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Pediatric Chest Tubes And Pigtails: An Evidence-Based Approach To The Management Of Pleural Space Diseases

Abstract

Pediatric thoracostomy procedures are used in the emergency department to treat diseases of the pleural space. As children have unique thoracic anatomy and physiology, they may present with management challenges that the emergency clinician must consider. This issue reviews the use of chest tubes and pigtail catheters in pediatric patients, techniques and indications for placement, and possible complications. Diagnostic and treatment options for diseases of the pleural space, such as spontaneous pneumothorax, traumatic injury, and parapneumonic effusions/empyema, are examined. Additionally, this issue discusses the use of imaging modalities to aid in the diagnosis of pleural space diseases and the emerging practice of ambulatory management in certain cases.

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CME Objectives

Upon completion of this article, you should be able to:
1. Diagnose pleural space disease based on signs and symptoms.
2. Choose the most effective imaging studies to aid in diagnosis.
3. Determine the types of procedural interventions necessary in pleural space disease and when they should be performed.
4. Identify which patients can be safely managed as outpatients.

Prior to beginning this activity, see "Physician CME Information" on the back page.

Case Presentations

A 4-year-old boy is brought in via EMS after a high-speed motor vehicle crash in which he was an unrestrained rear-seat passenger. His vital signs are: blood pressure, 90/59 mm Hg; heart rate, 135 beats/min; respiratory rate, 30 breaths/min; and oxygen saturation, 96% on room air. He is awake, but displays signs of altered mental status. He is maintaining his airway, has equal bilateral breath sounds, and has strong peripheral pulses. He has contusions on his face and abdomen, with an obvious right femur deformity. After 2 intravenous lines are placed, a supine chest x-ray is performed, which is read as normal. You accompany him for a head CT scan that reveals a small frontal subdural hematoma. CT scans of the neck, chest, abdomen, and pelvis are performed and reveal a left anterolateral pneumothorax. As he returns from the CT scanner, his mental status declines and he is emergently intubated to maintain his airway. Now that his airway is stabilized, you turn your attention to the pneumothorax. You remember hearing that assisted ventilation can increase the risk for tension pneumothorax physiology. Does his intubation mean that he must now have a chest tube placed?

Just as you are managing the boy who was in the motor vehicle crash, EMS notifies you that they are bringing in a 14-year-old adolescent boy who is having chest pain. He has a past medical history of cystic fibrosis and had been feeling well until he suddenly developed chest pain and difficulty breathing. His pulse oximetry reading is 94% on room air, his respiratory rate is 30 breaths/min, and his heart rate and blood pressure are normal. He has diminished breath sounds on the right side. You decide to obtain an upright chest x-ray that the radiologist reads, noting a small right-sided pneumothorax. What is the next step for this patient? Can a small pneumothorax be managed conservatively, or does his underlying lung disease require definitive treatment with a thoracostomy procedure?

Your next case is a 3-month-old girl with 1 day of respiratory distress. The mother states that the baby has been sick for 1 week with a bad cold. In the ED, the girl is in respiratory distress. You note her to be febrile, with a rapid respiratory rate and oxygen saturation of 88% on room air. Her lung exam reveals bilateral crackles with diminished breath sounds on the right and there is evidence of labored breathing. A chest x-ray reveals a moderately sized pleural fluid collection on the right. As you review this image, your thoughts are racing. Does she need a thoracostomy procedure? How can you confirm the diagnosis? Does it make a difference in her management if this is an effusion versus empyema? Should you call the surgeon to discuss the use of a video-assisted thoracostomy procedure?

Introduction

Thoracostomy procedures occur at a relatively infrequent rate in pediatric patients in the emergency department (ED). However, providing immediate interventional support for life-threatening problems of the pleural space is an essential skill for all emergency clinicians. Diseases of the pleural space include collections of air (spontaneous, traumatic, or secondary pneumothorax), fluid (effusion, chyle, or blood), or pus (empyema). Many different management strategies can be used for diseases of the pleural space, including conservative management, needle thoracostomy, catheter thoracostomy, tube thoracostomy, and video-assisted thoracoscopic surgery. The focus of this issue is on the use of chest tubes (tube thoracostomy) and pigtails (catheter thoracostomy). The existing literature was reviewed to develop a strategy for the emergency clinician that will guide in the diagnosis and management of diseases of the pleural space.

Critical Appraisal Of The Literature

A literature search was performed in PubMed using the following search terms (and their combinations): *pediatrics, children, chest tubes, pigtails, thoracostomy, pneumothorax, spontaneous pneumothorax, occult pneumothorax, hemothorax, chest trauma, blunt chest trauma, pleural effusion, empyema, parapneumonic effusion, emergency medicine, re-expansion pulmonary edema, emergency ultrasound,* and *chest CT scan.* Additionally, the bibliographies of articles were reviewed for additional relevant publications. A search of the Cochrane Database of Systematic Reviews using the search terms *chest tubes* and *pigtails* yielded 1 published article regarding simple aspiration versus intercostal tube drainage for primary spontaneous pneumothorax in adults.[1] A search of the National Guideline Clearinghouse (www.guideline.gov) using the search terms *chest tubes* and *pigtails* yielded 2 adult guidelines published by the British Thoracic Society (BTS) on pleural procedures[2] and management of spontaneous pneumothorax,[3] and 1 pediatric guideline published by the Infectious Diseases Society of America on management of community-acquired pneumonia.[4]

Many of the articles included are retrospective reviews performed primarily on adult populations. Due to the paucity of the need for procedural management of pleural disease in pediatric patients, robust prospective trials have not been performed. For this review, articles focusing on chest tube or pigtail catheter placement in the pediatric patient were primarily examined, although some studies did include simple aspiration, operative intervention, or more conservative management. Prospective studies were included when possible. Additionally, this issue discusses procedural techniques that are largely technical and, for the most part, do not have an evidence-based foundation, but are based on common practice standards. The main references for discussion on technical procedural care were found in the "Thoracostomy and Related Procedures" chapter of King and Henretig's *Textbook of Pediatric Emergency Procedures*.[5]

Etiology And Pathophysiology

The pleural membrane lines the inner surface of the chest wall in each hemithorax, and a potential space exists between this membrane and the chest wall. Introduction of a significant volume of air, fluid, or blood will cause the space to expand, which may impact respiratory mechanics. Abnormal increases in pleural volume directly impinge on lung volume. Loss of the normal approximation between the visceral pleura and the parietal pleura may cause the collapse of an affected lung. When atelectasis is present, shunting of blood takes place through the collapsed portion of the lung, resulting in hypoxemia. This decreased lung volume requires an increase in effort of breathing to maintain ventilation and, subsequently, increased oxygen consumption. Intrapleural air or fluid collections can also significantly affect the cardiovascular system by applying indirect compression of the heart and great vessels. This leads to decreased cardiac output and decreased venous return of blood flow to the heart, potentially resulting in clinically significant hypotension.[5]

Differential Diagnosis

The differential diagnosis for pleural space disease can be divided into 3 categories based on the occupying medium: air, blood, or other fluid. Often, the first step in identifying the cause of pleural space disease is identifying the occupying medium. Once identified, other factors such as pertinent patient history and/or appropriate imaging modalities will help lead to the correct diagnosis. **(See Table 1.)**

Prehospital Care

In the initial management of suspected pleural space disease, the priority for prehospital and transferring medical care clinicians should remain: airway, breathing, and circulation. Recognition of signs of severe chest injury or hemodynamic compromise should lead to prompt emergency intervention (such as needle thoracostomy to treat a tension pneumothorax) to prevent further deterioration. In less severe pleural space disease, consideration should be given to transferring (by ground or air) patients who require care at another institution and those who need positive-pressure ventilation.

Pneumothoraces lack communication with the outside environment and are thus affected by changes in atmospheric pressure. Consequently, if

Table 1. Differential Diagnosis: Air, Blood, Or Other Fluid In The Pleural Space

Diagnosis	Blunt or Penetrating Thoracic Trauma	Iatrogenic Causes	Other Causes
Pneumothorax	• Lung laceration • Tracheal rupture • Bronchial rupture • Rib fracture • Penetrating chest wall injury • Esophageal injury • Thoracic spine fracture/dislocation • Abdominal free air through the diaphragm	• Vessel catheter placement (subclavian, jugular) • Surgery • Thoracostomy • Positive-pressure ventilation	• Extending pneumomediastinum • Extending pneumopericardium • Pulmonary bleb/bullae rupture • Forceful Valsalva maneuver (lifting, straining) • Spontaneous • Altitude pressure change (scuba diving, air/space travel) • Esophageal rupture
Hemothorax	• Lung laceration • Intercostal vessel laceration • Internal mammary artery laceration • Thoracic spine fracture/dislocation • Aortic rupture • Myocardial rupture • Injury to hilar structures	• Vessel catheter placement (subclavian, jugular) • Surgery • Thoracostomy	N/A
Effusion	• Thoracic duct laceration	• Cerebrospinal fluid shunt leakage • Misplaced vascular catheters • Thoracic duct laceration	• Congestive heart failure • Nephritic syndrome • Ascites • Fistula drainage • Parapneumonic effusion • Lung abscess • Hypoalbuminemia • Infectious disease • Inflammatory disease • Neoplasm • Esophageal rupture with gastric leakage

Abbreviation: N/A, not applicable.

atmospheric pressure suddenly decreases (eg, in air transport), pneumothorax pressure becomes relatively supra-atmospheric, creating the potential for a tension pneumothorax. Many experts argue that performing tube thoracostomy protects against the effects of rapid changes in atmospheric pressure by allowing the pleural space to maintain pressure equilibrium.[5-7] This concept is physiologically based and is supported in the literature by at least 1 case report of a tension pneumothorax developing during air transport in military-related trauma.[8] Numerous retrospective reviews and 1 notable prospective study identify prehospital needle and tube thoracostomy as safe and efficacious in adult trauma patients.[9-12] Conversely, a retrospective review by Braude et al found that a certain proportion of adult trauma patients may actually be safely managed without tube thoracostomy prior to air transport, as long as needle thoracostomy is readily available if deterioration ensues.[13] Given the lack of prospective studies in children with pneumothoraces receiving air transport, multiple factors must be taken into account when considering tube thoracostomy in children. These factors include the experience of the clinician, severity of illness, transport time, and availability of emergency decompression, if needed.

When considering mechanical ventilation prior to air transfer in patients with a pneumothorax, again, most experts will recommend tube thoracostomy to prevent development of a tension pneumothorax.[5-7] In contrast, evidence for ED treatment of patients with occult pneumothoraces with mechanical ventilation points toward the minimalist approach. Two prospective studies on blunt traumatic occult pneumothoraces in children conclude that observation in lieu of tube thoracostomy is a viable option in patients who require mechanical ventilation.[14,15]

Emergency Department Evaluation

History

A proper history is crucial and will help to guide the physical examination and differential. Limited data exist regarding the historical features of spontaneous pneumothorax in children. Two retrospective studies totaling 33 patients found that the most common symptoms were chest pain, shortness of breath, and cough.[16,17] Sudden onset of these symptoms should raise suspicion of this diagnosis. Additionally, pediatric patients are much more likely to have an underlying predisposing factor compared to adults. A 1995 retrospective study reported that 42% of pediatric patients were found to have an underlying diagnosis.[16] Conditions leading to increased risk of spontaneous pneumothorax include cystic fibrosis, pneumonia, a congenital lung cyst, an upper respiratory infection, and Marfan syndrome. An additional retrospective study involving patients aged ≥ 13 years with Marfan syndrome found a 10-fold higher risk of spontaneous pneumothorax with radiographically detectable blebs and bullae.[18] History pertaining to patient anatomy and physiology should also be obtained in the event that procedural care is warranted, including cardiomegaly (the heart may be located adjacent to the lateral chest wall), abnormal situs, mediastinal tumors, prior surgery (pleural adhesions and scars), and anticoagulation. **See Table 2** for a list of relevant historical features.

Physical Examination

Examination of the patient with suspected pleural space disease should always begin with airway, breathing, and circulation. Abnormalities or changes in vital signs (tachypnea, tachycardia, hypotension), altered mental status, and/or tracheal deviation should halt any further workup until emergent life-saving procedures, such as needle thoracostomy, are performed. In the nonverbal or unaccompanied child, signs of prior surgery can be noted on examination and may include the presence of medical devices or other signs of disease affecting the chest (indwelling central venous catheter, ports and tubing, pacemakers, implanted defibrillators, cerebrospinal fluid shunt tubing, implanted infusion pumps, vagal nerve stimulators, postsurgical drains, transthoracic pacing wires, and monitoring catheters).[5] According to a 2014 prospective cohort study on occult pneumothoraces (pneumothoraces not identified on initial supine chest x-ray), traumatically injured children with nonoccult pneumothoraces were more

Table 2. Relevant Historical Features When Assessing Pleural Space Disease

Pertinent History	• Back pain • Chest pain • Chest tightness • Cough • Dyspnea • Hemoptysis • Pleurisy • Recent surgery • Sudden onset of symptoms • Trauma
Associated Conditions	• Asthma • Birt-Hogg-Dubé syndrome • Congenital lung cyst • Connective tissue disorder • Cystic fibrosis • Malnutrition • Marfan syndrome • Pneumonia • Pulmonary neoplasm • Pulmonary tuberculosis • Smoking

likely to have abnormal physical examination findings (tachypnea, thoracic wall tenderness, or abnormal chest auscultation) than children with occult pneumothoraces.[15] **See Table 3** for a list of relevant physical examination findings.

Diagnostic Studies

Chest Radiography

Chest x-ray is the most readily available and widely used imaging modality to evaluate for suspected pleural space disease. It offers a quick view of the thoracic cavity, and most clinicians are trained in its interpretation. Increased opacities outlining the periphery of the lung and costophrenic angle blunting are suggestive of fluid accumulation in the pleural space. Absence of lung markings seen at the periphery and the presence of a visible pleural line is diagnostic of a pneumothorax.

Development of a formula for estimating the size of a pneumothorax based on upright chest radiography has been attempted.[19,20] One method for estimating the size of a pneumothorax was developed by Collins et al by retrospectively analyzing adult pneumothorax cases from 19 patients to derive a formula from the sum of 3 interpleural distances and comparing that number to the calculated size on helical computed tomography (CT) scans.[20] **(See Table 4.)** This method has been found to be more accurate than previous methods.[21,22] However, none of the chest radiograph-based methods for estimating the size of a pneumothorax have been validated in the pediatric population. A further limitation of chest x-rays in the diagnosis of pneumothorax is that a supine chest x-ray (trauma evaluation) is the least sensitive of all plain radiographic techniques.[23,24] In a retrospective review of 338 adult trauma patients receiving a CT scan, a supine chest x-ray missed over half of all pneumothoraces.[25] The locations of the missed pneumothoraces tended to be in the least dependent areas, including the apical, anteromedial, and basal thorax. Lateral decubitus radiographs (88%-89% sensitive), followed by upright posterior-anterior radiographs (59% sensitive), are the most sensitive for revealing pneumothoraces.[24,26]

Computed Tomography

CT is considered to be the gold standard in pleural disease diagnostic testing, but the risk of radiation must be carefully considered in children.[27-29] A retrospective study including 20 adult trauma patients recognized that CT is more sensitive than radiography at identifying fluid or air in the pleural space and can easily separate those fluid collections into hydrothorax and hemothorax.[30] Similarly, a retrospective study of 85 adult patients with effusion or empyema noted that CT can help identify occult pleural space infection, and found an association between pleural thickening and effusion/empyema staging.[31] CT imaging can readily detect a pneumothorax and associated pulmonary blebs or bullae, which are often associated with primary spontaneous pneumothorax in children.[32]

Table 3. Relevant Physical Examination Findings When Assessing Pleural Space Disease

Examination Findings

- Altered mental status
- Chest wall findings:
    - Bleeding
    - Contusion
    - Laceration
    - Lesion
    - Tenderness
- Decreased vocal fremitus
- Diminished or absent breath sounds
- Hyperresonance on percussion
- Hypotension
- Hypoxemia
- Inferior displacement of the spleen or liver
- Intrathoracic bowel sounds (scaphoid abdomen)
- Pulsus paradoxus
- Tracheal deviation
- Tachycardia
- Tachypnea
- Unilateral enlargement of the hemithorax

Table 4. Calculated Pneumothorax Sizes Using The Collins Formula

Sum of Interpleural Distances (cm)	Estimated % Pneumothorax
1	8.9
2	13.6
3	18.3
4	23
5	27.7
6	32.4
7	37.1
8	41.8
9	46.5
10	51.2
11	55.9
12	60.6
13	65.3
14	70
15	74.7
16	79.4

$\% = 4.2 + [4.7 \times (\text{sum of interpleural distances})]$

Reprinted from *Respiratory Medicine*, Volume 100, Issue 8. Anne-Maree Kelly, Daragh Weldon, Anna Y.L. Tsang, Colin A. Graham. Comparison between two methods for estimating pneumothorax size from chest X-rays. Pages 1356-1359. Copyright 2006, with permission from Elsevier.

As CT has become more widely used in the evaluation of traumatic injury, identification of occult pneumothoraces is now common. A multicenter prospective observational study identified 2.8% of blunt trauma patients aged < 16 years as having an occult pneumothorax.[15] Given that conservative management of occult pneumothoraces is considered safe, the use of chest CT in pediatric trauma has limited utility in this regard. Emergency clinicians must consider limiting the amount of radiation that is delivered to the patient, as children are at an increased risk for long-term consequences. Epidemiological data indicate that, for children aged < 15 years, the projected number of future radiation-induced cancers related to a single chest CT scan is 1 in 570.[33] Chest CT as a diagnostic modality should be considered in recurrent cases of spontaneous pneumothorax, suspected underlying lung disorders (such as congenital lesion or mass), complicated parapneumonic effusions or empyemas, or trauma involving the tracheobronchial tree or thoracic vascular structures.

Ultrasound

The use of bedside ultrasound has dramatically improved the detection of pleural space diseases over the last 3 decades. The detection of pneumothoraces by ultrasound is confirmed by the absence of both lung sliding and comet-tail artifacts, commonly known as B lines.[34] **(See Figure 1.)** A prospective case-control study including 43 adult patients with pneumothoraces in an intensive care unit first described the high sensitivity of bedside ultrasound for the diagnosis of pneumothorax.[35] In a meta-analysis of 8 studies with a total of 1048 patients, ultrasound was found to be 90.9% sensitive and 98.2% specific in diagnosing pneumothorax at the bedside, compared to supine chest radiography, which was 50.2% sensitive and 99.4% specific.[36] However, the applicability of these data to pediatric patients remains unknown.

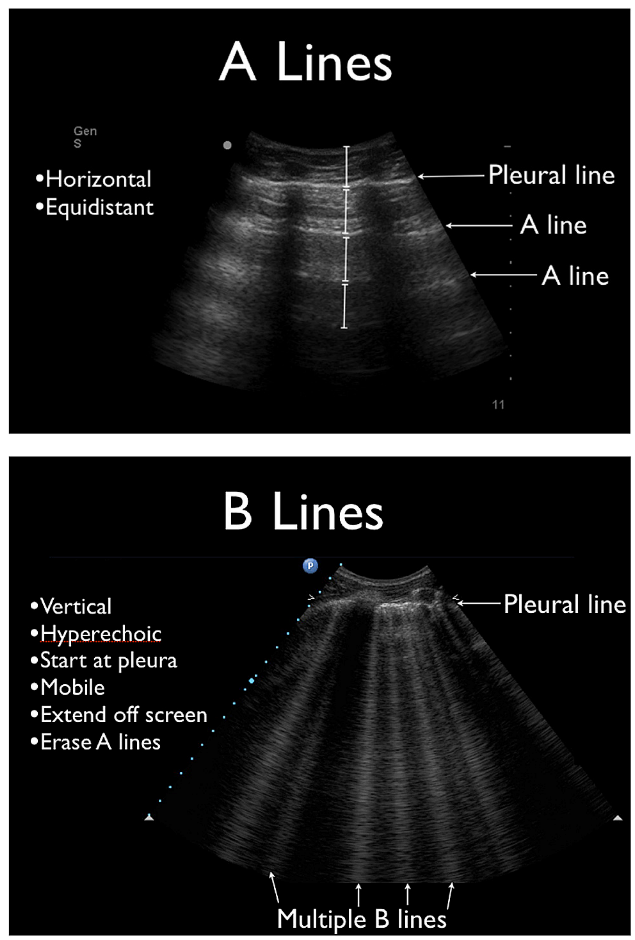
Pleural fluid collections are ideally suited for ultrasound imaging due to their acoustic properties. Ultrasound allows for distinction of pleural fluid from peripheral pulmonary infiltrates and also permits localization of pleural fluid for aspiration.[37] A prospective study of 320 adult patients with pleural fluid collection found distinguishing characteristics of transudative, exudative, and hemorrhagic effusions and empyema, which could readily be determined by ultrasound.[38] These findings may also be useful for the management of children with parapneumonic effusions. A retrospective study of 46 children found that those with high-grade ultrasound studies (evidence of organization such as fronds, septations, or loculations) benefited from operative intervention compared to pleural drainage or chest tube placement.[39] In summary, ultrasound is a quick and radiation-free alternative to chest radiography and CT that can be used effectively in the diagnosis of pleural space disease. However, this technique requires specialized training and is known to be operator-dependent.

Treatment

Equipment

All hospitals that care for children should have the proper equipment needed for emergent thoracostomy procedures. A number of organizations have established joint guidelines that delineate necessary resources to prepare hospital EDs to serve pediatric patients.[40] Equipment for these procedures includes tube thoracostomy trays and chest tubes in infant, child, and adult sizes (infant, 10F–12F; child, 16F–24F; adult, 28F–40F). **(See Tables 5 and 6, page 7.)** Sizing guides for chest tube placement can also be

Figure 1. Use Of Ultrasound To Assess For Pneumothorax



Lung sliding is found at the pleural line. A lines are artifacts that can be seen in a pneumothorax, but these can also be visible in a normal lung. Comet-tail artifacts (B lines) are present in a normal lung and will move with the lung during respiration. The presence of B lines exclude a pneumothorax. The absence of both lung sliding and B lines confirms a pneumothorax.
Photo courtesy of Mikaela Chilstrom, MD.

found on the commonly used length-based Broselow-Luten tape. Pigtails are smaller than chest tubes and are typically sized 6F-12F.

Landmarks And Anatomy

The optimal placement for insertion of an intrapleural drain is either the second intercostal space (ICS) in the midclavicular line (MCL) or between the anterior axillary and midaxillary line in the fourth to sixth ICSs.[5] **(See Figure 2, page 8.)** It is best to avoid the midclavicular approach in young girls to prevent future deformity of breast development. The area that is bordered by the lateral edge of the pectoral muscle, the lateral edge of the latissimus dorsi, and the fifth intercostal space is known as the safety triangle.[2] Insertion of a chest tube at this location minimizes risk to blood vessels, muscle, and breast tissue. Careful consideration must be given to the location of the diaphragm when performing any pleural procedure. The diaphragm encloses the abdominal contents, some of which is often above the level of the ribs. Thus, any condition or patient positioning that decreases abdominal pressure (such as elevating the head of the bed) will also decrease the risk of complications. If abdominal distention is present, pass a large-bore nasogastric tube to help reduce diaphragmatic elevation. Several case reports of abdominal placement of chest tubes have been published that further emphasize the need for caution and an understanding of patient anatomy.[41,42] Once the appropriate level of insertion has been determined, attention must be given to the ICS. The neurovascular bundle that supplies the thorax traverses the inferior border of each rib. The ideal insertion of any traumatic instrument in this space is directly above the inferior rib, in order to avoid injuring this bundle.

Tubes that are placed to drain air should be directed anteriorly and those placed to drain fluid should be directed posteriorly.[5] These locations will facilitate drainage in the supine patient, as the air and fluid will flow towards these respective areas of the pleura. For effusions, ideal placement is based on the location of the fluid collections on ultrasound.

Table 5. Resources And Equipment Needed For Emergent Thoracostomy Procedures

- Personal protective equipment: sterile gloves, mask, and gown
- Sterile towels, gauze, dressing, and tape
- Sterile prep solution
- Scalpel
- Local anesthetic, needle, and syringe
- Suture
- Heimlich valve or drainage assembly
- Pigtail catheter kit
  - Needle, syringe, guidewire, dilator catheter, and pigtail catheter
- Tube thoracostomy kit*
  - Chest tube, large hemostat, dissecting scissors, and small hemostat

*A chest tube size guide can be found in **Table 6**.

Techniques

Preprocedure

Where applicable, obtain informed consent. Identify the correct patient and site of procedure. Elevate the head of the bed to 30°. Position the patient with the correct side rotated towards the ceiling by placing the ipsilateral arm above the patient's head and rotating the body slightly toward the contralateral side. Don sterile attire and prepare a sterile surgical field. Anesthetize the skin along the site of insertion. Further considerations include the use of systemic analgesia, anxiolysis, and/or sedation.[5] Nitrous oxide should be avoided, as it may enter the pleural space by diffusion and cause a rapid increase in the volume of a pneumothorax.[43]

Needle Decompression

The most common insertion site for needle decompression of a tension pneumothorax is the second ICS at the MCL. A review of chest CT scans in adult trauma patients found that the fifth ICS at the anterior axillary line was actually more ideally suited for needle decompression due to the relatively smaller chest wall thickness at this location.[44] Using a standard 5-cm decompression needle in the second ICS at the MCL would result in a 42.5% failure to reach the pleural cavity in adults as compared to 16.7% in the fifth ICS at the anterior axillary line. With no studies assessing anatomical differences in chest wall thickness in children, the standard insertion site is at a nondependent area of the chest wall, ideally the second ICS at the MCL.[5] If there is failure to decompress the tension pneumothorax at this location, consider obtaining a longer decompression needle or switching to the fifth ICS at the anterior axillary line. Following rapid insertion of a large-caliber angiocatheter in the affected hemithorax and decompression of the tension pneumothorax (identified by

Table 6. Guide For Selecting Chest Tube Size

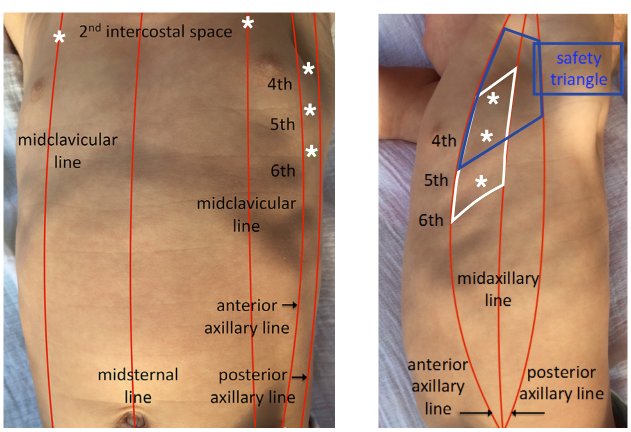
Patient Age (Weight)	Approximate Chest Tube Size (French)
Neonate (< 5 kg)	8-12
0-1 years (5-10 kg)	10-14
1-2 years (10-15 kg)	14-20
2-5 years (15-20 kg)	20-24
5-10 years (20-30 kg)	20-28
> 10 years (30-50 kg)	28-40
Adult (> 50 kg)	32-40

a rush of air through the catheter and hemodynamic stabilization), definitive treatment usually requires chest tube or catheter thoracostomy.[7]

Chest Tube Thoracostomy

The conventional procedure for chest tube insertion entails the use of pressure to force a blunt tool (such as a hemostat) to create a tunnel to the chosen ICS and to push the chest tube into the pleural space.[5] In order to avoid the intercostal neurovascular bundle that lies along the inferior border of each rib, incise the skin over the rib that lies directly below the intercostal area of insertion. Bluntly dissect the soft tissue, using a hemostat, subcutaneously and superiorly until you reach the pleural membrane. Guide the hemostat into the pleural cavity, being careful not to penetrate too deeply, to avoid directly damaging any lung tissue. Spread the clamp as you remove it to increase the size of the opening and allow for insertion of the chest tube. Keep in mind that in neonates and young children there will be a noticeable amount of chest wall deformity when applying force to enter the pleural space, which is a result of their relatively cartilaginous rib cage. Next, insert the chest tube using the hemostat as a guide. Make sure that all of the holes of the tube are completely within the pleural space. Some clinicians recommend rotating the tube 360° to decrease kinking and ensure that the tube does not meet any resistance that might suggest it is positioned incorrectly. Attach the tube

Figure 2. Chest Tube Insertion Landmarks



Optimal insertion site for intrapleural drainage for either a right or left hemithorax is denoted by *.

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to a water seal and apply suction. Secure the tube with sutures (such as a purse string, horizontal, or vertical mattress), then wrap the tails of the suture around the tube tightly several times to prevent the tube from slipping through the suture. The incision should then be covered with petroleum gel and sterile gauze to prevent infection.

In 1989, Mehrabani et al described a relatively atraumatic method of chest tube insertion by inserting a small curved hemostat into the distal hole of the catheter.[45] The curve of the hemostat can be used to direct the tube toward the desired location while preventing direct contact between the sharp edges of the open hemostat and the lung. An alternative method of chest tube insertion was described by Ahmed et al in a 1995 retrospective observational study of 24 patients using a modification of the Seldinger technique, the needle-wire-dilator technique, with a commercially available kit.[46,47] They found complications in 5 of the 24 patients related to kinking of the chest tube, which required replacement with a stiffer tube in 2 cases. This method of insertion is the same as that of the pigtail catheter insertion described in detail below.

Pigtail Catheter Thoracostomy

Fuhrman et al introduced the modified pigtail catheter for drainage of pleural fluids. The modified pigtail catheter is a redesigned vascular catheter that is inserted using a modification of the Seldinger technique.[48] The authors of that study argued that this method offered a simpler, less traumatic method for pleural drainage of fluid and air compared to conventional techniques. This method was assessed in a 1989 prospective interventional study of 16 pediatric patients, and it demonstrated successful drainage of air and fluid, thereby offering an alternative to standard tube thoracostomy.[49] A case series of pigtail catheters placed in a pediatric intensive care unit noted successful drainage with no further drainage procedures needed for patients with chylous fluid (100%, n = 20), serous fluid (96%, n = 72), hemothorax (81%, n = 16), and pneumothorax (75%, n = 20); empyema drainage was not successful (0%, n = 5).[50] The overall complication rate for pigtail catheters was 20% and included issues such as failure to drain, dislodging, kinking, loss of liquid ventilation fluid, empyema, and disconnection.

For this procedure, make an incision 1 rib lower than the ICS to be entered (typically the fifth ICS). Stretch the skin cephalad approximately 1 to 2 cm (this is also known as the z-track method, and reduces the risk of leakage through the catheter/skin tract) and pass an 18-gauge needle through the wound to puncture the thorax and pleura. Introduce a curve-tipped guidewire into the pleural space and withdraw the needle. Enlarge the puncture site by advancing an 8F flexible plastic dilator along the wire, penetrating the chest wall to a depth of about 1 inch. Remove the dilator and advance the catheter along the guidewire, position it in the pleura, use a Luer lock to secure to a negative-pressure source, and close the pleural drainage system. It is imperative that the side holes in the catheter be positioned completely inside the chest to be in the proper position.

Pigtail catheters have become more widely used since their introduction; however, emergency clinicians should be aware of associated complications owing to the smaller tube size and increased flexibility. A retrospective study of 111 adult patients found a 21% tube displacement rate, 9% blockage rate, and 13% rate of repeat pleural procedures.[51] Another retrospective study evaluated the use of pigtail catheters compared to large-bore chest tubes in children treated for pneumothoraces in the ED.[52] This study included 11 pigtails and 16 large-bore catheters placed by pediatric emergency physicians. None of the measured outcomes (success of evacuation, complication rate, or length of hospital stay) showed any statistically significant difference between the 2 tube types. There was a small difference in opioid pain medication dosing, with pigtail placement requiring less opioids; however, the difference was not statistically significant ($P = .12$).

Postprocedure

After insertion, intercostal catheters should be connected to a Heimlich valve[53] or an underwater seal device.[54] The initial use of suction in primary spontaneous pneumothorax is not recommended, due to the increased risk of re-expansion pulmonary edema.[3] Re-expansion pulmonary edema is a rare condition caused by the rapid expansion of collapsed lung tissue. An adult case series noted a greater risk of re-expansion pulmonary edema in larger pneumothoraces and in young adult patients (aged 20 to 39 years).[55] To date, there has been only 1 pediatric re-expansion pulmonary edema case series, which included 22 patients.[56] Almost half of the cases were associated with the perioperative period and there was no relationship to the duration of lung collapse. Treatment of re-expansion pulmonary edema is patient-specific and case-specific, but is primarily supportive, including positive-pressure ventilation and positive end-expiratory pressure.

Hemorrhagic output from tube thoracostomy following blunt or penetrating trauma should be closely monitored. The American College of Surgeons Committee on Trauma recommends consideration for surgical thoracotomy in adults for any immediate hemorrhagic output from a chest tube ≥ 1500 mL (approximately 30% of the circulating blood volume in adults), drainage of 200 mL/h for 2 to 4 hours, or the need for blood transfusion.[7] Pediatric-specific recommendations for surgical thoracotomy consideration include chest tube output ≥ 20 mL/kg, drainage > 3 to 4 mL/kg/h, or the need for blood transfusion. A retrospective case series that included 157 adults who received urgent thoracotomy for hemorrhage found that the risk of death was 3 times greater for those patients with a blood loss of 1500 mL compared to 500 mL, and the rate of death increased linearly with total chest hemorrhage.[57] Transfusion for pediatric chest trauma should be guided by hemodynamic status and not necessarily chest tube output. Initial fluid resuscitation should begin with a 20-mL/kg bolus of isotonic crystalloid solution. If a third bolus of fluids is required, consideration should be given to the use of 10 mL/kg of packed red blood cells.[7] Autotransfusion should be considered for any large volume of chest tube drainage. To perform an autotransfusion, attach a blood recovery unit to the large-bore chest tube and mix the blood with an appropriate amount of anticoagulant (either citrate phosphate dextrose or heparin) prior to transfusing the blood back into the patient.

Condition-Specific Treatment

Tension Pneumothorax

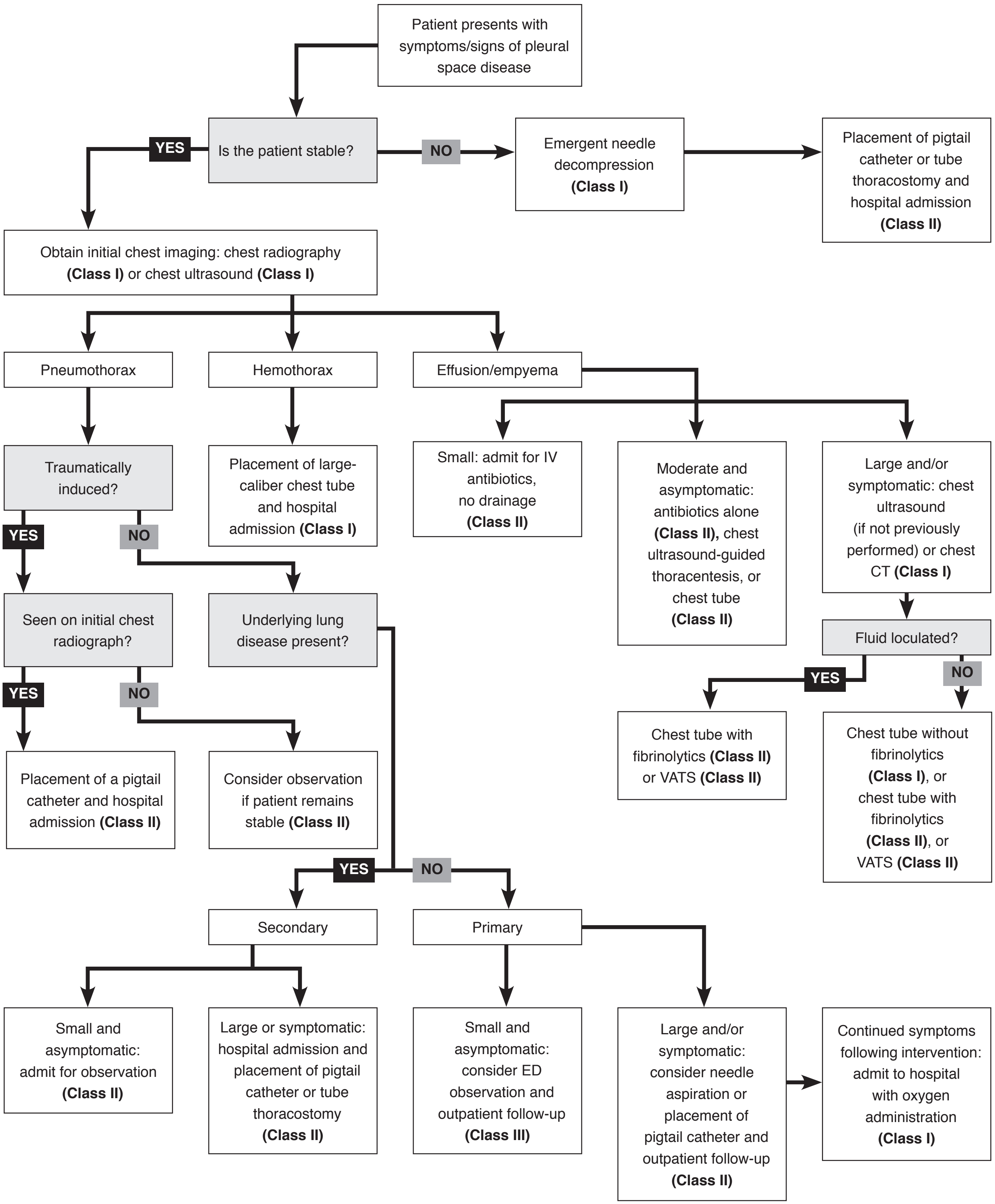
A tension pneumothorax occurs when air has leaked into the pleural space through a 1-way valve, causing the lung to collapse, and eventually resulting in a shift of the mediastinum to the contralateral side. Increased intrathoracic pressure decreases venous return to the heart and leads to cardiopulmonary arrest unless it is promptly treated. The diagnosis of a tension pneumothorax is made clinically and treatment should not be delayed for radiologic confirmation. Decompression includes needle thoracostomy followed by definitive treatment with catheter or tube thoracostomy.[7]

Primary Spontaneous Pneumothorax

A primary spontaneous pneumothorax is a pneumothorax that occurs in a person with no identifiable lung abnormality or disease. The treatment of a spontaneous pneumothorax in a clinically stable patient could include observation, 100% high-flow oxygen delivery, simple aspiration, large- or small-bore pleural catheter, or tube thoracostomy.[32] Conservative management has been well described. One such study included a cohort of 67 patients aged 15 to 29 years, and noted resolution in 85% of patients with simple pneumothoraces (no evidence of other pulmonary disease) without intervention.[58]

Simple oxygen administration can be an effective treatment for a spontaneous pneumothorax. In a prospective study of 10 patients aged ≥ 15 years, supplemental oxygen at high flow rates has been shown to increase the rate of gas absorption from the pleural cavity (up to 4-fold in > 30% pneumothorax).[59] The BTS and American College of Chest Physicians (ACCP) have both published recommendations regarding the management of a spontaneous pneumothorax in adults; however, neither guideline includes

Clinical Pathway For Management of Pleural Space Disease In Pediatric Patients



Abbreviations: CT, computed tomography; ED, emergency department; IV, intravenous; US, ultrasound; VATS, video-assisted thoracoscopic surgery.
For Class of Evidence definitions, see page 11.

specific recommendations for pediatric patients. The recommendations for treatment of a small primary spontaneous pneumothorax (BTS: ≤ 2 cm distance between the lung and chest wall; ACCP: < 3 cm distance between the apex and cupola) without associated dyspnea in patients who remain clinically stable is observation in the ED for 3 to 6 hours with 12- to 24-hour follow-up and instructions to seek medical attention if new or worsening symptoms occur.[3,60] The recommendations differ for patients requiring initial interventional care (eg, as would be required for an asymptomatic large primary spontaneous pneumothorax or symptomatic small primary spontaneous pneumothorax). The BTS recommends simple aspiration[3] and the ACCP consensus statement advocates for the use of thoracostomy tube or pleural catheter.[60] Patients who continue to have symptoms or who are clinically unstable should be admitted to the hospital with high-flow oxygen administration.[32]

Traumatic Pneumothorax/Hemothorax

A retrospective study of 68 pediatric thoracic trauma patients found that intercostal tube placement was the most frequent surgical intervention performed.[61] The use of tube thoracostomy in traumatic hemothorax or pneumothorax is consistent with the current recommendations by the American College of Surgeons Committee on Trauma. According to these recommendations, an acute hemothorax identified on chest radiography is best treated by large-caliber tube thoracostomy to evacuate blood, reduce the risk of clotting, and provide ongoing monitoring of blood loss.[7] There is, however, some room for physician discretion in otherwise asymptomatic pneumothorax cases where aspiration and observation may be appropriate. Two prospective studies have contributed to our knowledge of appropriate management of occult pneumothoraces.[14,15] Evaluating a combined 275 pediatric patients with occult pneumothoraces, both studies drew similar conclusions, noting that observation is a safe alternative for treatment of clinically stable pediatric patients with traumatic occult pneumothoraces.

Parapneumonic Effusion And Empyema

The primary treatment of parapneumonic effusion and empyema is not without controversy. Options for treatment include the use of antibiotics, thoracentesis, tube thoracostomy, fibrinolytics, video-assisted thoracoscopic surgery (VATS), and thoracotomy. A meta-analysis of 8 studies concluded that, compared to nonoperative management, primary operative therapy is associated with a lower inhospital mortality rate, reintervention rate, length of stay, time with tube thoracostomy, and time of antibiotic therapy.[62] Primary operative therapy was defined as treatment with antibiotics and either VATS or thoracotomy.

Since publication of that meta-analysis, there have been 2 prospective randomized trials comparing nonoperative versus operative treatment. The first study compared tube thoracostomy with intrapleural urokinase to VATS and found no difference in clinical outcome. However, urokinase treatment cost considerably less (median $6914) than VATS (median $10,146) ($P < .001$).[63] The second study compared small-caliber (12F) tube thoracostomy with intrapleural fibrinolysis to thoracoscopic decortication, and, again, found no advantage to VATS treatment, which incurred a substantially higher cost.[64] These cost differences are described in the literature in a cost-effectiveness study examining the differing treatment strategies of pediatric empyema.[65] Employing a base-case analysis using a Bayesian tree approach, the authors of the study concluded that a chest tube with instillation of fibrinolytics is the most cost-effective strategy. A more recent systematic review comparing VATS to a chest drain with fibrinolytics reached similar conclusions, and found that the best available evidence does not support the contention that VATS is superior to a chest drain with fibrinolytics.[66] **Table 7, page 12; and Figure 3, page 13,** highlight the most recent management guidelines of the Infectious Diseases Society of America regarding parapneumonic effusions.

Class Of Evidence Definitions

Each action in the clinical pathways section of *Pediatric Emergency Medicine Practice* receives a score based on the following definitions.

Class I
- Always acceptable, safe
- Definitely useful
- Proven in both efficacy and effectiveness

Level of Evidence:
- One or more large prospective studies are present (with rare exceptions)
- High-quality meta-analyses
- Study results consistently positive and compelling

Class II
- Safe, acceptable
- Probably useful

Level of Evidence:
- Generally higher levels of evidence
- Nonrandomized or retrospective studies: historic, cohort, or case control studies
- Less robust randomized controlled trials
- Results consistently positive

Class III
- May be acceptable
- Possibly useful
- Considered optional or alternative treatments

Level of Evidence:
- Generally lower or intermediate levels of evidence
- Case series, animal studies, consensus panels
- Occasionally positive results

Indeterminate
- Continuing area of research
- No recommendations until further research

Level of Evidence:
- Evidence not available
- Higher studies in progress
- Results inconsistent, contradictory
- Results not compelling

This clinical pathway is intended to supplement, rather than substitute for, professional judgment and may be changed depending upon a patient's individual needs. Failure to comply with this pathway does not represent a breach of the standard of care.

Complications

Chest tube insertion has historically been associated with serious complications, and the method of trocar-assisted insertion was especially traumatic. In 1974, Wilson et al reported 3 cases of lung perforation in neonates with underlying parenchymal disease.[67] A 1978 retrospective study by Moessinger et al found a 25% lung perforation rate following pleural catheter placement for treatment of neonatal pneumothorax.[68] Due to high complication rates, the trocar method had been all but abandoned in favor of the blunt dissection method. Using the blunt dissection method, Millikan et al reported a 1% chest tube malposition rate for tubes inserted in the hospital.[41] Emergently placed chest tubes have an even greater risk of malposition (26%) as diagnosed by CT in adult trauma patients.[69] Percutaneously placed chest tubes for blunt thoracic trauma in adults were noted to have an overall complication rate of 9.1%.[70] There have been numerous other case reports of complications following chest tube insertion, including Horner syndrome, traumatic arteriovenous fistula, bronchopleural fistula, abdominal placement of tube, and reversible cardiogenic shock.[42, 71-75]

Special Populations

Secondary Pneumothoraces

For cases of secondary pneumothoraces (spontaneous pneumothoraces associated with a pre-existing lung disease), the adult guidelines developed by both the BTS and the ACCP offer the current best-practice standards that can be applied to children. These guidelines are consistent in their recommendations for hospitalization in all cases and placement of a pleural catheter or chest tube if the pneumothorax is large (BTS: > 2 cm distance between the lung and chest wall; ACCP: ≥ 3 cm distance between the apex and cupola) or if the patient is symptomatic.[3,42] There is some evidence suggesting that the size of the tube is not an important factor in the success of treatment, and smaller tubes may be considered. A retrospective study in adults compared large-bore chest tubes (20F-28F) to pigtail catheters (10F-14F) in patients with secondary pneumothoraces. No significant difference was found in success rate, extubation time, recurrence rate, or complications.[76] However, there may be a lower limit of the sizing threshold for treatment of a secondary spontaneous pneumothorax, at least in adults.

A second retrospective study of patients aged ≥ 14 years, including 38 patients with a secondary spontaneous pneumothorax, reported a 52.6% treatment failure rate with a 7F small-bore pleural catheter.[77] Treatment failure in this study was defined as the need for placement of a traditional chest tube or surgical intervention after the use of a pigtail catheter. There are currently no studies examining chest tube size for secondary spontaneous pneumothoraces in children. Surgical interventions for recurrence of secondary spontaneous pneumothorax are performed at the discretion of surgical subspecialists.[32]

Penetrating Chest Trauma

The use of antibiotic prophylaxis to prevent infections from chest drains in blunt and penetrating trauma

Table 7. Factors Associated With Outcomes And Indication For Drainage Of Parapneumonic Effusions

Size of Effusion	Bacteriology	Risk of Poor Outcome	Tube Drainage With or Without Fibrinolysis or VATS
Small: < 10 mm on lateral decubitus radiograph or opacifies < 25% of the hemithorax	Bacterial culture and Gram stain results unknown or negative	Low	No; sampling of pleural fluid is not routinely required
Moderate: > 10 mm rim of fluid but opacifies < 50% of the hemithorax	Bacterial culture and/or Gram stain results negative or positive (empyema)	Low to moderate	No; if the patient has no respiratory compromise and the pleural fluid is not consistent with empyema (sampling of pleural fluid by simple thoracentesis may help determine presence or absence of empyema and need for a drainage procedure, and sampling with a drainage catheter may provide both diagnostic and therapeutic benefit); Yes; if the patient has respiratory compromise or if pleural fluid is consistent with empyema
Large: opacifies > 50% of the hemithorax	Bacterial culture and/or Gram stain results positive (empyema)	High	Yes; in most cases

Abbreviation: VATS, video-assisted thoracoscopic surgery.

Reprinted from John S. Bradley, Carrie L. Byington, Samir S. Shah, et al. The Management of Community-Acquired Pneumonia in Infants and Children Older Than 3 Months of Age: Clinical Practice Guidelines by the Pediatric Infectious Diseases Society and the Infectious Diseases Society of America, *Clinical Infectious Diseases*. 2011, Volume 53, Issue 7, Pages e25-e76, by permission of Oxford University Press.

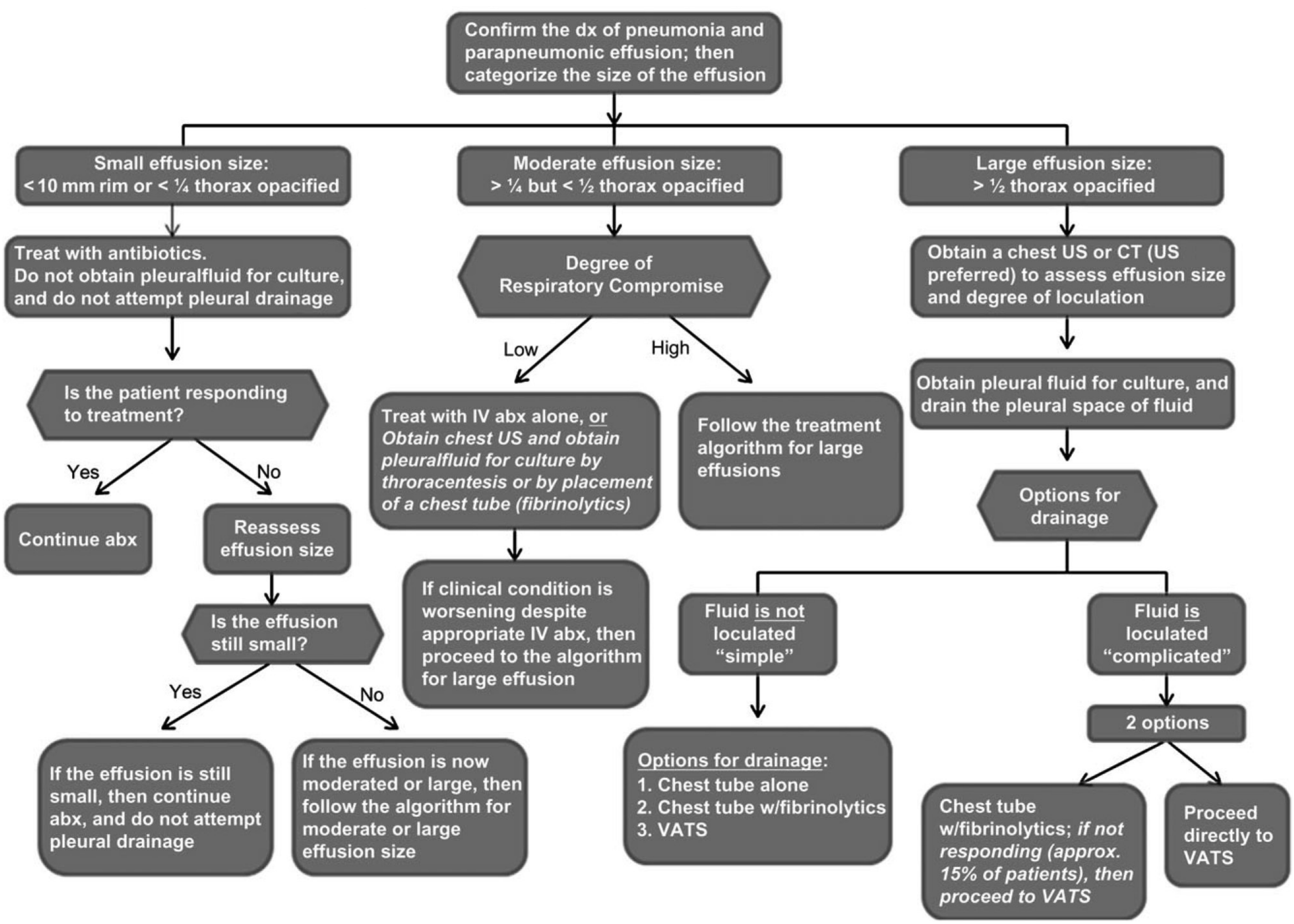
has caused considerable debate. The most recent Eastern Association for the Surgery of Trauma guidelines found insufficient evidence for recommendations for or against this practice.[78] However, a more recent meta-analysis of 11 articles involving a total of 1234 patients found that infectious complications were less likely to develop following antibiotic prophylaxis during placement of chest drains in penetrating, but not blunt, traumatic injuries.[79]

Controversies And Cutting Edge

Primary Spontaneous Pneumothorax: Ambulatory Management

There is an emerging body of evidence in the adult literature supporting the use of aspiration as the first-line intervention for large, asymptomatic primary spontaneous pneumothoraces and small, symptomatic primary spontaneous pneumothoraces.[72] The procedure involves aspiration by insertion of a 16- to 18-gauge cannula in the second ICS at the MCL connected to a 50-mL syringe and a 3-way stopcock. A 2007 Cochrane review identified only 1 study on this topic.[1] This randomized controlled trial compared needle aspiration versus chest tube insertion in 60 adult patients with a first episode of primary spontaneous pneumothorax.[80] No significant difference was found with regard to immediate success rate, early failure rate, duration of hospitalization, 1-year success rate, or number of patients requiring pleurodesis within 1 year. A more recent systematic review included 2 additional randomized controlled trials and concluded that needle aspiration was as safe and effective as tube thoracostomy in adults, with the added benefit of fewer hospital admissions and shorter length of stay.[81] Another adult retrospective study suggested that ambulatory management of a large spontaneous pneumothorax can be accomplished safely with placement of a pigtail catheter connected to a 1-way Heimlich valve.[82] The patients in the study were discharged

Figure 3. Management Of Pneumonia With Parapneumonic Effusion



Abbreviations: abx, antibiotics; CT, computed tomography; dx, diagnosis; IV, intravenous; US, ultrasound; VATS, video-assisted thoracoscopic surgery.
Reprinted from John S. Bradley, Carrie L. Byington, Samir S. Shah, et al. The Management of Community-Acquired Pneumonia in Infants and Children Older Than 3 Months of Age: Clinical Practice Guidelines by the Pediatric Infectious Diseases Society and the Infectious Diseases Society of America, *Clinical Infectious Diseases*. 2011, Volume 53, Issue 7, Pages e25-e76, by permission of Oxford University Press.

home and scheduled for a follow-up in 2 days. Upon follow-up, if the clinician was unable to perform manual aspiration and a confirmatory chest x-ray was negative for continued pneumothorax, then the catheter was withdrawn and the procedure considered a success. If aspiration was possible or the chest x-ray showed a persistent pneumothorax, then the patient was discharged home again for an additional outpatient follow-up. Patients who demonstrated continued failure of pneumothorax resolution were then hospitalized for suction and/or surgical intervention. The authors of that study noted a 78% success rate with outpatient management of the large spontaneous pneumothoraces that did not require hospitalization.[82] There have been no randomized controlled trials conducted in children with regard to needle aspiration or ambulatory pigtail catheter management for treatment of primary spontaneous pneumothorax.

Pigtail Versus Large-Caliber Tube Thoracostomy For Effusion/Empyema

Pigtail catheters have increased in popularity since their introduction in 1986 by Fuhrman et al.[66] A randomized trial published in 2002 used pigtail catheters in the treatment of empyema while investigating the use of intrapleural urokinase.[83] Since then, there have been at least 3 retrospective studies evaluating their use in parapneumonic effusion/empyema. A before-and-after study found that, compared to tube thoracostomy, pigtail catheter insertion was associated with decreased period of drain in situ, time to becoming afebrile, and procedure-to-discharge time, and the patients were less likely to require a secondary thoracotomy or tube repositioning/replacement.[84] A retrospective review of 43 patients aged 3 months to 18 years compared the use of 8.5F pigtail catheters placed using the Seldinger technique to that of larger-caliber chest tubes (12F-24F).[85] Soft pigtail catheters were associated with higher failure rates but shorter total duration of illness. There was no statistically significant difference in postprocedure analgesia duration or opioid dosing. The use of pigtail catheters for the treatment of parapneumonic effusion was also evaluated through a retrospective study of 32 children.[86] No significant difference in drainage days or length of stay was found between the chest tube and pigtail catheter group. Furthermore, the use of small-caliber tubes (12F) of stiff consistency proved adequate for drainage in 2 large, randomized controlled trials comparing operative versus nonoperative tube drainage with fibrinolytics.[45,46]

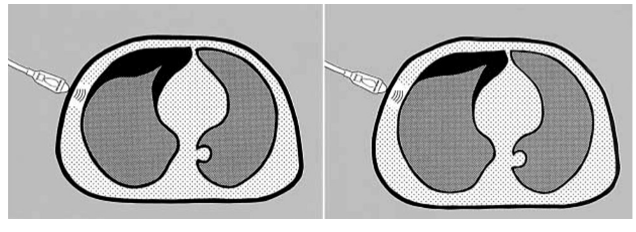
Ultrasound Guidance In Therapeutic Interventions In The Pleural Space

The use of ultrasound to aid in thoracic therapeutic interventions was first introduced in 1976.[87] A large, retrospective study in adults found that sonography allows for rapid localization of pleural fluid collections and instant monitoring of drainage of fluid collections and empyemas.[88] Ultrasound has been used to stage parapneumonic effusion in children and to help guide treatment modality. A retrospective study of 81 patients aged < 18 years found that ultrasound can discriminate the progressive stages of bacterial parapneumonic effusion.[89] With more-advanced stages of parapneumonic effusion (noted by the presence of fibrin septations or loculations) there is less of a chance that tube drainage will be successful. There is also evidence that ultrasound guidance decreases complications, and, thus, lowers the cost of care among adult patients undergoing thoracentesis.[90] A recent case series among pediatric patients described the successful use of ultrasound guidance for treatment of primary spontaneous pneumothorax with needle aspiration.[91] The "lung point" sign that was first studied prospectively in adult medical ICU patients, was used.[92] This technique allows for determination of pneumothorax resolution or re-expansion in real-time. **(See Figure 4.)** An anterior lung point (sternum to anterior axillary line) correlated with a small pneumothorax, whereas a posterior (posterior to posterior axillary line) or absent lung point correlated with a large pneumothorax.[92]

Disposition

Most patients with pleural space disease will require additional treatment and/or hospitalization beyond the care administered in the ED. An exception may be a patient with a small, asymptomatic primary spontaneous pneumothorax who is considered stable and reliable. In this instance, these patients can be observed in the ED for 3 to 6 hours with 12- to 24-hour follow-up and careful instructions to seek medical attention if new or worsening symptoms occur.[3,60] Interventional care of pneumothoraces that

Figure 4. A Theoretical Explanation Of The Lung Point



Left: at expiration, the pneumothorax has a defined volume on CT. A probe placed at a point slightly superior to the lung level will display a pneumothorax pattern. Right: at inspiration, the lung volume should slightly increase, therefore increasing the surface of the lung in contact with the wall. The probe remaining at the same location will thus display a fleeting pattern of lung, ie, lung sliding and/or B lines.

Reprinted from Springer and *Intensive Care Medicine*. Daniel Lichtenstein, The "lung point": an ultrasound sign specific to pneumothorax. 2000. Volume 26. Pages 1434-1440. Figure 6. With kind permission from Springer Science and Business Media.

Risk Management Pitfalls For Management Of Pleural Space Disease In Pediatric Patients

1. **"The pneumothorax in the patient with asthma was small and there were no symptoms, so I discharged to home."**
   Patients with an underlying lung disease should be admitted to the hospital for any size pneumothorax, regardless of symptomatology. There is a significant risk for worsening of their condition and subsequent need for pleural interventions.

2. **"The traumatic hemothorax seen on the chest x-ray was small, so I observed the patient without intervention."**
   All traumatic hemothoraces seen on chest radiography should be treated with tube thoracostomy. This will prevent further complications and respiratory/circulatory compromise. Tube thoracostomy in a patient with a hemothorax will allow for further monitoring of blood loss and help determine the need for surgical exploration.

3. **"There was no pneumothorax seen on a supine chest x-ray in this symptomatic trauma patient, so I ruled out any pneumothorax."**
   Supine chest x-ray is the least sensitive of the radiographic techniques in identifying a pneumothorax. All symptomatic patients should have an evaluation with either ultrasound and/or lateral decubitus chest radiography to more reliably rule out a pneumothorax.

4. **"I used nitrous oxide as sedation in preparation for chest tube placement."**
   Nitrous oxide should not be used as sedation in a patient with a pneumothorax, as it can enter the pleural space by diffusion and has been shown to cause an increase in the size of the pneumothorax.

5. **"I didn't place a chest tube for pneumothorax evacuation prior to air transport and they had to do it in the air under difficult conditions."**
   Sudden changes in atmospheric pressure (as experienced in air transport) increase the risk of tension physiology in a noncommunicating pneumothorax. Factors such as the patient's clinical status and symptoms, as well as the experience of the clinician must be used to determine whether chest tube placement is warranted. Transport without intervention may be considered as long as needle thoracostomy is readily available if deterioration ensues.

6. **"I evacuated a large pleural effusion seen on x-ray without obtaining any additional imaging."**
   A chest CT or ultrasound is recommended prior to any intervention to identify loculations in order to help determine the correct location and number of drainage sites needed.

7. **"I used suction to help evacuate a primary spontaneous pneumothorax."**
   The initial use of suction in primary spontaneous pneumothorax is not recommended due to the increased risk of re-expansion pulmonary edema. The preferred method is to attach the drainage tube to a water seal.

8. **"I treated a small parapneumonic effusion with oral antibiotics alone."**
   Both the Pediatric Infectious Diseases Society and the Infectious Diseases Society of America recommend intravenous antibiotics as the initial treatment of a small parapneumonic effusion.

9. **"I treated a second episode of spontaneous pneumothorax with evacuation and discharge to home without obtaining further workup or consultation."**
   Pediatric patients are much more likely to have an underlying predisposing factor compared to adults. Conditions leading to increased risk of spontaneous pneumothorax include cystic fibrosis, pneumonia, congenital lung cyst, and Marfan syndrome.

10. **"I did not consider surgical thoracotomy or blood transfusion with a large-volume output (> 20 mL/kg) of blood from a chest tube."**
    A large volume of hemorrhage from a chest tube suggests a significant injury that needs immediate life-saving action. Consideration should be given to surgical thoracotomy and/or blood transfusion. Autotransfusion is a safe alternative for blood transfusion in the appropriately selected patient, if performed correctly.

may be followed up as an outpatient include simple needle aspiration or placement of a pigtail catheter connected to a 1-way Heimlich valve, as long as the patient remains asymptomatic. Patients should be admitted to the hospital if they are symptomatic, deemed clinically unstable, identified as having a secondary spontaneous pneumothorax, sustained traumatically induced pneumo/hemothoraces, or if they require antibiotics for infectious effusion/empyema.

Summary

Primary Spontaneous Pneumothorax

Patients with a symptomatic small or asymptomatic large primary spontaneous pneumothorax will likely require initial interventional care. Although there is a paucity of pediatric literature on the subject, treatment options to consider for ambulatory management include needle aspiration or pigtail placement with connection to a 1-way Heimlich valve and close outpatient follow-up. Patients who continue to have symptoms or are clinically unstable should be admitted to the hospital with high-flow oxygen administration. For most patients with a small primary spontaneous pneumothorax without associated symptoms who are clinically stable, close outpatient follow-up is reasonable after a short period of observation in the ED. For patients who cannot reliably communicate symptoms (infants/toddlers and those with cognitive delay) or those with unreliable home environments, hospital observation with oxygen treatment is recommended.

Traumatic Hemothorax/Pneumothorax

For traumatically induced hemothoraces identified on initial chest radiography, the current standard of care is to perform a large-caliber tube thoracostomy followed by close monitoring in the hospital for continued blood loss. If readily visible on initial chest radiography, traumatic pneumothoraces may be treated with smaller-caliber pigtails. Asymptomatic occult pneumothoraces identified only on CT scan may be treated conservatively with in-hospital observation, even if mechanical ventilation is utilized for other purposes.

Parapneumonic Effusion/Empyema

Small effusions may be safely managed with intravenous antibiotics. Among the options for moderate symptomatic and large parapneumonic effusion/empyema, tube thoracostomy with a small-caliber (12F) chest drain and instillation of fibrinolytics is the most cost-effective treatment with comparable clinical efficacy. This procedure and treatment strategy is typically performed by interventional radiology at the discretion of the surgical subspecialist.

Time- And Cost-Effective Strategies

- Consider discharging a patient with a small, asymptomatic primary spontaneous pneumothorax home with outpatient follow-up. *Risk management caveat*: Be sure that the patient and family are reliable in obtaining close follow-up, and that the patient can adequately communicate new or worsening symptoms.
- Recommend chest tube insertion with fibrinolytics instead of VATS for empyema. Although the pediatric radiologist and surgeon have ultimate discretion when it comes to treatment for infectious empyema, there have been numerous articles detailing the cost savings of nonoperative management as a first-line therapy for pediatric empyema.
- Consider use of a pigtail in lieu of a large-caliber chest tube for treatment of air and fluid diseases of the pleural space. Pigtails have been associated with a decrease in the period of drain in situ, procedure-to-discharge time, and total duration of illness.

Case Conclusions

The 4-year-old boy involved in the motor vehicle crash, who was subsequently intubated and found to have an occult pneumothorax on chest CT, was stabilized and monitored in the pediatric intensive care unit. From your literature review, you recalled that an occult pneumothorax found in an otherwise stable patient does not necessarily need a thoracostomy. You found similar evidence to support observation in patients who are intubated, as long as their respiratory status remains stable. You elected to observe his respiratory status and withhold chest tube placement. He remained stable and did not require any further intervention involving his pleural space.

You performed a bedside ultrasound on the 14-year-old boy with cystic fibrosis and confirmed a small right-sided pneumothorax by noting the absence of lung sliding and B lines. You recalled that the sensitivity of ultrasound for finding a pneumothorax is 90.9% compared to only 50.2% by chest radiography. Additionally, a lung point was found at the anterior axillary line, suggesting a small pneumothorax. Due to the presence of respiratory symptoms, however, you elected to place a pigtail catheter to help evacuate the pneumothorax and admitted him to the hospital for further observation.

The 3-month-old girl was sent to radiology for an ultrasound to evaluate the parapneumonic effusion. The ultrasound confirmed the effusion and did not find any fibrin septations or loculations, suggesting the presence of a simple effusion. Based on the current Infectious Diseases Society of America guidelines for parapneumonic *effusion, you performed an ultrasound-guided pigtail placement without fibrinolytics. She was then admitted to the hospital for intravenous antibiotics.*

References

Evidence-based medicine requires a critical appraisal of the literature based upon study methodology and number of subjects. Not all references are equally robust. The findings of a large, prospective, randomized, and blinded trial should carry more weight than a case report.

To help the reader judge the strength of each reference, pertinent information about the study, such as the type of study and the number of patients in the study will be included in bold type following the references, where available. The most informative references cited in this paper, as determined by the author, will be noted by an asterisk (*) next to the number of the reference.

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1. **You receive a call from a remote outside hospital about a patient with a large, symptomatic secondary spontaneous pneumothorax. The treating physician has little to no experience in treating children and is seeking your expert advice. Which of the following recommendations would be considered best practice?**
   a. Immediate transport by helicopter, without intervention
   b. Transfer by helicopter, following sedation with nitrous oxide prior to pigtail placement
   c. Transfer by helicopter following pigtail placement
   d. Needle aspiration and, if the patient remains asymptomatic, arrange for close outpatient follow-up

2. **An asymptomatic patient with a large primary spontaneous pneumothorax had needle aspiration performed and was sent home. He returns to the ED with re-expansion of the pneumothorax. Which of the following would provide the most useful diagnostic information to help identify an underlying cause?**
   a. Ultrasound lung point sign
   b. Supine chest radiography
   c. Upright anterior-posterior chest radiography
   d. Chest CT

3. **The diagnosis of a pneumothorax by ultrasound is confirmed by which of the following?**
   a. Absence of both lung sliding and B lines
   b. Presence of both lung sliding and B lines
   c. Absence of lung sliding and presence of B lines
   d. Presence of lung sliding and absence of B lines

4. **A 1-year-old girl is brought to the ED and is found to have a small, asymptomatic primary spontaneous pneumothorax. What is the most appropriate management strategy for this patient?**
   a. Hospital admission with observation
   b. ED observation and outpatient follow-up if she remains stable
   c. Needle aspiration and outpatient follow-up
   d. Pigtail catheter placement with connection to a 1-way valve and outpatient follow-up

5. **A patient has a traumatically induced pneumothorax that was not visualized on initial supine chest radiography. Which of the following regarding management of the traumatic, occult pneumothorax is TRUE?**
   a. Tube thoracostomy is always indicated.
   b. Observation may be a safe alternative as long as the patient is stable.
   c. Tube thoracostomy is indicated if mechanical ventilation is required.
   d. Tube thoracostomy is unnecessary because the pneumothorax size is small.

6. **A patient presents to your ED after falling from a tree. Initial supine chest radiography identifies a small hemothorax. The patient is otherwise stable. What is the best course of action?**
   a. Needle thoracentesis
   b. Placement of a small-caliber pigtail catheter
   c. Hospital admission with observation
   d. Large-caliber tube thoracostomy

7. **A patient is found to have a large parapneumonic effusion by chest radiography. Ultrasound identifies a loculated collection of fluid. Which of the following is the most appropriate therapy?**
   a. Tube thoracostomy with fibrinolytics
   b. Tube thoracostomy alone
   c. Needle thoracentesis and intravenous antibiotics
   d. Intravenous antibiotics alone

8. **What is the most appropriate management for an asymptomatic patient with Marfan syndrome who presents with a small pneumothorax?**
   a. Observation in the ED and close outpatient follow-up
   b. Admission for observation in the hospital
   c. Placement of a small pigtail catheter and hospital admission
   d. Needle aspiration and hospital admission

9. **You perform needle aspiration in an asymptomatic patient with a large pneumothorax. In which of the following situations would you consider sending the patient home with outpatient follow-up?**
   a. The patient develops a cough after the procedure
   b. The patient has unreliable follow-up
   c. The patient has a remote history of asthma
   d. None of the above

10. **The size of a pneumothorax correlates to the location of the lung point on bedside ultrasound. Which of the following locations of the lung point would indicate a large pneumothorax?**
   a. Midclavicular line
   b. Anterior axillary line
   c. Posterior axillary line
   d. Lateral sternum

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Management Of Fever In Pediatric Patients With Central Venous Catheters

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The use of indwelling central venous catheters (CVCs) is essential for pediatric patients who require hemodialysis, parenteral nutrition, chemotherapy, or other medications. Fever is a common chief complaint in the emergency department, and fever in a patient with a CVC may be related to a common cause of fever, or it may be due to a catheter-associated bloodstream infection. Catheter-associated bloodstream infections may also lead to additional complications such as sepsis, septic shock, or septic complications including suppurative thrombophlebitis, endocarditis, osteomyelitis, septic emboli, and abscesses. Early evaluation, with close attention to the patient's airway, breathing, and circulation, is essential. Early resuscitation, along with timely and appropriate antibiotic therapy, has been shown to improve outcomes. This issue focuses on the approach to fever in pediatric patients with CVCs and the management and disposition of patients with possible catheter-associated bloodstream infections.

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- Patients with a CVC presenting with fever should be evaluated promptly, and antibiotics and other resuscitative measures should be administered within the first hour. This has been shown to improve outcomes, but will also decrease the time to appropriate disposition from the ED.
- The routine use of imaging is not indicated in most patients with a CVC presenting with fever. Imaging should be ordered selectively based on history and physical examination.
- Well-appearing, nonneutropenic oncology patients with a CVC may not require admission when they present with fever if appropriate follow-up can be ensured.
- Developing protocols to standardize the triage and immediate evaluation of these patients may save both time and money.
- Early consultation with subspecialty services may improve the time to definitive treatment and disposition.

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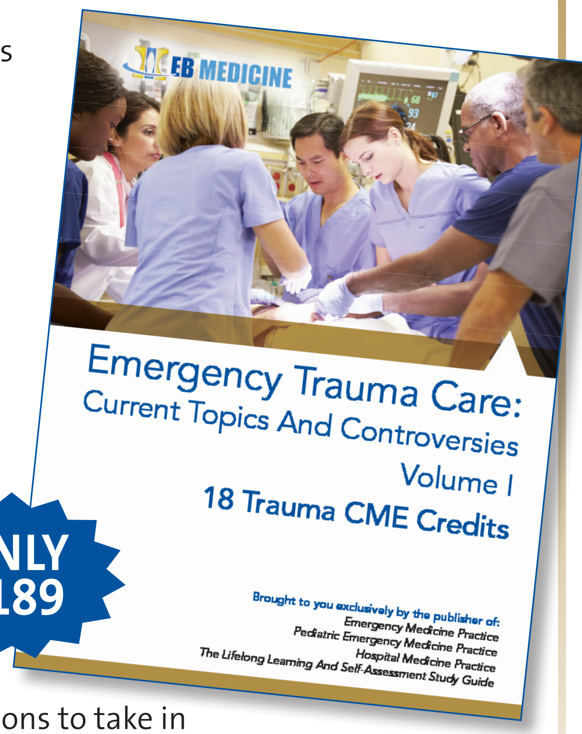

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