JOINT TRAUMA SYSTEM CLINICAL PRACTICE GUIDELINE (JTS CPG)

Wartime Thoracic Injury (CPG ID:74)

The goal of this CPG is to provide guidance on the diagnosis, initial treatment, and surgical management of thoracic injuries in the deployed or operational environment.

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BACKGROUND

Thoracic injuries are present in 12 to 50% of civilian trauma patients.[1] Over 90% of these civilian injuries are due to a blunt mechanism, and less than 10% require surgical intervention.[2] In contrast, significant thoracic trauma is present in only 10% of combat-injured patients, but the great majority of cases are associated with penetrating mechanism.[3,4] The most common thoracic injuries are pneumothorax, pulmonary contusion, and chest wall trauma, whereas injuries to the lung or great vessels have the highest mortality rate.[3] Tube thoracostomy is indicated as an initial diagnostic and therapeutic intervention for the majority of patients with thoracic trauma. For more severe injuries, thoracotomy (primarily anterolateral), sternotomy, or other surgical approach may be indicated on an emergency basis.

ROLES OF CARE AND THORACIC INJURY

Each role of care has unique approaches to the management of thoracic trauma:

- **Role 1:** The focus is treatment or stabilization of immediate life-threatening thoracic injuries, such as airway obstruction, and tension pneumothorax. Follow the Tactical Combat Casualty Care guidelines for treatment of chest trauma.[5]
- **Role 2:** Care is focused on resuscitation and damage control surgical procedures. Tube thoracostomy placement is a critical diagnostic and therapeutic intervention. Anterolateral thoracotomy or sternotomy may be required for acutely bleeding patients.
- **Role 3:** Definitive surgical treatment should be attempted for most injuries, with the possible exception of complex tracheobronchial or great vessel injuries.
- **Role 4:** Definitive therapy.

Table 1. Summary Recommendations for the Management of Thoracic Injuries

Summary Recommendations for the Management of Thoracic Injuries
1. Tube thoracostomy is indicated as the initial therapeutic intervention for most patients with penetrating thoracic trauma, and for any patient with suspected significant pneumothorax/hemothorax. At the Role 1 level, needle decompression is indicated for suspected tension pneumothorax.
2. Intrapericardial cardiac or great vessel injury should be suspected in any patient with penetrating thoracic or upper abdominal trauma, and generally can be diagnosed using ultrasonography or surgical pericardial window.
3. Left anterolateral thoracotomy (resuscitative thoracotomy) is the incision of choice in any penetrating thoracic trauma patient who is in extremis or profoundly unstable, who loses vital signs immediately before arrival, or has an observed loss of vital signs. This should be combined with right tube thoracostomy or extension of the thoracotomy to a clamshell if a mediastinal or right chest injury is suspected.
4. For a patient with palpable pulses and penetrating chest wound with hemopericardium, sternotomy is usually the preferred initial incision. If the diagnosis of hemopericardium is uncertain, sternotomy should be preceded by subxiphoid pericardial window.
5. The management of suspected subclavian vascular injuries is complex and technically demanding, and may require a combination of sternotomy, anterior thoracotomy, and supra/infraclavicular incisions.
6. For patients with suspected esophageal perforation, tracheobronchial injury, or blunt great vessel injury, the initial focus should be on stabilization, temporary control and wide drainage, rather than definitive repair.
7. For unstable patients with significant combined thoracic and abdominal trauma, exploratory laparotomy should be combined with bilateral tube thoracostomy and trans-diaphragmatic pericardial window to allow for a complete assessment and treatment of major injury.
8. Patients undergoing surgical intervention for acute thoracic trauma should be approached in the supine position and prepped for multiple potential incisions with a low threshold for additional incisional exposure to control life-threatening injuries. Posterolateral thoracotomy is rarely indicated in the acute trauma setting.
9. Observation of a small pneumothorax is not appropriate for any patient undergoing prolonged transport. In cases where clinical or radiographic findings are equivocal, clinicians should err on the side of tube thoracostomy prior to transport.
10. In rare circumstances, the use of Extra-Corporeal Membrane Oxygenation may be needed in the setting of a complex thoracic injury resulting in severe hypoxia, hypercapnia, or heart failure. For ECMO referrals 24/7, contact (210) 916-ECMO/DSN (312) 429-ECMO (leave message if not answered immediately); alternate contact is SAMMC operator at (210) 916-2500/DSN (312) 429-2500.

DIAGNOSIS OF THORACIC INJURIES

As with all trauma patients, the evaluation of a patient with thoracic trauma begins with a determination of airway patency, adequacy of breathing, hemodynamic stability, and neurological status. Where available, ultrasound and chest X-ray are useful diagnostic adjuncts.

PNEUMOTHORAX, HEMOTHORAX

1. In a patient with thoracic trauma and a clinically patent airway who has rapid, inadequate, or labored respirations, the diagnosis of pneumothorax must be assumed until proven otherwise.

2. Absent or markedly decreased breath sounds in a patient with known thoracic trauma indicate the need for intervention without additional diagnostic testing. In addition to treating pneumothorax or hemothorax when present, tube thoracostomy may be diagnostic of these conditions based on a rush of air or blood after tube placement.

3. In a patient with normal hemodynamics and adequate oxygenation and ventilation, it is reasonable to confirm a pneumothorax by chest X-ray or ultrasound prior to tube thoracostomy.

TENSION PNEUMOTHORAX

1. Signs and symptoms of tension pneumothorax include severe or progressive shortness of breath or hemodynamic compromise in the setting of chest trauma.

2. Differentiating between a simple pneumothorax and a tension pneumothorax is based on the presence of hemodynamic effects (hypotension and decreased perfusion) in the latter condition. While a patient with thoracic trauma and a pneumothorax may present with multiple injuries and an alternate explanation for hypotension (such as cardiac tamponade, intraabdominal bleeding, or hemothorax), immediate needle or tube thoracostomy is the necessary first step in this scenario. In the case of a tension pneumothorax, this maneuver should have both diagnostic and therapeutic benefit.

3. Patients who are hypovolemic are more susceptible to the hemodynamic effects of tension pneumothorax.

OPEN PNEUMOTHORAX (SUCKING CHEST WOUND)

Open pneumothorax occurs when a defect in the chest wall is sufficiently large to impair effective air exchange (air will preferentially pass through the defect if larger than 2/3 the tracheal diameter). In the case of an open pneumothorax due to a large chest wall defect, the diagnosis will be clinically obvious on physical examination.

RIB FRACTURES, FLAIL CHEST

1. Rib fractures are a clinical diagnosis based on chest wall pain and point tenderness (with or without crepitus) in the setting of blunt or penetrating chest wall trauma.

2. Maintain a high index of suspicion for associated injuries (pulmonary contusion, pneumothorax, splenic or liver laceration, etc.).

3. Rib fractures are associated with pneumothorax, hemothorax, solid abdominal organ injury, and thoracic great vessel injury. Patients must be assessed for these associated injuries.

4. Flail chest may be diagnosed clinically by gross chest wall instability or paradoxical chest wall movement with respiration. Practically, the differentiation between rib fractures alone and a flail segment is not important, as the initial management is the same for both conditions. The morbidity of this type of injury is determined by the underlying pulmonary contusion which may impair gas exchange and the consequences of low lung volumes due to pain.

PULMONARY CONTUSION

1. Pulmonary contusion is most common with blunt trauma or blast injury.

2. Patients with pulmonary contusion may present with respiratory distress and reduced breath sounds on the injured side. Often, symptoms may not manifest immediately after injury. Chest X-ray may show patchy opacity(s). However, lung contusion is primarily a clinical diagnosis.

3. It can be difficult to differentiate between pulmonary contusion and pneumothorax when imaging is not available. In this scenario, if the patient is significantly symptomatic and does not improve with initial pain management, one must assume that pneumothorax is present, and tube or needle thoracostomy is indicated (particularly prior to transport).

CARDIAC TAMPONADE

1. For low-velocity penetrating injuries, the possibility of intra-pericardial cardiac or great vessel injury should be considered when there is penetrating trauma in the "box" defined by the space inferior to the clavicles, superior to the costal margin and medial to the mid-clavicular line.

2. With high velocity gunshot wounds and multiple penetrating blast fragment wounds, intra-pericardial damage is possible with any penetrating injury to the chest or upper abdomen.

3. Ultrasound assessment is a rapid, simple, and widely available tool to assess for significant hemopericardium, which indicates intra-pericardial injury in this setting. When a hemopericardium and hypotension co-exist in a patient with significant trauma (of any mechanism), no further diagnostic evaluation is indicated. However a negative pericardial ultrasound in penetrating chest trauma does not definitively rule out cardiac injury or pericardial blood as sometimes blood can drain from the pericardium into either the right or left chest if there is a hole in the pleural pericardium.

4. Classic physical exam findings of tamponade (distended neck veins, muffled heart sounds) are not reliable.

5. In a hypotensive patient undergoing exploratory laparotomy for penetrating abdominal injury, a trans-diaphragmatic pericardial window is a rapid means to evaluate for hemopericardium/tamponade.

GREAT VESSEL INJURY

1. Most combat-related great vessel injuries are fatal at the point of injury.

2. In some cases, particularly after major blunt trauma, a patient may present with a contained great vessel injury associated with a mediastinal hematoma. Although a widened mediastinum on plain chest X-ray may be suggestive of this injury, computed tomographic angiography is necessary for diagnosis. Other X-ray findings suggestive of great vessel injury include apical capping, tracheal deviation, wide paratracheal stripe, and downward deviation of the left main bronchus.

3. If a contained great vessel injury is suspected (mediastinal hematoma), such an injury is unlikely to acutely cause hypotension, and other causes of bleeding and hypotension should be sought.

ESOPHAGEAL PERFORATION

1. Esophageal perforation is a rare injury since the esophagus is protected in the posterior mediastinum. It may be suspected due to wound trajectory, and occurs most often in association with other penetrating injuries.

2. The diagnosis is commonly delayed and there should be high index of suspicion for this rare injury depending on mechanism of injury and fragment trajectories. The diagnosis may be suspected or confirmed after placement of a tube thoracostomy for a pleural effusion/hemothorax. Contents of the drainage may contain gastrointestinal contents.

3. Endoscopy, esophagram and/or computed tomographic (CT) scan can confirm the diagnosis.[6]

TRACHEOBRONCHIAL INJURIES

1. Penetrating proximal thoracic tracheobronchial injuries are rarely encountered due to their proximity to the great vessels and heart and subsequent lethality.

2. Diagnosis requires a high index of suspicion. The most common diagnostic signs are subcutaneous emphysema, pneumothorax and hemoptysis. Hoarseness and dysphonia are also common symptoms. Respiratory failure, the presence of a pneumothorax on chest X-ray, or a large air leak after tube thoracostomy are typical but non-specific findings.

3. If there is concern for a tracheobronchial injury, bronchoscopy should be performed with documentation of injury location and severity of injury.[7] The most common locations are in the distal trachea and proximal mainstem bronchi (within 2cm of the carina).

DIAPHRAGMATIC INJURIES

1. Diaphragm injuries commonly occur with high energy blunt trauma or penetrating thoracoabdominal injuries. Diaphragm injury should be considered in any thoracoabdominal penetrating trauma.

2. Auscultation of bowel sounds in the chest are highly suggestive of diaphragm injury but are rarely identified. On ultrasound exam, bowel may be seen in the chest. If there is concern for diaphragm injury, placement of a nasogastric tube with subsequent chest X-ray may confirm the diagnosis.

3. Small diaphragm injuries typically go undetected until direct examination of the diaphragm at the time of surgery (laparotomy, laparoscopy, thoracotomy, thoracoscopy). A high index of suspicion for diaphragm injury should be maintained for penetrating wounds to the left and right upper quadrant.

4. Diaphragm injuries may allow blood from the abdomen to be drawn into the negative pressure region of the chest. In this case, abdominal bleeding may present as a hemothorax.

INITIAL MANAGEMENT FOR THORACIC TRAUMA

The most important early priority in the treatment of a patient with thoracic trauma is assessment and treatment for injuries that may be immediately life-threatening (listed below). Tube thoracostomy is often indicated in a severely injured thoracic trauma patient, and will generally provide useful clinical information (and potential treatment) regardless of diagnosis.

TENSION PNEUMOTHORAX

1. Clinical suspicion of tension pneumothorax requires rapid treatment, either with needle decompression and subsequent tube thoracostomy, or with immediate tube thoracostomy. The choice between these two alternatives depends on the immediate availability of thoracostomy supplies, the patient's condition, and the experience of the person performing the procedure.

2. Needle decompression should be performed with a large bore (14 gauge or larger) 3.25in/8cm catheter in the 4th or 5th intercostal space, anterior axillary line. The alternate needle decompression site is the 2nd intercostal space at the mid-clavicular line (this is the primary site in children). Ensure dedicated needle decompression catheters are available with all emergency medical supplies; shorter (5cm) catheters used for venous access should be avoided as these will rarely penetrate the thoracic cavity and thus be ineffective.

3. Needle decompression alone is insufficient treatment for a pneumothorax and certainly ineffective for hemothorax and should in most cases be followed by placement of a tube thoracostomy as soon as feasible and safe. For stable patients who have undergone needle thoracostomy, evaluation with ultrasound or chest X-ray to assess the need for chest tube placement is appropriate.

4. If tube thoracostomy placement is delayed, providers should be prepared to repeat needle decompression as needed. Failure to improve after two needle decompressions most likely indicates an alternative diagnosis to pneumothorax (e.g., hemothorax, pulmonary contusion, and diaphragm injury).

5. Tube thoracostomy is performed using blunt/open technique, as described in Appendix A: Specific Thoracic Procedures.

OPEN PNEUMOTHORAX

Initial management with placement of a vented chest seal is reasonable until a tube thoracostomy can be performed.

MASSIVE HEMOTHORAX

1. The return of blood under pressure or a large volume of blood after tube thoracostomy indicates significant intra-thoracic injury.

2. Parenchymal lung injuries are the most common source of hemothorax, but massive hemothorax is likely due to a chest wall vascular injury, hilar pulmonary injury, or great vessel/cardiac injury.

3. With the immediate return of 1,500ml of blood after tube thoracostomy, thoracotomy is indicated. When the initial blood loss is below 1,500mL but significant bleeding continues (more than 200-250ml/hr and/or ongoing transfusion requirements), thoracotomy is also indicated.

4. In a patient with hemothorax due to penetrating injury and loss (or impending loss) of vital signs during or immediately prior to arrival, emergency resuscitative thoracotomy is indicated. (See the JTS Emergency Resuscitative Thoracotomy CPG.[8])

5. All patients with massive hemothorax will require damage control resuscitation and massive blood product transfusion (as outlined in respective CPGs).

6. Anterolateral thoracotomy is the best approach for massive hemothorax in an acute trauma patient. Although a posterolateral thoracotomy (ideally with lung isolation) may provide more optimal exposure, it presents limitations if additional incisional exposure is needed, may place the contralateral lung at risk for aspiration, and requires positioning maneuvers that may be challenging in a bleeding, acutely injured patient.

7. If after ipsilateral anterolateral thoracotomy, an intra-pericardial injury is encountered, conversion to a clamshell (bilateral thoracosternotomy) incision (described below) is indicated.

8. If a proximal left subclavian injury is encountered after left anterolateral thoracotomy, conversion to a trapdoor incision (described below) is an option to improve exposure.

9. In patients with penetrating trauma to the torso, a high suspicion must be maintained for bleeding in the other body cavities (opposite chest or abdomen).

10. Autotransfusion of shed pleural blood using a chest tube collection system and autotransfusion accessory can be considered.[9]

SUSPECTED CARDIAC OR GREAT VESSEL INJURY

1. Cardiac tamponade due to combat trauma requires immediate surgical intervention.

2. Fluid resuscitation may temporarily stabilize a patient in tamponade.

3. Pericardiocentesis (ultrasound guided, if available) combined with blood transfusion may help temporize a patient until arrival to a surgical capability,[10] recognizing that blood re-accumulation is likely.

4. Patients with suspected isolated great vessel injury (contained mediastinal hematoma) should receive pain control. If hemodynamics allow, this should be followed by a short-acting beta blocker (e.g., esmolol drip) to prevent tachycardia and hypotension.

RIB FRACTURES, FLAIL CHEST

1. In the absence of associated massive or ongoing bleeding into the pleural space, there is no role for surgical intervention for blunt chest wall injury. The major clinical significance of blunt chest wall injury in most cases is the potential for associated contusion of the underlying lung, which can have a major detriment on oxygenation and pulmonary status.

2. If physical exam or chest X-ray suggests the possibility of pneumothorax or hemothorax, immediate tube thoracostomy is indicated. In cases where clinical or radiographic findings are equivocal, clinicians should err on the side of tube thoracostomy prior to transport.

3. The treatment of rib fractures and flail chest includes pain control, close monitoring, oxygenation and ventilatory support as needed. Consider local and regional anesthetics in addition to systemic pain medications.

THORACIC TRACHEOBRONCHIAL INJURY

1. Initial management is aimed at ensuring adequate oxygenation and ventilation.

2. Tube thoracostomy is an important early intervention. If negative pressure suction through a tube thoracostomy worsens respiratory function due to a large air leak, the tube should be taken off of suction and placed to water seal. An alternative is connecting the chest tube to a one-way Heimlich valve.

3. If one chest tube does not re-inflate the lung, then a second chest tube should be placed.

4. Advancing an endotracheal tube into the right mainstem bronchus may help manage a significant tidal volume loss from left-sided injuries.

5. Other maneuvers, when available, include the use of bronchial blockers or double lumen endotracheal tube.

EXTRA CORPOREAL MEMBRANE OXYGENATION (ECMO)

1. ECMO may allow oxygenation for problematic injuries, and the DoD ECMO team should be contacted early if this is considered. For ECMO referrals 24/7 contact: (210) 916-ECMO/DSN (312) 429-ECMO (leave message if not answered immediately); alternate contact SAMMC operator at (210) 916-2500/DSN (312) 429-2500. DoD ECMO team members can also be reached by email at: usarmy.jbsa.medcom-bamc.list.ecmo@mail.mil.

2. For specific ECMO indications, refer to the JTS Acute Respiratory Failure CPG.[11]

SURGICAL MANAGEMENT OF THORACIC TRAUMA

1. A patient with thoracic trauma for whom acute surgical intervention is planned has a life-threatening injury by definition. Therefore, the patient should be positioned to maximize options for necessary interventions: supine with arms out, prepped from chin to knees and chest to elbows. Large-bore access (IV, IO, or central venous) should be in place, and the airway secured with a cuffed endotracheal tube.

2. For a patient with penetrating thoracic trauma who is in extremis or who is profoundly unstable, left anterolateral thoracotomy is the incision of choice and should be combined with right tube thoracostomy. This incision can be extended across the midline (as a “clamshell” incision) for suspected intra-pericardial injury or right pleural space bleeding.

3. For a patient with palpable pulses and penetrating chest wound with hemopericardium, sternotomy is usually the preferred initial incision. If the diagnosis of hemopericardium is uncertain (ultrasound is unavailable or equivocal but there is a high clinical suspicion for cardiac injury), sternotomy should be preceded by subxiphoid pericardial window.

4. The management of subclavian vascular injuries is challenging. For suspected proximal left subclavian arterial injury, left anterior thoracotomy in the third interspace is a safe initial incision for proximal control. Proximal control of the right subclavian artery is best achieved via median sternotomy. Intravascular balloon

occlusion is an additional option to obtain proximal control of injuries to the great vessels. Refer to the JTS Vascular Injury CPG for further details.[12]

5. For repair of a subclavian artery injury after proximal control, the left or right proximal to mid-subclavian artery can be exposed via a supraclavicular incision. An infraclavicular incision provides exposure to the more distal subclavian artery and the subclavian vein. For more complex subclavian vascular injuries, a trapdoor incision will provide maximal exposure.

6. Lung parenchymal injuries should be resected in a non-anatomic fashion if possible. Anatomic resections should be performed only if the entire lobe has been damaged and is not salvageable. Trauma pneumonectomy should only be performed with non-salvageable hilar injuries and is associated with an extremely high mortality.

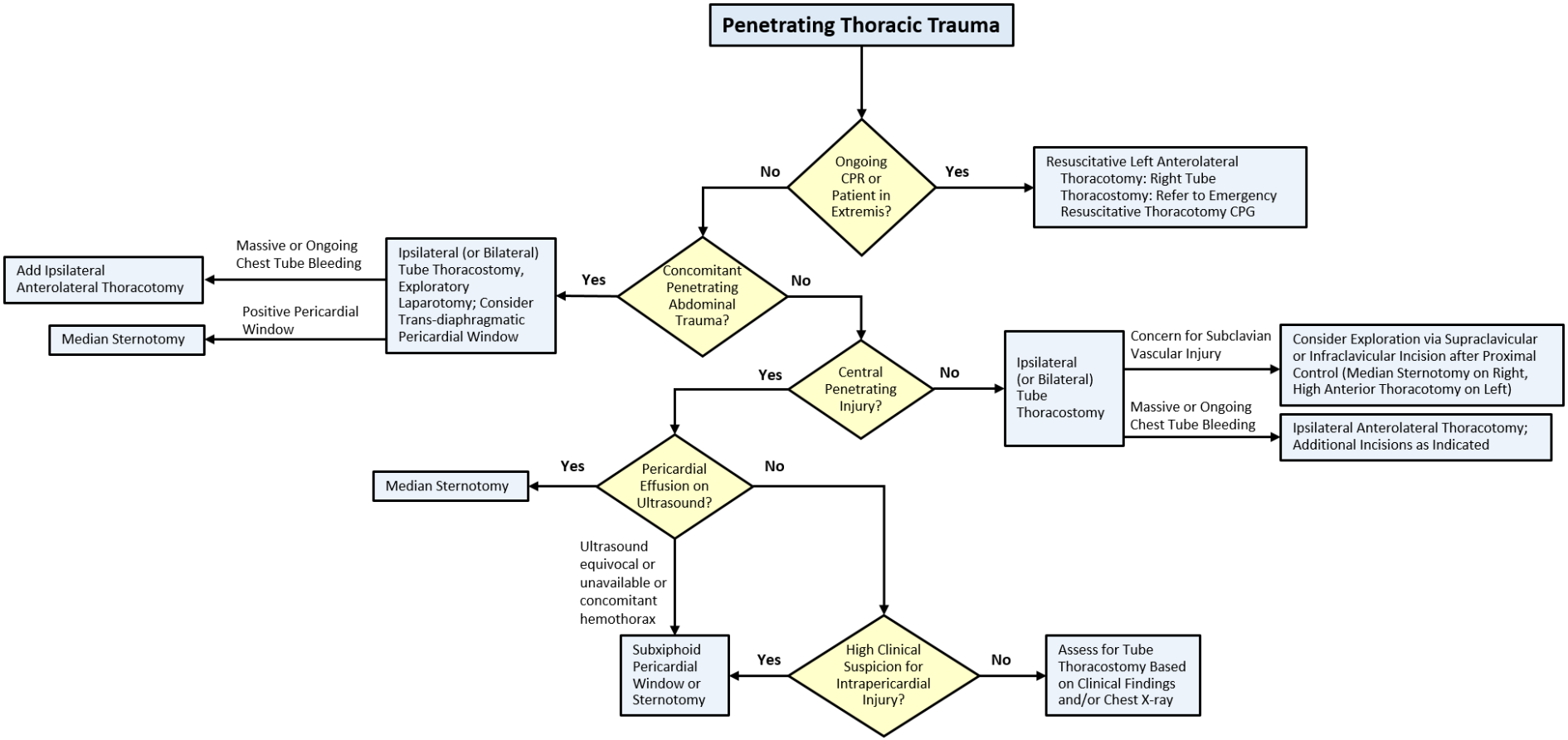
7. Posterolateral thoracotomy is rarely appropriate in the acute trauma setting. It is not appropriate in the damage control setting since it does not allow extension into frequently injured adjacent body cavities (abdomen, neck). It may be indicated for definitive repair of posterior mediastinal or lung injuries in a well-resuscitated patient after other injuries have been excluded or addressed.

8. In a patient with combined penetrating chest and abdominal trauma with hemodynamic instability, rapid insertion of bilateral chest tubes and midline laparotomy with pericardial window through the anterior diaphragm will allow for assessment of bleeding from all major body cavities. When needed, laparotomy can be extended to a sternotomy (for a positive pericardial window) or a separate anterolateral thoracotomy incision can be performed for ongoing pleural space hemorrhage. When the diaphragm is lacerated, an abdominal source of bleeding may present as bleeding into the chest cavity.

9. As described below, damage control philosophy and strategies apply to emergency thoracic surgery as well. Gauze packing and hemostatic adjuncts can help achieve temporary hemostasis of chest wall defects or injuries at the apex of the hemithorax.[13] Uncontrolled bleeding from the lung, pulmonary hilum or thoracic aorta can be packed as well.[14] Due to risk of iatrogenic tamponade, avoid packing of the pericardium.

10. Temporary chest closure can be considered after damage control procedures, or when there is concern for thoracic compartment syndrome due to massive resuscitation. Closure can be performed using a negative pressure vacuum closure or simply a large adhesive drape with a large-bore chest tube for drainage and suction.[14]

Figure 1. Algorithm for Surgical Management of Penetrating Thoracic Trauma



DAMAGE CONTROL TECHNIQUES [14-18]

1. The goals of damage control surgery, hemorrhage and contamination control, are the same regardless of location of injury. While hemorrhage control remains paramount in damage control thoracic surgery, contamination from the alimentary tract is infrequently encountered from esophageal injuries. Damage control surgery is a staged approach to life-threatening injury. As applied to thoracic surgery in the combat setting, damage control surgery consists of:

    a. Rapid transport from point of injury to a higher level of care and recognition of need for DCS (Role 2,3).

    b. Rapid control of hemorrhage and contamination (Role 2,3).

    c. Resuscitation with restoration of physiology in intensive care setting (Role 2-4).

    d. Return to surgery for completion of operative repairs (Role 3, 4).

    e. Definitive chest closure (Role 3, 4).

2. Packing may be used as a complement to hemostatic efforts for hemorrhage from the chest wall, lung, and vascular structures that have been repaired. When packing, no pressure should be placed on the heart or major, low-pressure vasculature (i.e. superior vena cava, inferior vena cava, pulmonary artery).

3. There is a stepwise increase in mortality with more extensive resections when lung injuries are encountered. Tractotomy and limited wedge resection are associated with higher survival rates compared to lobectomy. Trauma pneumonectomy carries the worse prognosis with mortality rates ranging from 50-100%.

4. Pulmonary tractotomy is performed by opening a through-and-through injury tract with a gastrointestinal anastomosis (GIA) stapler (or between straight vascular clamps) followed by control of the bleeding edges and/or air leaks with additional staplers or a running suture repair using a non-cutting needle.

5. Damage control surgical techniques to temporarily control massive hilar hemorrhage include: the hilar twist maneuver, temporary hilar clamping, and intra-pericardial control of the ipsilateral main pulmonary artery with a Rommel tourniquet. These techniques should be prioritized in an effort to defer or avoid pneumonectomy.

6. A pneumonectomy may be warranted in unstable patients with massive parenchymal destruction, massive hilar hemorrhage, or extensive bronchial disruption beyond repair.

7. Acute right heart failure is the most common cause of death after trauma pneumonectomy. Rapid increases in pulmonary vascular resistance/pressure lead to increased right ventricular end diastolic pressure followed by shifting of the interventricular septum leftward, which ultimately leads to left ventricular dysfunction. Principles of treatment center on judicious volume resuscitation, inotropic support, and reduction in pulmonary vascular resistance and right ventricular afterload. Early ECMO team contact is indicated.

8. Medications

    - Dobutamine and milrinone provide positive inotropic effects and serve as moderate pulmonary vasodilators, lowering right ventricular afterload while improving function.

    - Inhaled nitric oxide (20-40 ppm through the ventilator) is a pure pulmonary vasodilator that also improves right ventricular function by lowering right ventricular afterload. These medications are typically only available in the Role 4 setting or higher.

9. Cardiac injury may be associated with intra-cardiac valve or septum injury. Maintain a high-index of suspicion for injury to more than one cardiac structure or hidden, intra-cardiac injuries.

10. Cardiac bleeding after penetrating injury can be controlled initially with a skin stapler or Foley balloon.

11. Open cardiac massage should be performed by compressing the heart between two flat hands from the apex towards the outflow tracts.

12. Temporary chest closure should be considered in the damage control setting or if there is concern for thoracic compartment syndrome (increased intrathoracic pressure causing decreased venous return and decreased cardiac output). It is performed in a manner similar to that of temporary abdominal closure. Thoracostomy tubes (or mediastinal drains) and sterile surgical towels or gauze are placed, followed by placement of an occlusive dressing. Negative pressure is then applied to the temporary closure. A wound vacuum system can also be utilized in this setting. When a vacuum sponge closure is used, direct contact between the sponge and lung tissue should be avoided.

13. Timing for return for definite chest closure is determined by adequacy of resuscitation and normalization of physiologic parameters, as evidenced by reversal of triad of hypothermia, acidosis, and coagulopathy.

PERFORMANCE IMPROVEMENT (PI) MONITORING

Target Patient Population: All patients with chest injury of AIS code 2 or greater.

INTENT (EXPECTED OUTCOMES)

1. Tube thoracostomy will be used early in the management of any patient with penetrating chest trauma or suspected hemothorax, pneumothorax.

2. Needle decompression or tube thoracostomy is done for tension pneumothorax.

3. Ultrasound exam is used for patients with suspicion of cardiac injury, followed by sternotomy for exploration and repair if positive.

4. Patients with massive hemothorax > 1,500 ml are treated with thoracotomy at the first surgical capability.

5. Acute chest trauma requiring surgical intervention is treated by anterolateral thoracotomy, clamshell thoracotomy or median sternotomy as the appropriate initial approaches for acute chest trauma.

6. When chest and abdominal injury are suspected, the initial approach is tube thoracostomy (unilateral or bilateral depending on injury pattern) and laparotomy.

PERFORMANCE/ADHERENCE MEASURES

1. In any patient with penetrating chest injury, or with clinical or radiological diagnosis of hemo- or pneumothorax, a tube thoracostomy is placed prior to transport from the first surgical capability.

   The primary adherence measure is the percentage of patients with penetrating chest injury or diagnosed hemo- or pneumothorax who had a tube thoracostomy placed prior to transport from the first surgical capability.

2. In patients who receive needle decompression of the chest, the specific reason that tension pneumothorax was suspected is documented.

3. When pericardial tamponade is diagnosed by a surgical team, the initial incision is sternotomy or a specific reason for anterolateral or clamshell thoracotomy is documented (e.g., absent pulses).

4. For patients who undergo thoracotomy or sternotomy at the first surgical capability, the indication for the procedure is clearly documented.

5. In chest trauma patients with SBP < 90 or massive hemothorax > 1,500 ml or ongoing bleeding from chest tubes who undergo surgery, anterolateral thoracotomy or sternotomy is the initial incision.

   Within the subset of thoracic trauma patients with SBP < 90, a secondary adherence measure is the percentage of these patients who received anterolateral thoracotomy or sternotomy.

6. In the subset of patients with penetrating chest trauma and abdominal injury, the initial approach is tube thoracostomy (unilateral or bilateral depending on injury pattern) and laparotomy.

   Within these patients, a secondary adherence measure will be the percentage of patients with both a penetrating chest injury and abdominal injury who received a laparotomy and tube thoracostomy.

7. If ultrasound is available, E-FAST results are documented in all patients with significant chest injury (AIS code 2 or greater).

DATA SOURCES

- Patient Record
- Department of Defense Trauma Registry (DoDTR)

SYSTEM REPORTING & FREQUENCY

The above constitutes the minimum criteria for PI monitoring of this CPG. System reporting will be performed annually; additional PI monitoring and system reporting may be performed as needed.

The system review and data analysis will be performed by the Joint Trauma System (JTS) Director, JTS Program Manager, and the JTS Performance Improvement Branch.

RESPONSIBILITIES

It is the trauma team leader's responsibility to ensure familiarity, appropriate compliance and PI monitoring at the local level with this CPG.

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APPENDIX A: SPECIFIC THORACIC PROCEDURES [19,20]

TUBE THORACOSTOMY

1. Antibiotic prophylaxis (with gram positive coverage) should be given prior to tube thoracostomy to reduce infectious complications, provided this will not lead to a clinically significant delay in treatment. [21, 22]

2. There is no need to position the ipsilateral arm over the patient's head.

3. If time allows, prep the anterior and lateral chest on the affected side and administer antibiotics prior to incision.

4. Plan an incision at nipple level (male) or at the inframammary crease (female), centered over the anterior axillary line.

5. Infiltrate local anesthesia for a stable, awake patient.

6. After a generous transverse incision (2-4cm) into the sub-dermal fatty tissues, a curved clamp is used to bluntly dissect the muscle and soft tissue down to the level of the rib. A blunt clamp is then directed over the top of the rib into the pleural space. A rush of air or blood out of the chest will confirm a pneumothorax or hemothorax respectively.

7. The clamp should be spread within the chest wall, followed by digital palpation to confirm pleural space entry, and insertion of a chest tube in an apical and posterior direction.

8. For combat trauma injuries, a chest tube size of at least 24-french is appropriate. In the setting of known or suspected hemothorax, a tube size of at least 28-french is desirable to reduce the risk of tube occlusion from clotted blood.

9. After the tube is sutured securely to the skin, it should be attached to a closed drainage system. In the field setting, a one-way Heimlich valve may be used for temporary drainage.

SUBXIPHOID PERICARDIAL WINDOW

1. Only appropriate for a stable patient. Prep the patent widely for potential sternotomy and/or thoracotomy.

2. After a 4–6 cm vertical midline incision centered over the xiphoid process, dissect through the skin and fascia with knife or electrocautery.

3. The xiphoid process can then be grasped/lifted with a Kocher clamp or can be excised with a heavy scissor or with electrocautery to facilitate exposure.

4. Blunt dissection deep to the xiphoid, directed in a cephalad direction will expose fatty tissue over the anterior pericardium. If the diaphragm is encountered, the dissection should be redirected in a more cephalad direction.

5. After removing or dissecting this fatty tissue to expose the underlying whitish pericardium, the pericardium should be grasped with a forceps or clamp and sharply incised.

6. Any gross blood in the pericardial space indicates a positive pericardial window and mandates sternotomy.

7. Clear pericardial fluid indicates no injury. Occasionally, absence of pericardial fluid may indicate clot in the pericardium and further investigation, such as irrigation with warm saline, should be performed.

8. There is no need to close the pericardium after a negative pericardial window.

TRANS-DIAPHRAGMATIC PERICARDIAL WINDOW

1. If there is concern for intra-pericardial injury in a patient undergoing laparotomy for penetrating trauma, a trans-diaphragmatic pericardial window is rapid and highly effective in evaluating for such an injury.

2. The central tendinous portion of the diaphragm is grasped with clamps and incised vertically for 3-4cm to expose the underlying whitish fibrous pericardium. The pericardium is then grasped and sharply incised to assess the pericardial space for any gross blood. If there is none, the pericardium need not be re-approximated, although the diaphragm should be repaired with permanent suture.

MEDIAN STERNOTOMY

1. Indicated for suspected cardiac/great vessel injury based on ultrasound or positive pericardial window. In the setting of an obvious concomitant pleural space hemorrhage, anterolateral thoracotomy is preferable to sternotomy (with plans for conversion to a clamshell or trap door incision as needed to expose the heart or great vessels).

2. Does not provide for adequate exposure of left subclavian artery, distal aortic arch, or descending aorta, and provides for only limited exposure of the pleural spaces.

3. Begins with midline skin incision from sternal notch to just below xiphoid process, followed by sharp/blunt dissection both superiorly and inferiorly just deep to the sternum.

4. The sternum is divided in the midline with a sternal saw or Lebsche knife.

5. Bone wax can be used to decrease bleeding on the cut edges of the sternum, and cautery should be used to control bleeding from the sternal periosteal edges.

6. Both pleural spaces should be entered and opened widely where possible. This is facilitated by elevating the hemi-sternum, briefly holding ventilation, then opening the pleura overlying the lung with scissors or electrocautery. After the pleural space is entered, a suction device should be introduced to evacuate any blood.

7. After opening the pleural spaces, a standard chest retractor is placed. Mediastinal fat will be visible and should be divided in the midline down to the level of the fibrous pericardium. At the superior

limit of the incision, the innominate vein will be located within the mediastinal fat and care must be taken to avoid injury to this structure.

8. The pericardium is then grasped and opened sharply in the midline. A finger is then inserted into the pericardial space to allow opening the midline pericardium down to the level of the diaphragm and up to the level of the innominate vein using scissors or electrocautery. The pericardium should then be opened laterally in either direction along the diaphragm to facilitate exposure.

9. Heavy sutures should be placed in the pericardial edges on both sides then tied under tension to the skin edges or secured under tension to clamps overlying the chest wall. These sutures will minimize interference from the ventilating lungs and facilitate exposure of the heart and great vessels.

10. A sternotomy can be extended into a neck exploration incision if there is concern for carotid, jugular, or tracheal injury. For suspected proximal right subclavian vascular injury, sternotomy can be extended to a right supraclavicular incision. For suspected proximal left subclavian vascular injury, the incision can be extended into an anterolateral thoracotomy (or to a trap door incision, described below).

11. There is no indication to re-approximate the pericardium. For sternotomy closure, chest tubes are placed into the mediastinum (and into any open pleural space) and the sternum is re-approximated with a series of heavy interrupted wire sutures. Typically 3 wires are placed through each side of the manubrium, 1-2cm from the edge of the bone. For the sternal body, 3-4 additional wires are placed directly through the halves of the sternum or around the sternum through the costal interspaces. If wire is not available, large permanent suture (e.g., polyester suture, #2 or larger) is appropriate.

12. For a patient undergoing sternotomy in the setting of hemodynamic instability or ongoing massive resuscitation, temporary chest closure is advised in most cases. After placement of a laparotomy pad or wound vacuum sponge beneath the edges of both sides of the sternum to avoid laceration of the heart from movement, an occlusive adherent dressing is placed and chest tubes are placed to suction to evacuate any residual bleeding.

ANTEROLATERAL THORACOTOMY

1. Refer to JTS CPG on Emergency Resuscitative Thoracotomy.[8]

2. Useful for massive hemothorax; allows access to lung parenchyma, hilum, chest wall, and subclavian vessels.

3. For proximal left subclavian control, anterior thoracotomy in the 3rd interspace (above the 4th rib) will generally be adequate. See JTS Vascular Injury CPG.[12]

4. For general access to the pleural space, the 4th interspace is centered over the pulmonary hilum. Anterolateral thoracotomy at this level will provide access to most structures within the chest. The inframammary crease overlies the 5th rib medially in most patients, and therefore this crease provides a reasonable landmark for a 4th interspace anterolateral thoracotomy.

5. After incision of the skin and soft tissues parallel to the clavicle, from one fingerbreadth off of the sternum medially to the anterior or mid-axillary line laterally, divide the pectoralis major muscle in

the direction of its fibers, then bovie or cut the remaining fibrovascular tissues down to the top of the rib at the desired interspace.

6. Incise the intercostal muscle over the rib with electrocautery, then enter the pleural space using a blunt clamp, protect the lung, and divide the remaining muscle over the rib. Stop the intercostal incision about two finger-breadths lateral to the edge of the sternum to avoid the mammary vessels, but carry the intercostal incision as far laterally as safely possible to allow for maximal exposure.

7. Place a rib-spreader into the wound.

8. If additional exposure is needed, division of the medial costal cartilage will allow for additional rib spreading, or the incision can be extended to include a sternotomy and clavicular incision. (See description of trap door incision below.)

9. For thoracotomy closure, after the placement of chest tubes through separate stab incisions, "pericostal" sutures should be placed around the upper and lower ribs at the incision. Typically 3-5 sutures are needed, and any heavy suture (#1 or larger) may be used (although monofilament suture may have more of a tendency to dig into the intercostal muscle tissue when tied). Care must be taken to avoid the intercostal bundle with these sutures, by hugging the top of the upper rib but avoiding the bottom of the lower rib.

10. After chest tube and pericostal suture placement, the muscle is reapproximated with absorbable suture and the skin closed with staples.

CLAMSHELL INCISION (BILATERAL THORACOSTERNOTOMY)

1. Highly versatile incision, which provides adequate surgical access to virtually any structure in the thoracic cavity (with the exception of the esophagus and descending thoracic aorta).

2. Rarely appropriate as an initial incision (due to high level of incisional morbidity). Generally implemented after anterolateral thoracotomy if there is suspicion for bleeding into the contralateral pleural space, or heart or great vessel injury, or when there is inadequate exposure for an ipsilateral pleural space injury.

3. After anterolateral thoracotomy, divide the sternum transversely with a Lebsche knife, Gigli saw, or heavy shears. Both internal mammary vascular pedicles will need to be divided and controlled with ties or clips; bleeding from these may be unrecognized until adequate perfusion has been restored.

4. Create a contralateral thoracotomy (generally in the same intercostal space). Place bilateral rib spreading retractors. After initiating retraction, use scissors or cautery to release the sternum from the anterior pericardium to improve exposure.

SUPRACLAVICULAR INCISION

1. Most often indicated for suspected proximal or mid-subclavian vascular injury.

2. After an incision one fingerbreadth above and parallel to the clavicle from the midline to the distal clavicle, superficial fatty tissues, lymphatics and venous branches are divided and controlled to

expose the sternal and clavicular heads of the sternocleidomastoid muscle and the carotid sheath (located between the two muscle bellies).

3. After division of the sternocleidomastoid muscle heads just above their distal attachments, the proximal subclavian artery and its branches will be palpable and visible.

4. The anterior scalene muscle will be visible coursing anterior to the subclavian artery (posterior to the vein) and may need to be divided for adequate exposure. If this is the case, it is critical to free up and preserve the phrenic nerve, which runs directly along this muscle in a transverse direction.

5. The subclavian vein will be anterior and caudal to the artery.

6. For complex injuries, division of the clavicle (with a Gigli saw) or removal of part of the clavicle may facilitate additional exposure. Alternatively a supraclavicular incision can be combined with a separate infraclavicular exposure (for more distal subclavian access) or with a third interspace anterolateral thoracotomy (for control of the left subclavian artery at its origin).

INFRACLAVICULAR INCISION

1. If there is a known subclavian venous injury, an infraclavicular incision may provide for better exposure. This approach also provides better exposure of the more distal subclavian artery and its branches.

2. After an incision one fingerbreadth below and parallel to the clavicle from the mid-clavicular level to the lateral border of the pectoralis muscle, the pectoralis major muscle is opened transversely in the direction of its fibers.

3. The underlying clavipectoral fascia and pectoralis minor muscle are divided to expose the distal subclavian and axillary vessels. In this location, the artery will be posterior and cephalad to the vein, and the brachial plexus cords are closely associated with the artery.

TRAP DOOR INCISION

1. Combination of clavicular (or neck) incision, partial or complete median sternotomy and anterolateral thoracotomy (described above).

2. May be useful for combined penetrating cervical and mediastinal injuries or a severe injury to the proximal subclavian vessel/branches.

3. Rarely used as an initial incision due to high incisional morbidity (including risk of injuring the ipsilateral phrenic nerve, brachial plexus, thoracic duct, or other structures).

4. May be necessary for inadequate exposure after sternotomy and clavicular incisions (for right-sided injuries), or after left anterior thoracotomy and clavicular incisions (for left-sided injuries).

5. After supraclavicular incision, perform complete median sternotomy or partial median sternotomy to 4th intercostal space.

6. Incise the skin, soft tissues and muscle out to the anterior axillary line.

7. Divide the sternum laterally with sternal saw or a Lebsche knife, ligate the left internal mammary vessels, and continue the incision into the pleural space above the appropriate rib as an anterolateral thoracotomy.

THORACOABDOMINAL INCISION

1. Indicated for combined thoracic and abdominal injuries. May be particularly helpful for retrohepatic vena caval exposure.

2. May be created by continuing a resuscitative thoracotomy incision medially and inferiorly across the costal margin into the abdominal midline or by creating a separate midline abdominal incision after thoracotomy.

POSTEROLATERAL THORACOTOMY

1. Provides optimal exposure for esophagus, chest wall, descending thoracic aorta, and posterior hilum.

2. Rarely appropriate in the acute trauma setting, particularly in a multiply injured or acutely bleeding patient. This incision limits ability to treat concomitant injuries, limits anesthesia access for additional resuscitation lines, and limits ability to protect the spine. In addition, it generally requires ipsilateral lung isolation (using mainstem intubation, bronchial blocker, or double-lumen endotracheal tube), and potentially places the contralateral lung at risk for injury due to pooling of blood or secretions.

3. May be appropriate at Role 3 or higher level of care for evacuation of retained hemothorax or for addressing a complex lung injury or esophageal injury.

4. If beanbag is available, place on OR table; otherwise use large IV bags wrapped in towels placed in front of and behind the patient to secure him/her in a stable lateral position (in addition to strapping and taping the patient's hips and legs to the table).

5. Once the patient is in a secure lateral decubitus position, place a pillow between the legs, place the lower arm on an arm board straight at the elbow but flexed slightly at the shoulder, and place the higher arm in a flexed position at the elbow on a pillow or folded blankets.

6. After a wide prep and draping, mark mid-way between the medial border of the scapula and the vertebrae. Make a second mark one fingerbreadth below the inferior-most tip of the scapula. A posterolateral thoracotomy should connect these two marks in a gentle curve, then continue anteriorly parallel to the ribs.

7. After incising the skin and fatty subcutaneous tissue, divide the latissimus dorsi muscle transversely in the posterior aspect of the incision. The serratus anterior muscle, which runs anterior and deep to the latissimus, can be partially divided or mobilized and retracted anteriorly.

8. For most trauma situations, entering the chest right above the level of the tip of the scapula will provide an appropriate level for adequate exposure. After using electrocautery to divide the intercostal muscle along the top of the rib at this interspace, enter the pleural space with a blunt

clamp. Then pack the lung away with a moist laparotomy pad to allow extension of the intercostal incision widely along the top of the rib.

9. Encircling the lower rib at the posterior aspect of the incision with a right angle (taking care to avoid the intercostal bundle injury) will allow division of the rib with a rib shear to facilitate adequate retraction and exposure. However, this step is not mandatory. The creation of a "controlled fracture" by gradually opening a rib spreader will have the same desired effect of allowing adequate space to fit a hand comfortably into the pleural space.

10. Place a rib spreader.

11. For thoracotomy closure, after the placement of chest tubes through separate stab incisions, "pericostal" sutures should be placed around the upper and lower ribs at the incision. Typically 3-5 sutures are needed, and any heavy suture (#1 or larger) may be used (although monofilament suture may have more of a tendency to dig into the intercostal muscle tissue when tied). Care must be taken to avoid the intercostal bundle with these sutures, by hugging the top of the upper rib but avoiding the bottom of the lower rib.

12. After chest tube and pericostal suture placement, the muscle is reapproximated with absorbable suture and the skin closed with staples.

APPENDIX B: SPECIFIC THORACIC INJURY MANAGEMENT [19,20]

OPEN PNEUMOTHORAX

1. Treat by placing a chest tube through a separate incision and sealing the hole with an occlusive dressing. Complex chest wall defects may eventually require closure with mesh or muscle flap coverage at higher roles of care.

2. For patients with difficulty breathing, hypoxia or with large sucking chest wounds, maintain a low threshold to intubate prior to transport as positive pressure ventilation will overcome the effect of the sucking chest wound.

FLAIL CHEST

1. Generally associated with significant underlying lung contusion, which must be managed aggressively with supplemental oxygen and a low threshold for intubation and mechanical ventilation prior to air transport (or protracted ground evacuation).

2. In an awake patient with flail chest, pain control is critical to optimize pulmonary mechanics, although the use of intravenous narcotics must be balanced with the risk of respiratory depression.

3. Tube thoracostomy is appropriate prior to medical evacuation for any patient with flail chest, regardless of whether a pneumothorax or hemothorax is clinically evident.

4. There is a role for surgical stabilization of rib fractures (SSRF) in patients with flail chest or select patients with severely displaced rib fractures. SSRF should not be performed in a contaminated field, requires specialized equipment, and should only be done by surgeons familiar with the technique. For casualties undergoing further evacuation, SSRF should usually await Role 4 care. When performed, the original chest tube should be removed, the site cleaned and if possible excluded from the operative field and a new chest tube placed to reduce the risk of post-operative wound infection and osteomyelitis.

THORACIC VASCULAR INJURIES

1. The initial management of a thoracic vascular injury should be manual occlusion with a finger (for an artery) or a sponge stick (for a large vein). Temporary control can allow for additional resuscitation and exposure prior to attempted repair. For an aortic injury, a side-biting clamp may be placed (after aortic mobilization) for temporary control.

2. Repair of vessels should follow the principles detailed in the JTS CPG on Vascular Injuries, with shunting or repair by autogenous or synthetic grafts as indicated.

3. Incising the inferior pulmonary ligament mobilizes the lung to provide better exposure.

CARDIAC INJURIES

1. Isolated cardiac injuries are exposed by opening the pericardium and placing pericardial stay sutures.

2. Temporary control may be achieved with digital pressure, the use of a Foley catheter, or with skin staples.

3. For definitive repair, use pledgeted horizontal mattress sutures (2-0 or 3-0 polypropylene) on a large, tapered needle (MH or SH). Autologous pericardium can be used if commercial pledgets are not available. Sutures must be tied only to the point of hemostasis to avoid tearing potentially friable cardiac muscle. Take care to place sutures to avoid ligating coronary vessels.

4. Atrial injuries may be controlled with a side-biting clamp, followed by running closure with 2-0 or 3-0 polypropylene suture.

5. Temporary inflow occlusion (occluding the superior and inferior venae for brief intervals) may prove helpful in repair.

6. If distal coronary artery injuries are identified, they should be ligated to control the bleeding.

PARENCHYMAL LUNG INJURIES

1. Posterolateral thoracotomy is preferred for isolated lung injuries, but is only appropriate in a stable patient with adequate resuscitation and no other uncontrolled injuries. Anterolateral thoracotomy is more appropriate in the urgent or damage control setting.

2. Simple pulmonary parenchymal tears/bleeding may be repaired with absorbable suture on a tapered needle, or may be repaired with stapling of the lung parenchyma (with a GIA or TA middle-thickness staple load).

3. For deeper through-and-through injuries, a tractotomy may be performed by opening the injury tract with a GIA stapler or between straight vascular clamps, followed by running suture repair to control bleeding and air leaks from the exposed lung parenchyma.

4. For more severe/destructive lung injuries, non-anatomic partial lung resection with serial GIA stapler fires may be needed.

5. Hilar injuries or large parenchymal injuries with uncontrolled bleeding or massive air leak may require manual control of the hilum followed by hilar clamping for temporary control. Good communication with the anesthesia provider is essential to manage the resultant sudden decrease in lung volume and right heart strain. If repair is still not possible, pneumonectomy should be considered as a last resort due to the low survival associated with pneumonectomy in a trauma setting.

TRACHEOBRONCHIAL INJURIES

1. Airway control is the most important priority, and should be combined with tube thoracostomy(s). If after endotracheal intubation in a patient with a suspected airway injury, ventilation appears adequate and there is no other surgical indication, further intervention should be deferred to a higher role of care.

2. If there is difficulty with ventilation of the patient after tube thoracostomy due to a large air leak, the chest tube should be placed to water seal instead of suction.

3. When intervention is needed, median sternotomy (with cervical extension) provides exposure for the proximal and mid-trachea. Alternatively, cervical tracheal injuries can be approached from a collar incision. The distal trachea, carina, and proximal mainstem bronchi can only be visualized well via right posterolateral thoracotomy (with appropriate lung isolation). Injuries to the distal left mainstem bronchus or more distal left-sided bronchial tree generally require left thoracotomy for repair.

4. Tracheobronchial repair should employ absorbable suture (e.g., polydiaxanone or polyglactin), buttressed with pleural tissue or with intercostal or strap muscle wherever possible.

ESOPHAGEAL INJURIES

1. Most often will be identified during the course of exploration for other penetrating mediastinal injuries.

2. Although the resources for definitive repair may not be available in a deployed setting, the key principles in treatment are 1) adequate fluid resuscitation, 2) broad spectrum antibiotics, 3) debridement of any clearly non-viable tissue, 4) control of ongoing contamination, and 5) wide drainage.

3. For patients undergoing damage control procedures, chest tube drainage and a nasogastric tube placed above the level of injury are temporizing measures.

4. The preferred approach for intrathoracic esophageal injuries in a stable patient is posterolateral thoracotomy: right for the upper and mid-esophagus and left for the lower esophagus. Incising the inferior pulmonary ligament mobilizes the lung to provide better exposure.

5. Locate the injury by mobilizing the esophagus (aided by placement of a nasogastric or orogastric tube). Where possible, primary repair is preferred. After mobilizing the esophageal muscle above and below the mucosal injury to ensure complete visualization of the defect, the injury is repaired with a single layer or two layers of 3-0 absorbable sutures.

6. Buttress with muscle (intercostal or strap muscles, pericardium, diaphragm, etc.) should be used. Do not wrap the repair circumferentially. Drains should be placed near the repair.

7. If primary repair is not possible, wide drainage with proximal esophageal diversion should be considered. Resection should only be utilized in the setting of extensive tissue devitalization.

DIAPHRAGM INJURIES

1. Most often encountered at the time of abdominal exploration, all injuries of the diaphragm should be closed. If identified at the time of thoracotomy, one must evaluate for associated intra-abdominal injury. In the damage control setting, repair of diaphragm lacerations can be deferred until re-exploration.

2. The majority of injuries can be repaired with nonabsorbable running or interrupted sutures, 2-0 or larger. Mesh repair may be necessary but should be used with caution in the face of contamination.

3. Central tendon injuries of the pericardial diaphragm are rare, but when they occur they can cause tamponade physiology due to either cardiac herniation into the abdomen or herniation of the small or large intestine into the pericardium. Prior to closing central tendon tears, copiously irrigate the pericardial space with warm saline to wash out blood clots or enteric contents and carefully inspect the heart and pleural pericardium to ensure there are no other injuries or tears.[23]

CHEST WALL BLEEDING

1. Unlike bleeding from the low-pressure vascular system of the lung parenchyma, bleeding from intercostal arteries reflects systemic pressure and often will not resolve with tube thoracostomy alone.

2. Chest wall bleeding will typically be encountered after an anterolateral thoracotomy for massive or persistent chest tube bleeding. After assessing for non-chest wall bleeding sources, chest wall bleeding can almost always be temporized with manual pressure and packing. Temporary cessation of ventilation may allow for more accurate assessment and control of a chest wall bleeding site.

3. One must be cognizant of the subclavian vessels, which are closely associated with the anteroapical chest wall. If significant chest wall bleeding appears to be arising from this location, additional supra- or infraclavicular incisional exposure may be needed.

4. Once a direct site of chest wall bleeding is identified, it can be controlled with clips, suture, or cautery. Placing figure-of-eight pericostal sutures using a large, blunt needle (CT or MH) around the involved rib (proximal and distal to the bleeding site) may be effective.

5. Adequate visualization may require enlarging an incision, or making a separate counter-incision to improve the angle of approach.

6. In an unstable patient, chest wall bleeding can be temporized with packing using gauze or hemostatic adjuncts.

CONCOMITANT INJURIES

1. As described above, the management of patients with suspected combined thoracic and abdominal penetrating injury depends on initial stability.

2. In the face of hemodynamic collapse or loss of vital signs, emergency resuscitative thoracotomy is indicated for temporary control of thoracic bleeding, assessment for intra-pericardial bleeding, control of the descending thoracic aorta, and open cardiac massage.

3. In unstable patients with combined thoracic and abdominal injuries, or when CT scan is not available, midline laparotomy with tube thoracostomy (unilateral or bilateral, depending on injury pattern) and trans-diaphragmatic pericardial window is a safe approach.

4. For patients with combined injuries of the neck and chest, a cervical incision can easily be extended into a median sternotomy (for cardiac or great vessel injury or for proximal control of the right subclavian or either carotid artery), or into right or left supra- or infraclavicular incisions (for subclavian vascular injuries). In addition, a separate anterior or anterolateral thoracotomy may be indicated based on tube thoracostomy output or the need for proximal control of the left subclavian artery.

TRANS-MEDIASTINAL WOUNDS

1. Penetrating wounds which traverse the mediastinum via one or both pleural spaces represent a highly complex injury pattern, and every intra-thoracic structure is at risk. Intra-cardiac injuries (valve or septal injury) should also be suspected with this pattern of injury.

2. At the Role 2 level, care for suspected trans-mediastinal injury (after ensuring adequate airway and intravenous/intra-osseous access) should consist of bilateral tube thoracostomy and assessment for intrapericardial bleeding. Following the algorithms outlined above, surgical intervention may be appropriate. For unstable patients with suspected trans-mediastinal penetrating injury, a left anterior thoracotomy with right chest tube should be performed, with conversion to clamshell incision when needed to address intrapericardial or right chest bleeding.

3. At the Role 3 level with a hemodynamically stable patient, CT imaging should be performed to better estimate the missile trajectory(s), allowing a determination of structures at high risk for injury (keeping in mind that high-velocity weapons can inflict significant destruction outside the direct missile path). Using intravenous contrast with the CT allows assessment for vascular injuries without the need for invasive diagnostic angiography. Where available, esophagoscopy and bronchoscopy may be indicated if there is clinical or radiographic evidence of esophageal or tracheobronchial injury, respectively. Echocardiography can be utilized to assess for cardiac valvular injuries or septal defects. Definitive repair of these injuries can usually be delayed and should await Role 4 where the appropriate expertise and support is available.

RETAINED HEMOTHORAX

1. Retained hemothorax is defined as undrained blood after 72 hours of tube thoracostomy drainage. Except under extenuating circumstances (such as protracted delay for medical evacuation), the treatment of retained hemothorax should be deferred to Role 3 or higher where CT imaging is available.

2. If a retained hemothorax is suspected by a chest X-ray, CT imaging should be obtained. If the volume of undrained blood is estimated at greater than 300cc and if it is felt to be clinically significant, then additional drainage intervention should be considered.[24]

3. Additional drainage procedures may consist of an additional tube thoracostomy (low yield after 24 hours), video assisted thoracoscopic surgery (VATS) drainage, image-guided drainage catheters or instillation of intrapleural thrombolytics. None of these approaches has demonstrated clear superiority.[25] Thoracotomy may be required if less invasive interventions fail.

4. The intra-pleural administration of thrombolytics is an established but unproven adjunct to chest tube drainage for retained traumatic hemothorax. In the absence of active bleeding or other typical contraindications to thrombolytic therapy and in the absence of an ongoing air leak (which would contraindicate a period of clamping the chest tube), 50mg of altepase (tPA) in 100ml of normal saline may be administered into the pleural space via chest tube utilizing sterile technique. The chest tube should be clamped for several hours, then placed back on suction. This treatment can be repeated daily for up to three days. tPA will generally be available in a 1mg/ml concentration, such that the 50mg/50ml dose of tPA should be combined 1:1 with 50ml of sterile saline.

APPENDIX C: ADDITIONAL INFORMATION REGARDING OFF-LABEL USES IN CPGS

PURPOSE

The purpose of this Appendix is to ensure an understanding of DoD policy and practice regarding inclusion in CPGs of "off-label" uses of U.S. Food and Drug Administration (FDA)–approved products. This applies to off-label uses with patients who are armed forces members.

BACKGROUND

Unapproved (i.e. "off-label") uses of FDA-approved products are extremely common in American medicine and are usually not subject to any special regulations. However, under Federal law, in some circumstances, unapproved uses of approved drugs are subject to FDA regulations governing "investigational new drugs." These circumstances include such uses as part of clinical trials, and in the military context, command required, unapproved uses. Some command requested unapproved uses may also be subject to special regulations.

ADDITIONAL INFORMATION REGARDING OFF-LABEL USES IN CPGS

The inclusion in CPGs of off-label uses is not a clinical trial, nor is it a command request or requirement. Further, it does not imply that the Military Health System requires that use by DoD health care practitioners or considers it to be the "standard of care." Rather, the inclusion in CPGs of off-label uses is to inform the clinical judgment of the responsible health care practitioner by providing information regarding potential risks and benefits of treatment alternatives. The decision is for the clinical judgment of the responsible health care practitioner within the practitioner-patient relationship.

ADDITIONAL PROCEDURES

Balanced Discussion

Consistent with this purpose, CPG discussions of off-label uses specifically state that they are uses not approved by the FDA. Further, such discussions are balanced in the presentation of appropriate clinical study data, including any such data that suggest caution in the use of the product and specifically including any FDA-issued warnings.

Quality Assurance Monitoring

With respect to such off-label uses, DoD procedure is to maintain a regular system of quality assurance monitoring of outcomes and known potential adverse events. For this reason, the importance of accurate clinical records is underscored.

Information to Patients

Good clinical practice includes the provision of appropriate information to patients. Each CPG discussing an unusual off-label use will address the issue of information to patients. When practicable, consideration will be given to including in an appendix an appropriate information sheet for distribution to patients, whether before or after use of the product. Information to patients should address in plain language: a) that the use is not approved by the FDA; b) the reasons why a DoD health care practitioner would decide to use the product for this purpose; and c) the potential risks associated with such use.