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REVIEWS

Managing Iatrogenic Pneumothorax and Chest Tubes

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Iatrogenic pneumothorax has become an increasingly recognized complication of routine outpatient procedures, such as transthoracic needle biopsies of the lung and transbronchial lung biopsies. Patients with clinically significant pneumothorax are typically managed with evacuation via a percutaneously placed catheter or chest tube. Tube thoracotomy and chest tube management have traditionally been performed by cardiothoracic surgeons; however, with the increasing number of interventional radiologists and interventional pulmonologists, more chest tubes are being placed by specialists who do not admit and manage patients in the hospital setting. The responsibility for the admission of these patients to the hospital service has fallen to the internist. Hospitalists caring for such patients are often expected to manage the chest tube. General internal medicine training and the existing medical literature provide few guidelines to assist with this issue. We present a discussion of the current published literature and our management algorithms for hospitalists caring for patients admitted with iatrogenic pneumothorax. *Journal of Hospital Medicine* 2013;8:402–408. © 2013 Society of Hospital Medicine

A pneumothorax is a collection of air in the space outside the lungs that is trapped within the thorax. This abnormality can occur spontaneously or as the result of trauma. Traumatic pneumothoraces include those resulting from medical interventions such as a transthoracic and transbronchial needle biopsy, central line placement, and positive-pressure mechanical ventilation. This group is most accurately described as iatrogenic pneumothorax (IP).[1]

IP can be an expected complication of many routine thoracic procedures, but it can also occur accidentally during procedures near the lung or thoracic cavity. Some IPs may be asymptomatic and go undiagnosed, or their diagnosis may be delayed.[2] The majority of iatrogenic pneumothoraces will resolve without complications, and patients will not require medical attention. A small percentage can, however, expand and have the potential to develop into a tension pneumothorax causing severe respiratory distress and mediastinal shift.[3,4]

The incidence of IP ranges from 0.11% with mechanical ventilation to 2.68% with thoracentesis, according to an analysis of 7.5 million uniform hospital discharge abstracts from 2000.[5] A 2010 systematic review of 24 studies that included 6605 patients suggested a 6.0% incidence of pneumothorax following thoracentesis.[3] The highest risk of IP is seen with computed tomography (CT)-guided lung biopsy, with 1 series of 1098 biopsies showing a 42% incidence; chest tube evacuation was required in 12% of these cases.[4] A Veterans Administration study of patient safety indicators from 2001 to 2004 found that risk-adjusted rates of IP were increasing over time.[6] It is unclear whether this increase is due to increasing numbers of interventional procedures or to better rates of detection. IP poses a considerable cost to the medical system, with safety studies finding that patients with IP will stay in the hospital approximately 4 days longer and incur an additional $17,000 in charges.[7]

In addition to this financial burden, the lack of consistency in training and guidelines for management of pneumothorax is thought to add to chest tube-related complications.[8] In 2001, the American College of Chest Physicians (ACCP) published guidelines for the management of spontaneous pneumothorax that do not specifically address IP.[9] In 2010, the British Thoracic Society (BTS) updated their guidelines and included a brief statement on IP that described a higher incidence for it than for spontaneous pneumothorax and noted its relative ease of management.[10] Despite the lack of specific guidelines dedicated to IPs, common clinical practice is to manage iatrogenic defects in a manner similar to that for spontaneous ones. However, studies have shown that the management of pneumothorax remains diverse and that the adherence to these published guidelines is suboptimal.[10,11] The BTS guidelines favor needle aspiration as the first-line treatment,[10] whereas the ACCP recommends drainage with catheters over aspiration.[9]

The possibility of this complication, along with the rising rate of invasive interventions being performed, has led to expanded surveillance criteria for IP. Surveillance imaging, clinical observation, or a combination

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of the 2 may be required, depending on the institution, the risk of the procedure, and the preference of the treating clinician. The algorithms presented here were designed in alignment with both major society guidelines and with the intention of simplifying the treatment regimen for the ease of adoption by hospitalists.

ETIOLOGY AND RISK FACTORS

The etiology and risk factors for IP are multiple, with the most common being interventional-based procedures. In 535 Veterans Administration patients, the most common precursor procedures were transthoracic needle biopsy (24%), subclavian vein catheterization (22%), thoracentesis (20%), transbronchial biopsy (10%), pleural biopsy (8%), and positive pressure ventilation.[12] IP can also be a rare complication of pacemaker manipulations,[5] and less commonly, bronchoscopy.[13] Patient factors that increase the risk of pneumothorax in the setting of an intervention include age, chronic obstructive lung disease, primary lung cancer, malignant and parapneumonic pleural effusions, empyema, and chronic corticosteroid use.[4] As might be expected, patients with structural lung disease (eg, emphysema with bullae) and poor healing ability (eg, corticosteroid dependent), tend to have IPs more often and to require more complicated interventions for resolution.[14,15] In some studies, operator experience seems to be inversely related to the rate of IP, and the use of ultrasound is correlated with lower rates of this complication.[1,3]

PATIENT PRESENTATIONS AND DIAGNOSIS

Clinical signs and symptoms of a significant pneumothorax vary in severity but most often include dyspnea, tachypnea, chest pain, and pleurisy (see Box 1). Post procedure signs or symptoms require further evaluation with imaging, usually a plain chest radiograph. CT can be useful for further evaluation. Small anterior pneumothoraces may be difficult to detect without lateral radiographic imaging or computed tomogram. Ultrasound is being used more frequently at the bedside to make this diagnosis, and various studies of trauma patients have found that it has good sensitivity and specificity.[16,17] These results have been validated by a recent meta-analysis comparing ultrasound to chest radiographs for the detection of pneumothorax among trauma, critically ill, and postprocedural patients.[18] This study demonstrated superior sensitivity and similar specificity for ultrasound versus chest radiographs for detection of pneumothorax. More ominous signs, such as tachycardia or hypotension, can be indicative of tension pneumothorax, which requires emergent evacuation.

Box 1: Clinical Signs and Symptoms of Pneumothorax

Dyspnea
- Pleuritic chest pain
- Tachypnea
- Hypoxia
- Decreased breath sounds on affected side
- Hyper-resonant percussion on affected side
- Subcutaneous emphysema

MANAGEMENT

Once the diagnosis of pneumothorax has been established, treatment options should be guided by defect size and clinical assessment following a defined treatment algorithm (Figure 1). As emphasized by the BTS and ACCP guidelines, we advocate considering the use of symptoms along with defect size to determine the best management course.

Observation

Defects that involve<20% of the hemithorax in a patient who is clinically asymptomatic and hemodynamically stable can be safely managed by oxygen supplementation and hospital observation. Repeat imaging can be obtained after 12 to 24 hours of defect detection or with symptom change. Patients who display resolution may be discharged home.

Patients who show persistence without progression but are asymptomatic may also be discharged safely, with follow-up imaging and clinical evaluation 48 hours later.[9,10] This was demonstrated by Kelly and colleagues,[19] who described the outcomes of 154 patients in a retrospective cohort study. Of the 91 patients treated with outpatient observation, 82 resolved without additional interventions. A recent review article by the same author cites conservative management of small pneumothoraces as being widely accepted.[20] If reimaging shows progression of defect or if the patient becomes more symptomatic, the pneumothorax should be evacuated by 1 of the methods described below.

Aspiration

Aspiration is defined by the ACCP Delphi consensus statement as the removal of pleural air via needle or cannula followed by immediate removal of needle or cannula.[9] This option mandates careful patient selection. It should be considered for small pneumothoraces that cause only mild dyspnea in patients who have no known parenchymal disease. These patients should be observed overnight in the hospital and reimaged 24 hours after aspiration of the pneumothorax. Several authors have reported success with aspiration alone. Yamagami et al.[21] noted the efficacy of manual aspiration immediately after CT-guided biopsy, with a success rate exceeding 90%. They also noted that evacuated volumes >543 mL correlated with the need for further intervention with a chest tube. This technique is advocated for small pneumothoraces that are recognized shortly after the procedure.

Similarly, Delius and colleagues[22] managed 131 pneumothoraces with aspiration as an alternative to

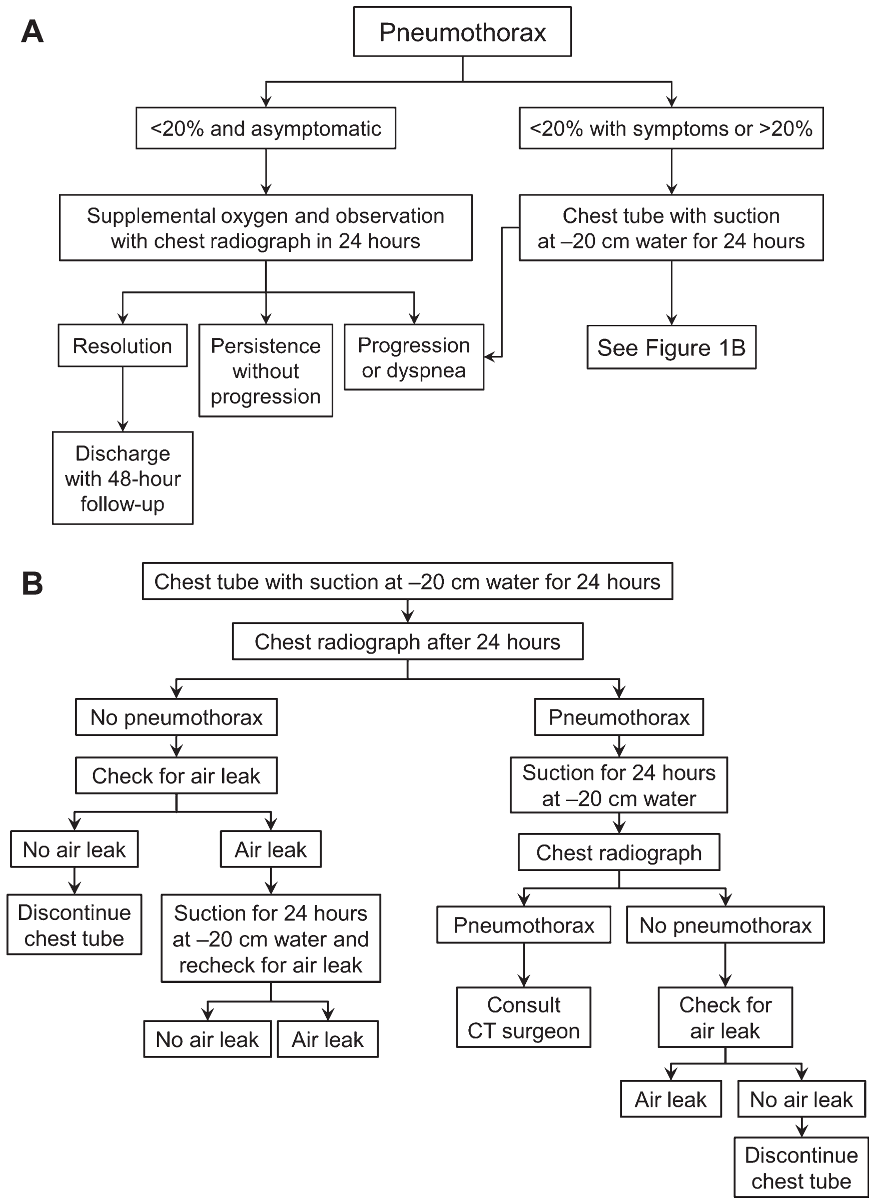

FIG. 1. Initial management of iatrogenic pneumothorax. (A) Chest tube evacuation depends on defect size, symptoms, and progression at 24 hours. (B) Chest tube management of iatrogenic pneumothorax. Abbreviations: CT, cardiothoracic.

chest tube placement. Of these, 79 were iatrogenic. Aspiration achieved a 75% success rate for all IPs. Small defects defined as <20% of volume had an even higher resolution rate of 87%. Similar findings were demonstrated by Talbot-Stern et al.[23] in their prospective study of 76 pneumothoraces. Among those that were iatrogenic, 82% resolved after simple aspiration. Faruqi et al.[24] also showed that aspiration is a viable option for IPs. Of the 57 patients with pneumothorax included in their study, 35 were treated with aspiration alone. Iatrogenesis was the culprit in 12 of the 35 manually aspirated cases. Aspiration achieved a success rate of 91.7% in IP. A recent Cochrane database systematic review compared simple aspiration with intercostal tube drainage for primary spontaneous pneumothorax.[25] The authors reported no difference between these methods in terms of success rate, early failure rate, duration of hospital stay, 1-year success rate, or number of patients who required pleurodesis at 1-year follow-up.

Because the algorithms presented in this article were specifically designed for the use by hospitalists, we intentionally omitted aspiration from the decision trees. Most hospitalists would not be expected to evacuate IPs. However, knowledge regarding this option and appropriate follow-up are valuable to internists, because many interventionalists admit patients to the hospital service for overnight observation. An asymptomatic postaspiration patient, who on subsequent imaging demonstrates resolution or persistence without progression of pneumothorax, may be discharged with 48-hour follow-up.

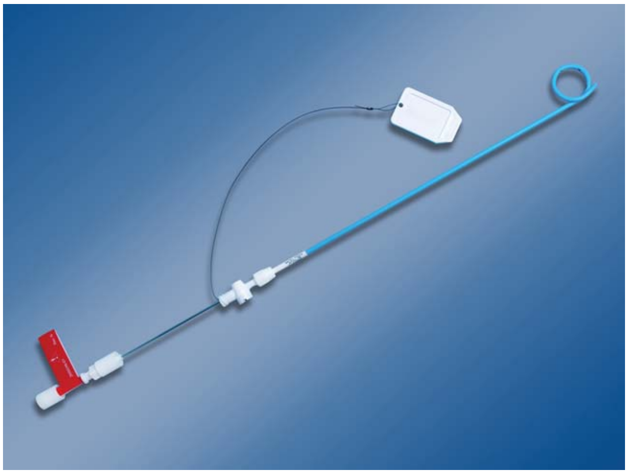

FIG. 2. Example of pigtail catheter. Medi-tech (Boston Scientific Corp, Natick, MA) pigtail catheters are 1 of the small, percutaneously placed drainage devices available for smaller, uncomplicated pneumothoraces.

Placement of Catheter or Chest Tube Drainage

Most patients with a clinically significant pneumothorax will require evacuation of the air. Pneumothoraces larger than 20% or that produce symptoms warrant chest tube management and inpatient observation (Figure 1B). Traditionally, large tubes with −20 cm of water on continuous suction are used and have been studied the most widely. Several authors have shown that smaller tubes can effectively drain a pneumothorax.[26–29] Small-bore catheters (8F–14F), which can be inserted percutaneously, have been shown to provide effective lung re-expansion with minimal morbidity[8] and may be better tolerated by patients with uncomplicated pneumothoraces (Figure 2). Terzi and colleagues[30] have shown that smaller tubes cause less discomfort to patients at rest, with cough, and at the time of tube removal.

At most US institutions, catheters and chest tubes are connected to all-purpose drainage systems. Although commercially available through a variety of manufacturers, they share similar design principles because they replicate the 3-bottle system described in detail elsewhere in the literature.[31] We have limited our discussion to 3 pleural evacuation systems because it is our intention to familiarize hospitalists with the units that they are most likely to encounter. The first 2 systems have been studied and described by Baumann and colleagues[32] as being commonplace and reasonably reliable. These include the Oasis (Atrium Medical Corp., Hudson, NH) (Figure 3A) and the Pleur-evac (Teleflex Inc., Limerick, PA). The third unit is the Thopaz digital thoracic drainage system (Medela Inc., McHenry, IL) (Figure 3B). The Thopaz is unique in its inclusion of a suction source and digital capability. Although it utilizes the same principles of all pleural evacuation devices, its setup and information output require that one be familiar with its digital format.

Suction Versus Water Seal

The chest tube should be placed initially to a suction pressure level of −20 cm of water for 24 hours to maximize lung expansion and evacuate all extrapulmonary air. Suction pressure is set on the Pleur-evac and Atrium drainage systems by a manual dial that reads to a water pressure of 0 to −40 cm. The default setting from the manufacturer is −20 cm of water. This level of suction is present only when the drainage system is connected to a wall or a portable suction device. The only confirmation of suction presence in the Atrium system is the deployment of the orange bellows (located under the dial) to the level of the arrow tip (Figure 3A). The Pleur-evac system has a red stripe along the circular edge of the dial that appears at the set level of suction when negative pressure is being applied. It is important to be aware that when patients are disconnected from the wall or the portable suction apparatus, they are on *water seal* or *gravity*. These terms are synonymous with no suction. On the Thopaz, a digital menu directs operation, and levels of suction can be selected from water seal (no suction) up to −40 cm of water. We recommend using suction to −20 cm of water given the scarce evidence supporting higher levels of negative pressure. Some clinicians prefer placing patients on water seal for some time before moving toward tube discontinuance, but this is a matter of preference, and no substantial evidence exists to show that any 1 method is superior.[8,33]

Assessing for Air Leak

If there is improvement or resolution of the pneumothorax after 24 hours, the presence of an air leak should be assessed; if no leak is present, the chest tube can be safely removed. In the context of chest tubes, the term *air leak* refers to residual air between the lung and the chest wall. It is possible to see

FIG. 3. Drainage systems for pneumothorax. (A) Atrium Oasis drainage system. This multiple-chamber drainage device allows for controlling the level of suction applied from −8 to −40 cm H_2O pressure (indicated by the letter A in the figure), a water seal chamber (indicated by the letter B in the figure), air leak detection by funneling air through a column of contained water (indicated by the letter C in the figure), quantification of total fluid collection (indicated by the letter D in the figure), and visual evidence of active suction pull with orange-colored bellows (indicated by the letter E in the figure). (B) Thopaz digital drainage system. This portable suction unit, with its accompanying collection container (at left), allows greater mobilization of patients (used with permission of Medela Inc., McHenry, IL).

resolution of a pneumothorax on chest radiographs and still have an air leak. This situation is created by a perfect balance between the pleural air evacuation by the catheter and the flow of air exiting from the lung puncture. This would result in reaccumulation of the pneumothorax if the chest tube is removed prematurely. It should also be kept in mind that chest radiographs may miss a small pneumothorax given their relatively low sensitivity.[18] Therefore, the absence of an air leak needs to be documented before the chest tube is discontinued. Depending on the type of drainage system (Atrium, Pleur-evac, or Thopaz), this assessment can be done in several ways. All systems can be assessed for air leak by clamping the actual chest tube for 2 to 4 hours and then repeating the chest radiograph. Clamping a chest tube simulates the condition of not having a chest tube. Chest tubes should never be clamped without supervision and only with the knowledge of nursing personnel. The onset of chest pain or dyspnea in a patient with a clamped tube mandates immediate removal of the clamp and a return to suction. A repeat chest radiograph showing reaccumulation or expansion of the pneumothorax after clamping indicates that the air leak has not resolved and the chest tube must remain in place and returned to suction. Simpler and more time-efficient methods of detecting air leaks are available with both cardiothoracic drainage systems.

For the Atrium and Pleur-evac models, there is a graded panel through which one can visualize air leaks being funneled through water (Figure 4A). Having the patient cough several times or perform a Valsalva maneuver should release any air trapped within the chest into this chamber, where bubbles can be visualized as they travel through the water. The presence of bubbles indicates the presence of residual air in the chest, pointing to a possible leak. In contrast, the Thopaz system offers a graphical display of the air flowing into the system that can be reviewed over the 24-hour period. When the graph line reaches a 0 flatline graph, no airflow is being detected and no air leakage is suspected (Figure 4B). If no air leaks are detected, the chest tube may be discontinued. Those patients with a failed air leak test should have their chest tubes continued under suction for another 24 hours, with the above tests then repeated. The same holds true for those patients with persistent pneumothorax at 24 hours.

Removal of chest tubes is a simple process that requires the tube to be pulled out of the patient without allowing air to enter the site where the tube was present and where it entered the thorax. Most interventionalists will discontinue the tubes that they have placed. Some small catheters have an internal string that has to be released so the catheter will "straighten" and pull out easily. Knowledge of the type of catheter or tube that was placed is critical before removal to prevent complications and patient discomfort. Standard chest tubes are straight, smooth plastic and pull out easily but require rapid occlusion of the larger puncture site in the chest wall with an occlusive dressing that often includes petroleum or water-soluble gel. Some physicians will leave a suture tie when placing the chest tube so that it can be tied down to occlude the site instead of using a dressing.

FIG. 4. Assessment of air leaks. (A) Air leak detection chamber of the Atrium Oasis drainage system showing a failed air leak test. The air leak is characterized by the presence of bubbles in the water. The graduated system allows for monitoring of the air leak. A high leak is represented by the number 5 and a low leak by the number 1. The absence of bubbles represents the absence of an air leak. (B) Graphical data readout of the Thopaz digital drainage system. The graphical data allow for objective assessment of air leaks over time, potentially decreasing interobserver variability and misinterpretation of information. A flatline graph represents the absence of an air leak (used with permission of Medela Inc., McHenry, IL).

Consultation of the Cardiothoracic Surgeon or Interventional Pulmonologist

We recommend the involvement of cardiothoracic surgery or interventional pulmonology for patients with nonresolving pneumothorax lasting longer than 48 hours because additional procedures may be necessary. One of the rare but serious complications of a persistent pneumothorax is the formation of a bronchopleural fistula. This communication between the bronchial tree and the pleural space can lead to significant morbidity and mortality. The treatment of a bronchopleural fistula includes medical and surgical options that are beyond the scope of this article but require the expertise of a cardiothoracic surgeon or interventional pulmonologist.[34] Most patients who will not require additional procedures will heal within 48 hours.[11,35] Decisions regarding more invasive treatment measures can then be made as necessary.[26]

PRACTICAL TIPS

Hospitalists caring for patients with chest tubes are often asked to troubleshoot at the bedside. Scenarios that may be encountered include nonfunctioning tubes, catheter migration, and tube discomfort. Ensuring patency of the tube entails visualizing the tube from the point of entry into the chest wall to the collection chamber and inspecting for kinks or debris clogging the tube. Smaller catheters can be easily kinked during patient positioning and can become clogged. Respiratory variation, which is the movement of the column of fluid in the collection chamber or in the tubing with inspiration and expiration, suggests that the chest tube is patent. This should be part of the daily examination in a patient with a chest tube, and it should also be the first step in assessing sudden dyspnea, hypoxia, pain, or hemodynamic instability. Clogged tubes should be referred to the interventionalists or other physicians who placed them. Chest tubes are typically sutured at the site of entry and securely bandaged to avoid migration but occasionally can be dislodged. This should prompt placement of another tube by an experienced operator. Last, chest tubes can be uncomfortable for patients who may require systemic analgesics. Additionally, tube positioning may ease some of the discomfort. Chest tubes are commonly placed along the midaxillary line and the posterior thorax, leading to discomfort in the recumbent position. Directing the tube anteriorly helps ease some of the discomfort. This can be done using all-purpose sponges to build a barrier between the skin and the chest tube as it is directed anteriorly. Additional sponges are placed above the tube for extra protection. The gentle curve accomplished by padding the underside of the tube also keeps the tube patent by avoiding sharp kinks as the catheter exits the thorax.

FUTURE TRENDS

Future trends in the management of IP may include shorter duration of tube management (1–4 hours of suction with air leak evaluation and removal) and the use of even smaller catheters. Outpatient management of IP with small pigtail catheters or small-caliber tubes in addition to 1-way valves is also being investigated. The benefits of these practices may include greater patient comfort and lower cost. These approaches will need larger-scale replication and careful patient selection before they become standard practice.[28,36]

Ultrasound can be used to assess the presence and size of pneumothoraces that are difficult to visualize by standard chest radiographs. Several studies have established ultrasonography as an effective method of diagnosing pneumothorax and have shown it to have superior sensitivity compared with chest radiography.[1,18] In the future, the use of ultrasound will likely be more widespread given its performance, portability, ease of use, and relatively low cost.

SUMMARY

IP is a known and costly complication of many medical procedures. The aforementioned algorithms help simplify the management of chest tubes for hospitalists caring for patients with this common complication. This stepwise approach may not only help curtail added expenses related to IPs by decreasing the length of inpatient stays but may also improve patient satisfaction.

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