Practice Management Guidelines for Management of Hemothorax and Occult Pneumothorax

Nathan T. Mowery, MD, Oliver L. Gunter, MD, Bryan R. Collier, DO, Jose' J. Diaz, Jr., MD, Elliott Haut, MD, Amy Hildreth, MD, Michelle Holevar, MD, John Mayberry, MD, and Erik Streib, MD

STATEMENT OF THE PROBLEM

Thoracic trauma is a notable cause of morbidity and mortality in American trauma centers, where 25% of traumatic deaths are related to injuries sustained within the thoracic cage.[1] Chest injuries occur in ~60% of polytrauma cases; therefore, a rough estimate of the occurrence of hemothorax related to trauma in the United States approaches 300,000 cases per year.[2] The management of hemothorax and pneumothorax has been a complex problem since it was first described over 200 years ago. Although the majority of chest trauma can be managed nonoperatively, there are several questions surrounding the management of hemothorax and occult pneumothorax that are not as easily answered.

The technologic advances have raised the question of what to do with incidentally found hemothorax and pneumothorax discovered during the trauma evaluation. Previously, we were limited by our ability to visualize quantities <500 mL of blood on chest radiograph. Now that smaller volumes of blood can be visualized via chest computed tomography (CT), the management of these findings presents interesting clinical questions.

In addition to early identification of these processes, these patients often find themselves with late complications such as retained hemothorax and empyema. The approach to these complex problems continues to evolve.

Finally, as minimally invasive surgery grows and finds new applications, there are reproducible benefits to the patients in pursuing these interventions as both a diagnostic and therapeutic interventions. Video-assisted thoracoscopic surgery (VATS) has a growing role in the management of trauma patients.

PROCESS

A computerized search of the National Library of Medicine MEDLINE database was undertaken using the PubMed Entrez interface. English language citations during the period of 1965 through 2008 using the primary search strategy:

hemothorax[mh] pneumothorax[mh] AND humans[mh] NOT (case reports[pt] OR letter[pt] OR comment[pt] OR news[pt])

Review articles were also excluded. The PubMed Related Articles algorithm was also used to identify additional articles similar to the items retrieved by the primary strategy. Of ~127 articles identified by these two techniques, those dealing with either prospective or retrospective studies examining hemothorax and pneumothorax were selected, comprising 43 institutional studies evaluating diagnosis and management of adult patients with hemothorax or pneumothorax (Table 1). The articles were reviewed by a group of nine surgeons who collaborated to produce this practice management guideline.

The correlation between the evidence and the recommendations is as follows:

Level 1

This recommendation is convincingly justifiable based on the available scientific information alone. It is usually based on Class I data; however, strong Class II evidence may form the basis for a Level 1 recommendation, especially if the issue does not lend itself to testing in a randomized format. Conversely, weak or contradictory Class I data may not be able to support a Level 1 recommendation.

Level 2

This recommendation is reasonably justifiable by available scientific evidence and strongly supported by expert critical care opinion. It is usually supported by Class II data or a preponderance of Class III evidence.

Level 3

This recommendation is supported by available data, but adequate scientific evidence is lacking. It is generally supported by Class III data. This type of recommendation is useful for educational purposes and in guiding future research.

RECOMMENDATIONS

Diagnosis

1. Ultrasound can reliably be used to identify pneumothorax and pleural effusion (Level 2).
2. CT of the chest is indicated in patients with persistent opacity on chest radiograph after tube thoracostomy to determine whether significant undrained fluid exists (Level 2).

Submitted for publication November 23, 2009.
Accepted for publication December 13, 2010.

From the Department of Surgery (N.T.M., A.H.), Wake Forest University, Winston-Salem, North Carolina; Department of Surgery (O.L.G.), Washington University at St. Louis, St. Louis, Missouri; Department of Surgery (B.R.C., J.J.D.), Vanderbilt University Medical Center, Nashville, Tennessee; Department of Surgery (E.H.), Johns Hopkins University, Baltimore, Maryland; Department of Surgery (J.M.), Oregon Health and Science University, Portland, Oregon; and Department of Surgery (E.S.), Indiana University, Bloomington, Indiana.

DOI: 10.1097/TA.0b013e31820b5c31

TABLE 1. Practice Management Guidelines for Pulmonary Contusion and Flail Chest 1991–Present

Author(s)	Year	Reference Title	Class	Comments and Consensus
McNamara et al.[19]	1970	Thoracic injuries in combat causalities in Vietnam. *Ann Thorac Surg.* 1970;10: 389–401.	III	(n = 547) Descriptive article addressing how the majority of patients need only tube thoracostomy, but others may benefit from early thoracotomy. Original description of 1,500 mL initial chest tube output as surgical indication in chest injury.
Karmy-Jones et al.[21]	2001	Timing of urgent thoracotomy for hemorrhage after trauma: a multicenter study. *Arch Surg.* 2001;136:513–518.	III	(n = 157) Risk of death in patients who underwent thoracotomy with a total chest tube output of 1,500 mL was greater than those whose chest tube output was <500 mL. Thoracotomy should be considered after initial output of between 500 mL and 1500 mL of blood, or ongoing output of 500 mL within the first hour after insertion.
Mansour et al.[20]	1992	Exigent postinjury thoracotomy analysis of blunt versus penetrating trauma. *Surg Gynecol Obstet*. 1992;175:97–101.	III	(n = 83) Following penetrating trauma, indications for urgent operating room thoracotomy are refractory shock, excessive and ongoing thoracic bleeding, or pericardial tamponade. Excluding descending thoracic aortic injury, patients with a blunt thoracic trauma should be operated on for refractory shock as opposed to persistent chest tube output alone.
Kish et al.[14]	1976	Indications for early thoracotomy in the management of chest trauma. *Ann Thorac Surg.* 1976;22:23–28.	III	(n = 59) A large civilian experience with immediate and early thoracotomy after injury. 84% patients were able to be managed nonoperatively with or without chest tubes. Mortality is higher for blunt trauma. Indications for thoracotomy include shock and chest tube output indicative of significant hemorrhage.
Siemens et al.[15]	1977	Indications for thoracotomy following penetrating thoracic injury. *J Trauma.* 1977;17:493–500.	III	(n = 190) Indications for immediate thoracotomy following penetrating trauma to the thorax include central wound location, initial tube thoracostomy output >800 mL, retained hemothorax, and evidence of cardiac tamponade. Conclusions are not wholly supported by data presented.
Bilello et al.[22]	2005	Occult traumatic hemothorax: when can sleeping dogs lie? *Am J Surg.* 2005;190: 841–844.	III	(n = 78) Small hemothorax after blunt trauma measuring <1.5 cm on chest CT can be managed nonoperatively.
Kwon et al.[8]	2006	Isolated computed tomography diagnosis of pulmonary contusion does not correlate with increased morbidity. *J Pediatr Surg.* 2006;41:78–82; discussion 78–82.	III	(n = 46) CXR is adequate in the assessment of pulmonary contusion in pediatric trauma patients. If coronary contusion is noted both on CXR as well as CT scan, increased hospital and ICU length of stay is required. Pulmonary contusion only found on CT scan is not associated with increased morbidity.
Soldati et al.[7]	2006	Chest ultrasonography in lung contusion. *Chest*. 2006;130:533–538.	II	(n = 121) Ultrasound can visualize pulmonary contusion with high specificity (96.1%) and sensitivity (94.6%), which compares favorably to CT scan. Ultrasound may have utility in following progression of pulmonary contusion in trauma patients without pneumothorax.
Rocco et al.[6]	2008	Diagnostic accuracy of bedside ultrasonography in the ICU: feasibility of detecting pulmonary effusion and lung contusion in patients on respiratory support after severe blunt thoracic trauma. *Acta Anaesthesiol Scand*. 2008; 52:776–784.	III	(n= 15) Ultrasound is superior to playing radiographs for the assessment of pulmonary contusion and pleural effusion. Sensitivity/specificity for pleural effusion 94%/99% and for pulmonary contusion, 86%/97%. CT scan is recognized as the gold standard evaluation for chest injury. Small sample size.
Velmahos et al.[10]	1999	Predicting the need for thoracoscopic evacuation of residual traumatic hemothorax: chest radiograph is insufficient. *J Trauma*. 1999;46:65–70.	II	(n = 58) CXR misclassifies chest opacity in 47% of cases. Management was changed in 31% of patients on the basis of the chest CT scan. Plain radiographs are insufficient to judge the presence of retained hemothorax, particularly after penetrating trauma. CT estimation of retained fluid volume seems to correlate with operative findings.
Divisi et al.[11]	2004	Video-assisted thoracoscopy in thoracic injury: early or delayed indication? *Acta Biomed*. 2004;75:158–163.	III	(n = 112) Retrospective study of hemodynamically stable trauma patients who underwent VATS for a variety of injuries. Time to surgery was correlated with hospital stay. No significant complications mentioned, unclear indications for surgery, but VATS was suggested as a therapeutic and diagnostic measure for chest injuries. No comparison to a control group treated with the current standard of care (thoracostomy).
Watkins et al.[9]	2000	Empyema and restrictive pleural processes after blunt trauma: an under-recognized cause of respiratory failure. *Am Surg*. 2000;66:210–214.	III	(n = 28) Estimated 5% to 10% of patients with respiratory failure after blunt trauma developed empyema. Most common CXR finding was pleural effusion; most common operative finding was pleural rind. Recommended early and aggressive evaluation and management of pleural fluid collections after blunt trauma, including utilization of CT scan for definitive diagnosis and operative planning. No comparison to a control group treated with the current standard of care (thoracostomy).
Paci et al.[13]	2006	The role of diagnostic VATS in penetrating thoracic injuries. *World J Emerg Surg*. 2006;1:30.	III	(n = 16) VATS can identify anatomic injuries in penetrating chest trauma. VATS may be useful for the evaluation and treatment of thoracoabdominal injury, including diaphragmatic injuries that are infrequently identified on CT scan. Small sample size.

TABLE 1. Practice Management Guidelines for Pulmonary Contusion and Flail Chest 1991–Present (continued)

Author(s)	Year	Reference Title	Class	Comments and Consensus
Karmy-Jones et al.[25]	2008	Residual hemothorax after chest tube placement correlates with increased risk of empyema following traumatic injury. *Can Respir J*. 2008;15:255–258.	III	(n = 102) Retained hemothorax evident on plain X-ray following placement of initial chest tube may lead to empyema in 33%. Patients with higher ISS may benefit most from evacuation.
Scherer et al.[30]	1998	Video-assisted thoracic surgery in the treatment of posttraumatic empyema. *Arch Surg*. 1998;133:637–641; discussion 641–642.	III	(n = 36) Complication rates were similar between VATS and thoracotomy. Furthermore, there is no difference in pain control, operative duration, or adequacy of treatment. VATS should be considered for evacuation of either empyema or retained hemothorax, although one must be prepared to perform thoracotomy.
Ben-Nun et al.[31]	2007	Video-assisted thoracoscopic surgery in the treatment of chest trauma: long-term benefit. *Ann Thorac Surg*. 2007;83:383–387.	III	(n = 77) Retrospective study evaluating comparison made between trauma patients who required either thoracotomy or VATS. Patients who underwent VATS had better long-term results with regard to pain, analgesic use, requirement of pain clinic service, cosmesis, complete recovery, and returned to normal lifestyle. VATS should be considered in patients who require thoracic operation following trauma.
Vassiliu et al.[26]	2001	Timing, safety, and efficacy of thoracoscopic evacuation of undrained post-traumatic hemothorax. *Am Surg*. 2001;67:1165–1169.	II	(n = 24) Patients with retained hemothorax estimated to be >500 mL on CT scan by postinjury day 2 should be considered for early VATS. Surgery done before postinjury day 3 results in significant reduction of operative difficulty, contamination/infection of hematoma, and hospital length of stay. Three patients who were not drained developed empyema.
Velmahos and Demetriades[4]	1999	Early thoracoscopy for the evacuation of undrained haemothorax. *Eur J Surg*. 1999;165:924–929.	II	(n = 12) VATS should be strongly considered for evacuation of retained hemothorax when CT scan identifies >500 mL of blood. VATS should ideally be performed within the first week after injury. Plain radiographs are insufficient to diagnose retained hemothorax, CT is the gold standard. VATS evacuation of hemothorax was associated with improvement of postoperative oxygenation.
Morales Uribe et al.[28]	2008	Best timing for thoracoscopic evacuation of retained post-traumatic hemothorax. *Surg Endosc*. 2008;22:91–95.	II	(n = 102) VATS is most successful when performed within 5 d after injury. This timing decreases the likelihood of conversion to thoracotomy and the need for further intervention. VATS is touted as the procedure of choice for treatment of retained hemothorax after trauma.
Liu et al.[12]	1997	Video-assisted thoracic surgery in treatment of chest trauma. *J Trauma*. 1997;42:670–674.	III	(n = 50) Descriptive article about 50 trauma patients who underwent VATS. This surgical technique can be used successfully to diagnose and manage a large variety of posttraumatic complications in hemodynamically stable patients.
Heniford et al.[23]	1997	The role of thoracoscopy in the management of retained thoracic collections after trauma. *Ann Thorac Surg*. 1997;63:940–943.	II	(n = 25) VATS should be performed for retained collection >500 mL on CT scan. No empyemas were identified when thoracoscopy was performed within 7 d of admission. Four of 25 required conversions to thoracotomy and 5 of 25 were complicated by pneumonia. Infectious complications were more common in thoracotomy. Empyema increased the risk of VATS failure and need for open thoracotomy.
Fabbrucci et al.[24]	2001	Video-assisted thoracoscopy in the early diagnosis and management of post-traumatic pneumothorax and hemothorax. *Surg Endosc*. 2008;22:1227–1231.	III	(n = 81) Retrospective study comparing outcomes of patients with pneumothorax and hemothorax managed by VATS and thoracotomy. VATS may be useful in the following scenarios: persistent air leak, persistent blood drainage of ≥100 mL/h but <200 mL/h of blood or some combination of the two. VATS did not increase hospital length of stay and may be a useful adjunct to tube thoracostomy alone. Very little data to draw any conclusions, patient characteristics are not directly described.
Meyer et al.[27]	1997	Early evacuation of traumatic retained hemothoraces using thoracoscopy: a prospective, randomized trial. *Ann Thorac Surg*. 1997;64:1396–1400; discussion 1400–1401.	I	(n = 39) In patients with retained hemothorax within 72 h of initial chest tube drainage, VATS was associated with significantly shorter duration of chest tube drainage, shorter postoperative length of stay, and lower hospital costs compared with second tube thoracostomy. Ten of 24 patients randomized to chest tube failed and required surgery. Study protocol terminated early secondary to clear benefit of VATS. Small sample size.
Oguzkaya et al.[34]	2005	Videothoracoscopy versus intrapleural streptokinase for management of post traumatic retained haemothorax: a retrospective study of 65 cases. *Injury*. 2005;36:526–529.	III	(n = 65) VATS is a more effective procedure then intrapleural streptokinase for the treatment of posttraumatic retained hemothorax. VATS associated with significantly shorter hospital length of stay and decreased need for additional therapy.
Pollak and Passik[33]	1994	Intrapleural urokinase in the treatment of loculated pleural effusions. *Chest*. 1994; 3:868–873.	III	(n = 8) Two of 8 patients with hemothorax. Intrapleural urokinase may be useful to improve drainage and resolution of loculated, exudative, or clotted pleural collections before development of fibrosis. Resolution seen in 5 of 9 collections with improvement in 2 others. Small sample size.

TABLE 1. Practice Management Guidelines for Pulmonary Contusion and Flail Chest 1991–Present (continued)

Author(s)	Year	Reference Title	Class	Comments and Consensus
Kimbrell et al.[32]	2007	Intrapleural thrombolysis for the management of undrained traumatic hemothorax: a prospective observational study. *J Trauma*. 2007;62:1175–1179.	II	(n = 25) Twenty-five consecutive patients with undrained hemothorax (>300 mL) treated with urokinase or streptokinase protocol. Thrombolysis was effective in 92% of patients with two failures that required surgical intervention. Intrapleural thrombolysis should be considered as an initial treatment for undrained traumatic hemothorax.
Ball et al.[37]	2006	Are occult pneumothoraces truly occult or simply missed? *J Trauma.* 2006;60: 294–298.	II	(n = 44) Expert radiologists with up-to-date technology are only able to identify occult pneumothorax in a minority (24%) of cases, and up to 75% are completely missed on playing radiographs. Low threshold should be given to obtaining CT of the chest in the setting of trauma as few occult pneumothoraces are seen with plain radiographs.
Garramone RR[41]	1991	An objective method to measure and manage occult pneumothorax. *Surg Gynecol Obstet*. 1991;173:257–261.	III	(n = 26) Retrospective study of 26 patients with of occult pneumothorax, 14 of whom were treated with chest tube. Pneumothorax size $<5 \times 80$ mm require chest tube in 3 pneumothoraces (17%), whereas size $\geq 5 \times 80$ mm required chest tube in 11 pneumothoraces (85%). Neither rib fractures nor positive pressure ventilation made any significant difference. Chest tube was placed in small, occult pneumothorax for increasing subcutaneous emphysema and increasing pneumothorax size. Small occult pneumothoraces can be managed with close observation regardless of rib fractures or positive pressure ventilation.
Collins et al.[38]	1992	Occult traumatic pneumothorax: immediate tube thoracostomy versus expectant management. *Am Surg*. 1992; 58:743–746.	III	(n = 26) In the setting of occult pneumothorax, patients treated with chest tube required longer hospital and ICU length of stay with no increase in morbidity or mortality. Occult pneumothorax can be observed with serial CXR, and chest tube should be placed if pneumothorax increases.
Wolfman et al.[39]	1998	Validity of CT classification on management of occult pneumothorax: a prospective study. *AJR Am J Roentgenol*. 1998;171:1317–1320.	II	(n = 36) Miniscule pneumothorax ($<1 \times 4$ cm) and anterior pneumothorax ($>1 \times 4$ cm) can be managed by observation, particularly in the absence of positive pressure ventilation, 24 of 27 (89%). Anterolateral pneumothorax (>1 by 4 cm, extending beyond mid coronal line) should be managed with chest tube. Patients should be monitored closely with serial CXR until resolution to evaluate for need of tube thoracostomy.
Hill et al.[35]	1999	The occult pneumothorax: an increasing diagnostic entity in trauma. *Am Surg*. 1999;65:254–258.	III	(n = 67) Occult pneumothorax identification increased as a result of more sensitive testing with CT scan. Thirty-nine percent of all pneumothorax were identified on CT scan only. Occult pneumothorax identified in 2.2% of all blunt trauma, and 7.9% of all patients who underwent abdominal CT scans.
Ball CG[36]	2005	Incidence, risk factors, and outcomes for occult pneumothoraces in victims of major trauma. *J Trauma*. 2005;59:917–924; discussion 924–925.	II	(n = 49) Six percent of trauma patients were found to have occult pneumothorax, and 55% of pneumothoraces were not initially detected on plain chest film. Predictors of occult pneumothorax included subcutaneous emphysema, polar a contusion, rib fractures, and female gender. One of 8 patients with occult pneumothorax treated expectantly required thoracostomy. Thirteen percent of patients treated with thoracostomy experience complications, 9% required repositioning. Chest tube is not mandatory in occult pneumothorax. CXRs inadequate to identify occult pneumothorax. Low threshold for CT of the chest should be considered in blunt trauma.
Enderson et al.[42]	1993	Tube thoracostomy for occult pneumothorax: a prospective randomized study of its use. *J Trauma.* 1993;35:726–729.	I	(n = 40) Randomized controlled trial comparing observation versus thoracostomy in occult pneumothorax. Eight of 21 patients in the observation group required to thoracostomy for progression of pneumothorax while on positive pressure ventilation, 3 of these developed tension pneumothorax. Complications were similar between observed versus thoracostomy group; however, there were more major complications in the observation group. Patients with occult pneumothorax on positive pressure ventilation should be managed with tube thoracostomy. No clear definition of occult pneumothorax given. Unclear significance in the modern setting of low tidal volume ventilation.
Brasel et al.[43]	1999	Treatment of occult pneumothoraces from blunt trauma. *J Trauma*. 1999;46:987–990; discussion 990–991.	I	(n = 39) Randomized, controlled trial. Eighteen patients underwent thoracostomy, 21 patients observed. No difference between progression of pneumothorax, length of stay, or respiratory complications, irrespective of positive pressure ventilation. Occult pneumothorax can be safely observed, regardless of the need of positive pressure ventilation. Close follow-up is recommended.
de Moya et al.[40]	2007	Occult pneumothorax in trauma patients: development of an objective scoring system. *J Trauma*. 2007;63:13–17.	III	(n = 50) Retrospective evaluation of occult pneumothorax size and subsequent management. Overall incidence of occult pneumothorax 1.8%. PPV for a score >31 was 78%, NPV for a score <20 was 70%. An objective scoring system for occult pneumothorax may be useful to predict requirement to chest tube. Pneumothorax score was not used to determine when thoracostomy would be placed; it was determined retrospectively and was not validated.

TABLE 1. Practice Management Guidelines for Pulmonary Contusion and Flail Chest 1991–Present (continued)

Author(s)	Year	Reference Title	Class	Comments and Consensus
Eren et al.[44]	2008	The risk factors and management of posttraumatic empyema in trauma patients. *Injury*. 2008;39:44–49.	III	(n = 71) Retrospective study identified the rate of development of empyema 4.0% after penetrating trauma, and 2.6% after blunt trauma, 3.1% for all patients. Independent risk factors identified for the development of empyema were duration of tube thoracostomy >6 d, ICU length of stay, pulmonary contusion, retained hemothorax, and need for exploratory laparotomy.
Aguilar et al.[46]	1997	Posttraumatic empyema. Risk factor analysis. *Arch Surg*. 1997;132:647–650; discussion 650–651.	III	(n = 25) Retrospective study that identified independent risk factors for the development of empyema after trauma to be pulmonary contusion, persistent pleural effusion, and the use of multiple chest tubes within the same hemithorax. Hospitalization after empyema was on average 2.5 wk longer than patients without. Causative organism identified in 60%, three-quarters of these were *Staphylococcus aureus*. The average time to diagnosis 12 d. Antibiotics were not found to be helpful in prevention. Empyema is a significant clinical entity and should be aggressively prevented.
Navsaria et al.[29]	2004	Thoracoscopic evacuation of retained posttraumatic hemothorax. *Ann Thorac Surg*. 2004;78:282–285; discussion 285–286.	III	(n = 46) VATS is an accurate, safe, and reliable operation for retained posttraumatic pleural collections. Thoracoscopy was successful in avoiding thoracotomy in 80% of cases, even in the setting of delayed surgery. Success rate of VATS was not related to time interval between injury and surgery. VATS should be considered for any retained, posttraumatic pleural fluid collection.
Helling et al.[45]	1989	Complications following blunt and penetrating injuries in 216 victims of chest trauma requiring tube thoracostomy. *J Trauma*. 1989;29:1367–1370.	III	(n = 216) Retrospective study finding that patients with blunt chest injury had a higher incidence of complications in comparison to penetrating injuries, 44% versus 30%. They did not, however, have higher incidence of retained hemothorax or empyema. In patients who require tube thoracostomy, the morbidity and complications are greater for those with blunt chest injury as opposed to penetrating.
Eddy et al.[47]	1989	Empyema thoracis in patients undergoing emergent closed tube thoracostomy for thoracic trauma. *Am J Surg*. 1989;157:494–497.	III	(n = 117) Retrospective study identifying incomplete drainage of pleural space to be the most significant factor associated with development of empyema. Bacteriology of empyema mostly related to gram-positive organisms.
Schermer et al.[49]	1999	A prospective evaluation of video-assisted thoracic surgery for persistent air leak due to trauma. *Am J Surg*. 1999;177:480–484.	II	(n = 39) VATS is as safe as nonoperative management in patients with persistent, posttraumatic air leak (>3 d) who are otherwise ready for discharge. VATS decreases the number of chest tube days and hospital length of stay in this patient population. VATS with resection of injury and pleural abrasion should be considered for any patient with persistent, posttraumatic air leak.
Carrillo et al.[48]	1998	Thoracoscopy in the management of posttraumatic persistent pneumothorax. *J Am Coll Surg*. 1998;186:636–639; discussion 639–640.	III	(n = 11) Persistent posttraumatic pneumothorax (at 48 h despite chest tube) can be treated successfully with VATS with stapled resection of injury. Etiology was identified in 10 of 11 patients. The remaining patient underwent chemical pleurodesis. All patients had resolution of air leak and were able to be controlled with minimal pain medications. VATS is effective in treating persistent posttraumatic pneumothorax.

3. Primary VATS of stable penetrating thoracoabdominal wounds is safe and effective for the diagnosis and management of selected diaphragm and pulmonary injuries (Level 2).

Management of Massive Hemothorax

1. Patient physiology should be the primary indications for surgical intervention rather than absolute numbers of initial or persistent output (Level 2).
2. 1500 mL via a chest tube in any 24-hour period regardless of mechanism should prompt consideration for surgical exploration (Level II).

Management of Hemothorax

1. All hemothoraces, regardless of size, should be considered for drainage (Level 3).
2. Attempt of initial drainage of hemothorax should be with a tube thoracostomy (Level 3).
3. Persistent retained hemothorax, seen on plain films, after placement of a thoracostomy tube should be treated with early VATS, not a second chest tube (Level 1).
4. VATS should be done in the first 3 days to 7 days of hospitalization to decrease the risk of infection and conversion to thoracotomy (Level 2).
5. Intrapleural thrombolytic may be used to improve drainage of subacute (6-day to 13-day duration) loculated or exudative collections, particularly patients where risks of thoracotomy are significant (Level 3).

Management of Occult Pneumothorax

1. Occult pneumothorax, those not seen on chest radiograph, may be observed in a stable patient regardless of positive pressure ventilation (Level 3).

3. Scoring systems are not accurate in predicting which patients will need a tube thoracostomy for occult pneumothorax (Level 3).
4. A persistent air leak on postinjury day 3 should prompt a VATS evaluation (Level 2).

SCIENTIFIC FOUNDATION

Historical Background

Hemorrhage from or within the chest has been detailed in numerous medical writings dating back to ancient times. Although lesser forms of trauma were commonly treated in the ancient physician's daily practice, major injuries, especially those to the chest, were difficult to treat and often lethal.

By the 18th century, treatment for hemothorax was advocated; however, surgeons disagreed as to its form. A number of surgeons, including John Hunter in 1794, advocated the creation of an intercostal incision and drainage of the hemothorax. Those of the opposing view recommended closure of chest wounds without drainage. Although Hunter's method was effective in evacuating the hemothorax, the morbidity associated with the creation of an iatrogenic pneumothorax as a result of the procedure was significant. The risks associated with wound closure or conservative management included the possibility that empyema with sepsis would develop or that persistent trapped lung with permanent reduction of pulmonary function would result.

Observing the advantages and dangers of both forms of therapy, Guthrie, in the early 1800s, proposed early evacuation of blood through an existing chest wound. He asserted that if bleeding from the chest persisted, the wound should be closed in the hope that existing intrathoracic pressure would halt the bleeding. If the desired effect was accomplished, he advised that the wound be reopened several days later for the evacuation of retained clotted blood or serous fluid.

By the 1870s, early hemothorax evacuation by trocar and cannula or by intercostal incision was considered standard practice. Not long after this, underwater seal drainage was described by a number of different physicians. This basic technique has remained the most common form of treatment for hemothorax and other pleural fluid collections to this day.[3]

Diagnostic Evaluation of Hemothorax

Plain Films

The upright chest radiograph remains the primary diagnostic study in the acute evaluation of hemothorax. In the normal unscarred pleural space, a hemothorax is noted as a meniscus of fluid blunting the costophrenic angle or diaphragmatic surface and tracking up the pleural margins of the chest wall when viewed on the upright chest X-ray (CXR) film. As much as 400 mL to 500 mL of blood is required to obliterate the costophrenic angle as seen on an upright chest radiograph. In the acute trauma setting, the portable supine chest radiograph may be the first and only view available from which to make definitive decisions regarding therapy. The presence and size of a hemothorax is much more difficult to evaluate on supine films. As much as 1,000 mL of blood may be missed when viewing a portable supine CXR film. CXR has been found to be a poor predictor of patients requiring a VATS.[4]

Ultrasound

Trauma ultrasonography is used at some trauma centers in the initial evaluation of patients for hemothorax. One drawback of ultrasonography for the identification of traumatic hemothorax is that associated injuries readily seen on chest radiographs in the trauma patient, such as bony injuries, widened mediastinum, and pneumothorax, are not readily identifiable on chest ultrasonography. One advantage is the ability to detect pneumothorax more quickly in circumstances than plain films or CT would allow.[5] There continues to be a push to move ultrasound application to the intensive care unit (ICU) bedside to allow the intensivist to gain information without the burden of transporting patients. Ultrasound has reliably been shown to document the presence and volume of a pleural effusion. Intensivists have also attempted to use it to document pulmonary contusions with less success.[6,7] The current role of ultrasound in the ICU would appear to be when CT is unavailable or if the patient's physiology would not permit transport. The sensitivity and specificity are not superior to CT, and ultrasound does not offer a global picture of the thoracic anatomy.

Computed Tomography

Computed tomographic scan is a highly accurate diagnostic study for pleural fluid or blood. In the initial trauma setting, it does not necessarily have a primary role in the diagnosis of hemothorax and pulmonary contusion but is complementary to chest radiography. CT may actually be too sensitive in identifying clinically nonsignificant injuries.[8] This is an area of controversy not addressed in this Practice Management Guidelines. Because many victims of blunt trauma do undergo a chest and/or abdominal computed tomographic scan evaluation, hemothorax not seen on initial chest radiographs might be identified and treated.

Computed tomographic scan may also be value later in the course of the chest trauma for localization and quantification of any retained collections of clot and potential empyema within the pleural space. Numerous authors have suggested the need for further evaluation of persistent abnormal plain film findings or patients who fail to progress on the ventilator with CT.[9,10] Early, aggressive investigation of potential hemothorax can lead to the discovery of pathologic processes that can have an effect on patient's short and long-term recovery. Conversely, delaying further imaging may severely limit the physicians options for operative approaches.[9]

Primary Video-Assisted Thoracoscopy

Surgeons continue to explore the utility of VATS procedures for both primary diagnosis and therapy. In stable trauma patients with thoracic injuries, proceeding directly to VATS to identify injuries even before placement of a chest tube has been shown to be safe.[11,12] It is unknown based on the current literature if such a course of actions leads to shorter hospitalizations or fewer complications than tube thoracostomy alone. In the case of thoracoabdominal wounds, VATS can identify injuries missed on CT.[11,13]

Evaluation of the Evidence Supporting Early Operative Management for Massive Hemothorax

Thoracotomy is the procedure of choice for surgical exploration of the chest when massive hemothorax or persistent bleeding is present. Traditional criteria indicating the necessity to proceed with urgent thoracotomy are as follows:

- More than 1,500 mL of blood immediately evacuated by tube thoracostomy.
- Persistent bleeding from the chest, defined as 150 mL/h to 200 mL/h for 2 hours to 4 hours.
- Persistent blood transfusion is required to maintain hemodynamic stability.

These criteria were developed from expert opinion and not from prospective trials. In fact, submitting these criteria to prospective study would be difficult and unethical. Instead, the evidence to supporting indications for urgent thoracotomy based on tube thoracostomy output is derived from a variety of descriptive retrospective studies over the past 30 years. In these case series of mostly penetrating chest injuries, surgeons merely contrasted patients who "required" urgent thoracotomy with those patients who did not.[14–19] The military experience in World War II and Vietnam also helped to establish many of the indications for penetrating trauma to the chest.[19] Indications for urgent thoracotomy were based on physiology, a premise is still recommended, and minimum chest tube output amounts (i.e., 800 mL) which has inflated over time. The numbers for both initial output and persistent output have continued to increase as surgeons have taken more liberties over time. These early studies suffered from a lack of statistical power or ability to differentiate from a control group. Mansour et al.[20] attempted to establish a difference between penetrating and blunt injury observing that patients with blunt trauma rarely required urgent intervention based on chest tube output. They suggested that physiology and refractory shock rather than absolute volumes of output should be the indication for urgent thoracotomy. Karmy-Jones et al.[21] attempted to define the indications for urgent thoracotomy more clearly in a multicenter retrospective trial. They advocated thoracotomy when total chest tube output exceeded 1,500 mL in a 24-hour period regardless of the mechanism of injury. In this series, mortality increased linearly with chest tube output and the mortality at 1,500 mL was three times greater than at 500 mL. This finding lends validity to the proposed volume of 1,500 mL as an indicator for thoracotomy, but this report did not elaborate on the coexisting physiologic parameters that were present at different chest tube outputs.

Evaluation of the Evidence Supporting Early Operative Management for Retained Hemothorax

Tube thoracostomy drainage is the primary mode of treatment for hemothorax. In adult patients, large-bore chest tubes, usually 36 F to 42 F, is the traditional means used to achieve adequate drainage in adults.

Surgeons debate how large a hemothorax can be safely observed. Billelo et al.[22] contended that collections <1.5 cm on CT can be observed, but their report is severely limited by a lack of long-term follow-up to determine the true risk of fibrothorax or empyema. Others contend that empyema can be prevented entirely by evacuation of hemothorax in the first 7 days.[23,24] Conversely, radiographically apparent hemothorax after chest tube placement leads to a 33% rate of empyema.[25] Most authors have used the estimated volume of 500 mL, the amount needed to be seen on plain X-ray, as the entry point into studies looking at evacuation of retained hemothorax.[4,23,26] It is unknown whether complications of retained hemothorax including empyema and fibrothorax could be decreased by a more aggressive approach.

After tube thoracostomy is performed, a repeat chest radiograph should always be obtained. This helps identify chest tube position, helps determine completeness of the hemothorax evacuation, and may reveal other intrathoracic pathology previously obscured by the hemothorax. The presence of retained hemothorax on postplacement CXR has been shown to be an independent predictor of the development of an empyema in 33% of patients.[25] If drainage is incomplete as visualized on the postthoracostomy chest radiograph, placement of a second drainage tube should be discouraged. In a prospective randomized trial, Meyer et al.[27] showed that patients who had retained hemothorax on plain films 72 hours after initial chest tube output benefited from early VATS instead of a second chest tube. Patients undergoing VATS had significantly shorter duration of chest tube drainage, fewer days in the hospital after the procedure, and lower hospital costs than putting in a second chest tube. In addition, 10 of the 24 patients who underwent a second chest tube required surgical intervention later in their hospital stay.

Evaluation of the Evidence for the Timing of Surgical Intervention

The timing of surgical intervention for retained hemothorax continues to be controversial. VATS performed early in the patient's hospital course may be associated with less morbidity.[12,23,27,28] Early VATS (before day 3) results in statistically significant reduction in operative difficulty, contamination/infection of clot, and hospital length of stay compared with those performed later.[26] There seems to be no absolute contraindication to attempting VATS in a delayed fashion as successful procedures have been performed as far out as 14 days.[29] The surgeon should be prepared and counsel the patient that conversion to thoracotomy becomes more likely after 5 days.[26,28]

Operative Approach

Successful thoracoscopic surgery for retained hemothorax is being reported with greater frequency. Several surgeons have made the claim that VATS has distinct advantages over open thoracotomy for the evacuation of retained hemothorax and empyema.[28,30] Benefits named include fewer pulmonary complications, shorter time to recovery, and less long-term disability.[31] Infectious complications have been shown to be higher in thoracotomy.[23]

Fibrinolytics

In an effort to move to a nonoperative method of evacuating retained hemothorax, authors have proposed using various fibrinolytics. Some authors have been able to document clot evacuation using intrapleural fibrolytics.[32,33] Although these studies have demonstrated safety, it is difficult to gauge the contribution of the fibrolytic agent made in the success of the evacuation rather than well-placed drains. Oguzkaya et al.[34] showed that VATS is a more effective procedure than intrapleural streptokinase for the management of posttraumatic retained hemothorax with VATS patients having a statistically significant shorter hospital stay and decreased need for additional therapy. Currently, fibrinolytic agents would have to be seen as a second-line agent behind surgical intervention when the risks of surgery are too great to the patient's overall outcome.

Evaluation of the Evidence Supporting Management for Occult Pneumothorax

As computed tomographic scan is being performed more commonly in the evaluation of trauma patients, many injuries are now identified, which had previously not been detected. Occult pneumothorax, usually defined as a pneumothorax that is seen on chest CT but not on plain films, is being diagnosed more frequently.[35,36] Some authors have argued that some of these occult pneumothoraces are missed[37] rather than invisible injuries. Retrospective data would support that placing a chest tube will lead to longer hospital stays and longer ICU stay.[38] The issue is trying to determine the lesions that will progress and that can safely be observed. Wolfman et al.[39] used the location of the pneumothorax to predict which would fail observation and found only very small anterior pneumothorax could be observed with a high rate of success (81%). De Moya et al.[40] attempted to categorize pneumothoraces using a scoring system based on size and location in a retrospective analysis.

Another key question has been the factor of positive pressure ventilation. Many authors have excluded all patients who were to undergo positive pressure ventilation[35,41] while others included them in the analysis.[38] Enderson et al.[42] attempted to answer the question in a prospective fashion. They found that patients with pneumothoraces treated with observation who underwent positive pressure ventilation developed an unacceptable rate of complications with 3 of the 15 patients on positive pressure developing a tension pneumothorax. Conversely, Brasel et al.[43] found the opposite to be true in a prospective randomized study. They found no increase in complications regardless of whether chest tube or observation was chosen. Notably, two of the three patients in the observation arm who required a chest tube for progression of the pneumothorax did so after being placed on positive pressure ventilation. Both studies suffered from low numbers but would support the notion that the majority of patients with occult pneumothoraces will not have progression regardless of the presence of positive pressure ventilation.

Evaluation of the Evidence Supporting Management of Posttraumatic Empyema

Approximately 3% of patients with chest trauma will develop a posttraumatic empyema. This number is slightly higher in penetrating trauma.[44,45] Many authors have attempted to define the risk factors for posttraumatic empyema. There are consistent risk factors that appear in multiple studies including persistent pleural effusion/hemothorax and the duration of a tube thoracostomy.[44] In addition, the placement of multiple tubes has been associated in a prospective[27] and retrospective[46] fashion to lead to empyema. These findings have lead authors to recommend complete evacuation of the chest following trauma to avoid the morbidity of empyema.[47]

Other Indications for VATS in the Trauma Field

There is also data to support the use of VATS for other indications. In addition to its value in diagnostic evaluation and evacuation of retained hemothorax, authors have described its value in treating persistent pneumothorax/air leak. The safety and high success rate in identifying the causative lesion has been documented for this indication.[48] Schermer et al.[49] found that in patients with a persistent air leak, undergoing a VATS at day 3 had shorter hospital stays and less days with a chest tube. Given the data concerning increased chest tube days and empyema risk, one could hypothesize that this might also decrease late complications.

Summary

To summarize, plain films are used a screening tool, but additional imaging in the form of CT is needed in any patient that has persistent radiographic abnormalities after placement of simple tube thoracostomy. The physician should attempt to clear the chest cavity of all retained hemothorax as early in the hospital course as the patient's physiology will allow. The preferred methods of this would be a VATS over a second chest tube. VATS can be attempted in the first 5 days with a low conversion rate to thoracotomy, but there is a decreasing success rate after this time period. Surgery outside of this initial window does not preclude attempting a thoracoscopic approach for retained hemothorax or for empyema but should be undertaken with both the surgeons and patient's expectations for an increased possibility of open thoracotomy. The decision to perform early evacuation of retained hemothorax with VATS technology is likely to greatly diminish the number of patients who develop the sequelae of empyema and fibrothorax. Although it adds an operative procedure to the patient's management, this approach provides definitive treatment, while avoiding the morbidity of a formal thoracotomy, and decreases total hospital stay when compared with more conservative management methods.

REFERENCES

1. Manlulu AV, Lee TW, Thung KH, Wong R, Yim AP. Current indications and results of VATS in the evaluation and management of hemodynamically stable thoracic injuries. *Eur J Cardiothorac Surg.* 2004;25:1048–1053.
2. Richardson JD, Miller FB, Carrillo EH, Spain DA. Complex thoracic injuries. *Surg Clin North Am.* 1996;76:725–748.

3. Rusch VW, Ginsberg RJ. Chest wall, pleura, lung and mediastinum. Schwartz SI, ed. *Principles of Surgery.* New York, NY: McGraw-Hill; 1999;667–790.
4. Velmahos GC, Demetriades D. Early thoracoscopy for the evacuation of undrained haemothorax. *Eur J Surg.* 1999;165:924–929.
5. Soldati G, Testa A, Pignataro G, et al. The ultrasonographic deep sulcus sign in traumatic pneumothorax. *Ultrasound Med Biol.* 2006;32:1157–1163.
6. Rocco M, Carbone I, Morelli A, et al. Diagnostic accuracy of bedside ultrasonography in the ICU: feasibility of detecting pulmonary effusion and lung contusion in patients on respiratory support after severe blunt thoracic trauma. *Acta Anaesthesiol Scand.* 2008;52:776–784.
7. Soldati G, Testa A, Silva FR, Carbone L, Portale G, Silveri NG. Chest ultrasonography in lung contusion. *Chest.* 2006;130:533–538.
8. Kwon A, Sorrells DL Jr, Kurkchubasche AG, Cassese JA, Tracy TF Jr, Luks FI. Isolated computed tomography diagnosis of pulmonary contusion does not correlate with increased morbidity. *J Pediatr Surg.* 2006; 41:78–82.
9. Watkins JA, Spain DA, Richardson JD, Polk HC Jr. Empyema and restrictive pleural processes after blunt trauma: an under-recognized cause of respiratory failure. *Am Surg.* 2000;66:210–214.
10. Velmahos GC, Demetriades D, Chan L, et al. Predicting the need for thoracoscopic evacuation of residual traumatic hemothorax: chest radiograph is insufficient. *J Trauma.* 1999;46:65–70.
11. Divisi D, Battaglia C, De BB, et al. Video-assisted thoracoscopy in thoracic injury: early or delayed indication? *Acta Biomed.* 2004;75:158–163.
12. Liu DW, Liu HP, Lin PJ, Chang CH. Video-assisted thoracic surgery in treatment of chest trauma. *J Trauma.* 1997;42:670–674.
13. Paci M, Ferrari G, Annessi V, de FS, Guasti G, Sgarbi G. The role of diagnostic VATS in penetrating thoracic injuries. *World J Emerg Surg.* 2006;1:30.
14. Kish G, Kozloff L, Joseph WL, Adkins PC. Indications for early thoracotomy in the management of chest trauma. *Ann Thorac Surg.* 1976;22:23–28.
15. Siemens R, Polk HC Jr, Gray LA Jr, Fulton RL. Indications for thoracotomy following penetrating thoracic injury. *J Trauma.* 1977;17: 493–500.
16. Mattox KL. Thoracic injury requiring surgery. *World J Surg.* 1983;7: 49–55.
17. Reul GJ Jr, Beall AC Jr, Jordan GL Jr, Mattox KL. The early operative management of injuries to great vessels. *Surgery.* 1973;74:862–873.
18. Oparah SS, Mandal AK. Operative management of penetrating wounds of the chest in civilian practice. Review of indications in 125 consecutive patients. *J Thorac Cardiovasc Surg.* 1979;77:162–168.
19. McNamara JJ, Messersmith JK, Dunn RA, Molot MD, Stremple JF. Thoracic injuries in combat casualties in Vietnam. *Ann Thorac Surg.* 1970;10:389–401.
20. Mansour MA, Moore EE, Moore FA, Read RR. Exigent postinjury thoracotomy analysis of blunt versus penetrating trauma. *Surg Gynecol Obstet.* 1992;175:97–101.
21. Karmy-Jones R, Jurkovich GJ, Nathens AB, et al. Timing of urgent thoracotomy for hemorrhage after trauma: a multicenter study. *Arch Surg.* 2001;136:513–518.
22. Bilello JF, Davis JW, Lemaster DM. Occult traumatic hemothorax: when can sleeping dogs lie? *Am J Surg.* 2005;190:841–844.
23. Heniford BT, Carrillo EH, Spain DA, Sosa JL, Fulton RL, Richardson JD. The role of thoracoscopy in the management of retained thoracic collections after trauma. *Ann Thorac Surg.* 1997;63:940–943.
24. Fabbrucci P, Nocentini L, Secci S, et al. Video-assisted thoracoscopy in the early diagnosis and management of post-traumatic pneumothorax and hemothorax. *Surg Endosc.* 2008;22:1227–1231.
25. Karmy-Jones R, Holevar M, Sullivan RJ, Fleisig A, Jurkovich GJ. Residual hemothorax after chest tube placement correlates with increased risk of empyema following traumatic injury. *Can Respir J.* 2008;15:255–258.
26. Vassiliu P, Velmahos GC, Toutouzas KG. Timing, safety, and efficacy of thoracoscopic evacuation of undrained post-traumatic hemothorax. *Am Surg.* 2001;67:1165–1169.
27. Meyer DM, Jessen ME, Wait MA, Estrera AS. Early evacuation of traumatic retained hemothoraces using thoracoscopy: a prospective, randomized trial. *Ann Thorac Surg.* 1997;64:1396–1400.
28. Morales Uribe CH, Villegas Lanau MI, Petro Sanchez RD. Best timing for thoracoscopic evacuation of retained post-traumatic hemothorax. *Surg Endosc.* 2008;22:91–95.
29. Navsaria PH, Vogel RJ, Nicol AJ. Thoracoscopic evacuation of retained posttraumatic hemothorax. *Ann Thorac Surg.* 2004;78:282–285.
30. Scherer LA, Battistella FD, Owings JT, Aguilar MM. Video-assisted thoracic surgery in the treatment of posttraumatic empyema. *Arch Surg.* 1998;133:637–641.
31. Ben-Nun A, Orlovsky M, Best LA. Video-assisted thoracoscopic surgery in the treatment of chest trauma: long-term benefit. *Ann Thorac Surg.* 2007;83:383–387.
32. Kimbrell BJ, Yamzon J, Petrone P, Asensio JA, Velmahos GC. Intrapleural thrombolysis for the management of undrained traumatic hemothorax: a prospective observational study. *J Trauma.* 2007;62: 1175–1178.
33. Pollak JS, Passik CS. Intrapleural urokinase in the treatment of loculated pleural effusions. *Chest.* 1994;105:868–873.
34. Oguzkaya F, Akcali Y, Bilgin M. Videothoracoscopy versus intrapleural streptokinase for management of post traumatic retained haemothorax: a retrospective study of 65 cases. *Injury.* 2005;36:526–529.
35. Hill SL, Edmisten T, Holtzman G, Wright A. The occult pneumothorax: an increasing diagnostic entity in trauma. *Am Surg.* 1999;65:254–258.
36. Ball CG. 2005 Incidence, risk factors, and outcomes for occult pneumothoraces in victims of major trauma. *J Trauma*. 2005;59:917–924; discussion 924–925.
37. Ball CG, Kirkpatrick AW, Fox DL, et al. Are occult pneumothoraces truly occult or simply missed? *J Trauma.* 2006;60:294–298.
38. Collins JC, Levine G, Waxman K. Occult traumatic pneumothorax: immediate tube thoracostomy versus expectant management. *Am Surg.* 1992;58:743–746.
39. Wolfman NT, Myers WS, Glauser SJ, Meredith JW, Chen MY. Validity of CT classification on management of occult pneumothorax: a prospective study. *AJR Am J Roentgenol.* 1998;171:1317–1320.
40. de Moya MA, Seaver C, Spaniolas K, et al. Occult pneumothorax in trauma patients: development of an objective scoring system. *J Trauma.* 2007;63:13–17.
41. Garramone RR Jr, Jacobs LM, Sahdev P. An objective method to measure and manage occult pneumothorax. *Surg Gynecol Obstet.* 1991; 173:257–261.
42. Enderson BL, Abdalla R, Frame SB, Casey MT, Gould H, Maull KI. Tube thoracostomy for occult pneumothorax: a prospective randomized study of its use. *J Trauma.* 1993;35:726–729.
43. Brasel KJ, Stafford RE, Weigelt JA, Tenquist JE, Borgstrom DC. Treatment of occult pneumothoraces from blunt trauma. *J Trauma.* 1999;46:987–990.
44. Eren S, Esme H, Sehitogullari A, Durkan A. The risk factors and management of posttraumatic empyema in trauma patients. *Injury.* 2008;39:44–49.
45. Helling TS, Gyles NR III, Eisenstein CL, Soracco CA. Complications following blunt and penetrating injuries in 216 victims of chest trauma requiring tube thoracostomy. *J Trauma.* 1989;29:1367–1370.
46. Aguilar MM, Battistella FD, Owings JT, Su T. Posttraumatic empyema. Risk factor analysis. *Arch Surg.* 1997;132:647–650.
47. Eddy AC, Luna GK, Copass M. Empyema thoracis in patients undergoing emergent closed tube thoracostomy for thoracic trauma. *Am J Surg.* 1989;157:494–497.
48. Carrillo EH, Schmacht DC, Gable DR, Spain DA, Richardson JD. Thoracoscopy in the management of posttraumatic persistent pneumothorax. *J Am Coll Surg.* 1998;186:636–639.
49. Schermer CR, Matteson BD, Demarest GB III, Albrecht RM, Davis VH. A prospective evaluation of video-assisted thoracic surgery for persistent air leak due to trauma. *Am J Surg.* 1999;177:480–484.