19. Cortellaro F, Colombo S, Coen D, Duca PG (2012) Lung ultrasound is an accurate diagnostic tool for the diagnosis of pneumonia in the emergency department. Emerg Med J 29:19–23
20. Rahman NM, Singanayagam A, Davies HE, Wrightson JM, Mishra EK, Lee YC et al (2010) Diagnostic accuracy, safety and utilization of respiratory physician-delivered thoracic ultrasound. Thorax 65:449–453

21. Brooks A, Davies B, Smethhurst M, Connolly J (2004) Emergency ultrasound in the acute assessment of haemothorax. Emerg Med J 21:44–46
22. Chavez MA, Shams N, Ellington LE, Naithani N, Gilman RH, Steinhoff MC et al (2014) Lung ultrasound for the diagnosis of pneumonia in adults: a systematic review and meta-analysis. Respir Res 15:50
23. Abboud PA, Kendall J (2003) Emergency department ultrasound for hemothorax after blunt traumatic injury. J Emerg Med 25:181–184
24. Whitson MR, Mayo PH (2016) Ultrasonography in the emergency department. Crit Care 20:227
25. Wilkerson RG, Stone MB (2010) Sensitivity of bedside ultrasound and supine anteroposterior chest radiographs for the identification of pneumothorax after blunt trauma. Acad Emerg Med 17:11–17
26. Soult MC, Weireter LJ, Britt RC, Collins JN, Novosel TJ, Reed SF et al (2015) Can routine trauma bay chest X-ray be bypassed with an extended focused assessment with sonography for trauma examination? Am Surg 81:336–340
27. Hyacinthe AC, Broux C, Francony G, Genty C, Bouzat P, Jacquot C et al (2012) Diagnostic accuracy of ultrasonography in the acute assessment of common thoracic lesions after trauma. Chest 141:1177–1183
28. Eibenberger KL, Dock WI, Ammann ME, Dorffner R, Hörmann MF, Grabenwöger F (1994) Quantification of pleural effusions: sonography versus radiography. Radiology 191:681–684
29. Röthlin MA, Näf R, Amgwerd M, Candinas D, Frick T, Trentz O (1993) Ultrasound in blunt abdominal and thoracic trauma. J Trauma 34:488–495
30. Mahmood I, Abdelrahman H, Al-Hassani A, Nabir S, Sebastian M, Maull K (2011) Clinical management of occult hemothorax: a prospective study of 81 patients. Am J Surg 201(6):766–769
31. Usta E, Mustafi M, Ziemer G (2010) Ultrasound estimation of volume of postoperative pleural effusion in cardiac surgery patients. Interact CardioVasc Thorac Surg 10:204–207
32. Blackmore CC, Black WC, Dallas RV, Crow HC (1996) Pleural fludi volume estimation: a chest radiograph prediction rule. Acad Radiol 3:103–109