Straightening Out Chest Tubes
What Size, What Type, and When

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KEYWORDS

- Chest tube • Tube thoracostomy • Small-bore chest tube • Large-bore chest tube • Pneumothorax
- Pleural effusion • Empyema • Hemothorax

KEY POINTS

- Although chest tubes range in size (6–40 French [Fr]) and shape (straight tubes vs pigtail catheters), small-bore tubes (<14 Fr) are effective for most pleural processes.
- Various types of pneumothorax and malignant and infected complicated pleural effusions have been successfully managed with small-bore chest tubes. Benefits of the smaller size include patient comfort and ease of placement.
- Large-bore chest tubes may be necessary for barotrauma-associated pneumothoraces in mechanically ventilated patients and in the postoperative setting. However, abundant literature supports a paradigm shift towards the more routine use of small-bore chest tubes for managing pleural disease.
- The Seldinger technique can be used for placement of small and large-bore chest tubes and ultrasound guidance is recommended.

Chest tube placement is one of the most common procedures performed to manage pleural disorders. The main purpose of tube thoracostomy is evacuation of air or fluid from the pleural cavity. Hippocrates first described its use in the fifth century BC for the treatment of empyema.[1] In 1876, Hewett[2] described the use of a bottle as a closed chest tube drainage system for management of empyema. Since then, chest tube design, methods of insertion, and drainage systems have evolved significantly.

Although chest tube placement is straightforward, it may be associated with significant morbidity and mortality. According to the United Kingdom National Patient Safety Agency, 12 deaths and 15 cases of serious harm occurred from chest tube placement in the United Kingdom between 2005 and 2008.[3] A survey of the hospitals in the United Kingdom also found a very high complication rate from chest tube placement, and stressed the importance of informed consent and proper training.[4] Thus, a need exists for enhancing the knowledge of various types of chest tubes and their placement techniques.

GUIDING CHEST TUBE PLACEMENT

Chest tubes are hollow cylindrical plastic catheters with drainage side holes designed for placement within the pleural cavity. Usually a radiopaque strip is present on the side of the chest tube to assist in visualization on chest radiographs. The most proximal hole of the chest tube, sentinel eye, is usually situated on this strip and visible on the chest radiograph as a defect in the line; this helps ensure that all drainage holes are inside the pleural cavity. Length markings on the tube note the distance of the sentinel eye from the skin insertion site.

Chest tubes should be inserted into the "triangle of safety,"[3] an area bordered anteriorly by the lateral border of the pectoralis major, posteriorly by the lateral border of the latissimus dorsi, and inferiorly by a horizontal line at the level of the fifth intercostal space (Fig. 1). Staying in this triangle prevents injury to underlying vessels and organs. The chest tubes may be directed differently depending on the pathologic process. For pneumothorax, the tube is often aimed anterior and apical; for drainage of fluid, it is often directed posterior and basilar. For loculated effusions, the chest tube placement may be dictated by the location of the fluid.

Although various methods are used to correctly position chest tubes, including physical examination, fluoroscopy, and computed tomography (CT) scan, ultrasound is becoming increasingly popular to ensure proper placement. Ultrasound improves successful placement of the chest tube, especially in loculated pockets of pleural fluid.[5–7] Based largely on extrapolation of data from thoracentesis literature, ultrasound is believed to decrease the risk of chest tube misplacement or injury to surrounding organs.[8–12] The British Thoracic Society (BTS) pleural disease guidelines strongly recommend the use of ultrasound guidance for chest tube placement.[3]

CHEST TUBE TYPES BASED ON INSERTION TECHNIQUE

Chest tubes can be classified based on their method of insertion (Table 1), including blunt dissection into the pleura (Fig. 2), the Seldinger guidewire technique (Figs. 3 and 4), and the trocar

| Table 1 Chest tube methods of insertion and size	
Chest tube insertion methods	Blunt dissection Seldinger technique Placement by trocar
Chest tube sizes	Small-bore chest tube ($\leq$14 French) Large-bore chest tube (>14 French)

technique (Fig. 5). For various reasons, including a trend towards the use of smaller chest tubes and because of increased patient comfort, the Seldinger technique is becoming more popular in many institutions.

Blunt Dissection

Blunt dissection is the oldest technique for chest tube insertion. Using sterile technique and local anesthesia, an incision is made in the skin and subcutaneous tissue, parallel to the rib. The subcutaneous tissue and intercostal muscles are dissected and the pleural space is entered above the rib with the help of a clamp. Digital palpation of the pleural space is often performed and then the distal end of the chest tube is grasped with the clamp and directed into the pleural space.[3] The main advantages of this method include the ability to perform digital exploration in the pleural space, assessing for loculations and proper positioning, and the ability to direct the tube into the most appropriate position within the thoracic cavity. However, compared with the other techniques, this method is more painful, requires

Fig. 1. Triangle of safety bordered by the pectoralis major, the latissimus dorsi, and a line at the level of the fifth intercostal space.

Fig. 2. A large-bore straight chest tube and instruments used for placement by blunt dissection (36-French, Argyle Straight Thoracic Catheter, Covidien, Mansfield, MA, USA; scissors; scalpel; forceps).
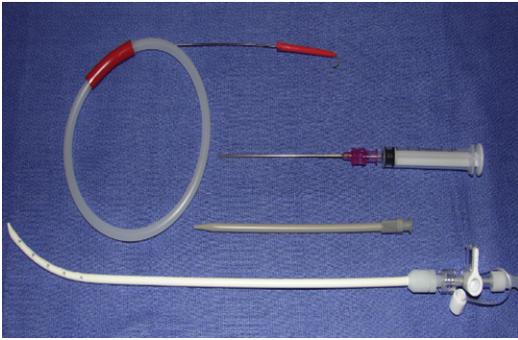
Fig. 3. A small-bore pigtail chest tube, commonly placed using the Seldinger technique (14-French, Wayne Pneumothorax Set, Cook Medical Inc, Bloomington, IN, USA; Guidewire; needle; dilator; chest tube).

a larger incision, and leaves a bigger scar after the tube is removed.

Seldinger Technique

Chest tubes placed by the Seldinger technique are placed with the help of a guidewire, and conceptually entail a similar process as central venous line placement. While using sterile technique and topical anesthesia, a needle is inserted into the pleural space with aspiration of fluid or air into a syringe. Thereafter, the guidewire is advanced through the needle, which is subsequently removed. One or more dilators are placed over the guidewire and advanced until a sensation of "give way" is felt on entry into the pleural space. The dilator is then removed and the chest tube, which is loaded on a stylet, is passed over the wire into the pleural space. On entering the pleural space, the chest tube is advanced into the pleural
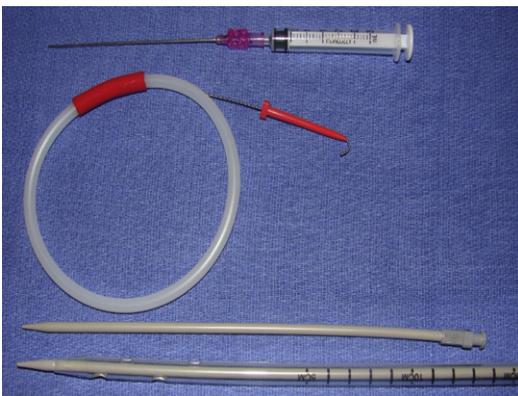
Fig. 4. A large-bore straight chest tube placed using the Seldinger technique (24-French, Thal-Quick Chest Tube, Cook Medical Inc, Bloomington, IN, USA; Needle; guidewire; dilator; chest tube).

Fig. 5. Trocar straight chest tubes (24-French and 10-French, Argyle Trocar Catheter, Covidien, Mansfield, MA, USA). Note the sharp metal tip at the insertion ends.

space, the stylet is removed, and the tube is secured and attached to a drainage apparatus.[3] This technique may be used for both small and large chest tubes. The main advantages of this technique include the smaller incision, minimal tissue dissection resulting in less pain for the patient, and a more aesthetic scar after removal of the tube. Disadvantages include an inability to digitally manipulate the pleural space and limited ability to direct the tube to an exact location in the pleural space.

Trocar Placement

In this technique, a sharp-tipped rod (the trocar) is passed through the chest tube and then used to pierce the pleural space. An incision is made in the skin and subcutaneous tissue and the trocar/tube combination is pushed into the pleural space. The chest tube is left in the pleural space and the trocar withdrawn. Although technically simple, this "harpoon" technique has a high risk of complications, mainly because of the danger of impaling the lung or surrounding organs.[3,13–15] Hence, in the authors' opinion, these tubes are not recommended for routine use.

CHEST TUBE SIZE AND CONFIGURATION

Chest tubes come in a variety of sizes based on the external diameter, ranging from 6 to 40 French (Fr). One French is equal to one-third millimeter, and thus a 9-Fr chest tube is 3 mm in diameter. Broadly speaking, chest tubes may be straight or coiled at the end ("pig-tail"). Tunneled pleural catheters, discussed elsewhere in this issue by Myers and Michaud, are chest tubes used for out-patient long term management of pleural effusions and are tunneled to prevent dislodgement and infection. In the context of nonmalignant pleural disease, chest tubes are typically placed for hours or days. By convention, as shown in **Table 1**, a small-bore chest tube (SBCT) is typically 14 Fr or smaller, whereas a large-bore chest tube (LBCT) is typically

more than 14 Fr in diameter. SBCTs are typically placed using the Seldinger technique, whereas LBCTs can be placed with dissection or using the Seldinger technique or a trocar.

ADVANTAGES AND DISADVANTAGES OF SMALL-BORE CHEST TUBES

SBCTs accounted for 7% of the chest tubes placed at a university health care system in the early 1990s.[16] However, the use of SBCTs is currently increasing.[17] Because of the smaller size, less to no dissection is required, and thus insertion tends to be less painful. Furthermore, the small incision usually causes less scar formation and typically does not require suturing after removal of the chest tube. Disadvantages of small-bore catheters include their lower flow rate, and thus the potential inability to evacuate large air leaks or rapid accumulation of viscous fluid, such as blood. An in vitro study comparing chest tubes of various sizes and manufacturers concluded that small-bore tubes have a significantly lower flow rate compared with the large-bore catheters.[18] Caution is advised to select a larger tube when big air leaks are expected, such as in patients on mechanical ventilation and with postpneumonectomy stump dehiscence. Finally, the flow of similar-sized tubes varies among different manufacturers, probably because of tube length and the material used to construct the catheter. Therefore, practitioners should be familiar with the chest tubes available in their institution before attempting chest tube placement.

Complications of SBCTs include injury to surrounding organs (0.2%), malposition (0.6%), empyema (0.2%), and drain blockage (8.1%).[3] Viscous fluids like blood or pus may clog the smaller chest tubes because of the low flow. The use of 30 mL of sterile saline to flush the tube every 6 to 8 hours can generally prevent tube blockage, and therefore routine flushing is advised.[19]

ADVANTAGES AND DISADVANTAGES OF LARGE-BORE CHEST TUBES

LBCTs have been conventionally placed for various reasons, including in the surgical field in the setting of trauma, postoperatively, and for empyema. LBCTs are less susceptible to clogging or kinking and are well suited for these indications. Disadvantages, however, include the need for tissue dissection, painful insertion, larger incisions, and a generally more invasive approach. Complications include injury to surrounding organs (1.4%), malposition (6.5%), empyema (1.4%), and drain blockage (5.2%).[3]

SMALL-BORE CHEST TUBES VERSUS LARGE-BORE CHEST TUBES IN DIFFERENT CLINICAL SCENARIOS

Several indications exist for chest tube placement (Table 2). This discussion summarizes the data surrounding the use of SBCTs versus LBCTs in these indications. The most challenging decision confronting physicians is most likely related to size of tube rather than whether it should be a straight or "pigtail" catheter and more studies are needed in this area.

Pneumothorax

Although LBCTs were initially thought necessary for patients with pneumothorax, several studies have shown the efficacy of smaller tubes for this indication. Because a pneumothorax may be large or small, iatrogenic or spontaneous, related or unrelated to underlying parenchymal disease, and have other variables, it is prudent to evaluate each type of pneumothorax individually when deciding the appropriate size of chest tube.

Primary spontaneous pneumothorax

It is important to determine if a spontaneous pneumothorax is primary or secondary. According to the recent BTS guidelines,[20] needle aspiration can be attempted as first-line management of primary spontaneous pneumothorax in patients if the pneumothorax is larger than 2 cm from the lung margin to the inside of the chest wall at the level of the hilum, as determined by chest radiograph, or if the patient is symptomatic. If simple aspiration fails to reexpand the lung, an SBCT should be inserted; LBCTs are not recommended. The American College of Chest Physicians defines a small pneumothorax as 3 cm or smaller, from the apex of the lung to the cupola.[21] This discrepancy highlights the importance of making treatment decisions based on patient symptoms while also

Table 2 Indications for tube thoracostomy	
Pneumothorax	Primary spontaneous pneumothorax
	Secondary spontaneous pneumothorax
	Traumatic pneumothorax
	Iatrogenic pneumothorax
Pleural effusions	Malignant pleural effusion
	Parapneumonic effusion and empyema
	Hemothorax
	Postoperative effusion

considering the size of the pneumothorax. CT scan of chest is more sensitive for evaluating the size of a pneumothorax.[20]

Multiple studies show that there is no significant difference in failure rate between LBCTs and SBCTs for primary spontaneous pneumothorax, thus supporting the role of the small tubes. One study showed no difference in failure rate (28% vs 35%) in patients receiving SBCTs (9 Fr) versus LBCTs (20–32 Fr).[22] In another study, the failure rate was 18% to 21% using SBCTs (5-Fr central venous catheters) or LBCTs (14–20 Fr).[23] The failure rate was 24% in patients who received a 7-Fr chest tube in another study.[24] Finally, 2 additional large retrospective studies showed failure rates of 12.5% to 15% with 8-Fr chest tubes[25] and 7% with 12-Fr chest tubes.[26] These studies were limited by their retrospective nature and incorporation of secondary spontaneous pneumothoraces. Regardless, the treating physician should be aware of the potential risk of failure with chest tube placement of any size.

Secondary spontaneous pneumothorax

Secondary spontaneous pneumothorax is caused by underlying lung abnormalities, including conditions such as bullous emphysema, cystic fibrosis, and *Pneumocystis pneumonia*. According to the BTS guidelines,[20] a secondary spontaneous pneumothorax larger than 2 cm or in symptomatic patients should undergo an SBCT placement. A smaller pneumothorax can be aspirated with a 16- or 18-gauge needle, although this cohort of patients should be admitted to the hospital and observed carefully while receiving supplemental oxygen.

In a retrospective review of 168 patients with secondary spontaneous pneumothorax, Chen and colleagues[27] reported the use of small-bore (10–16 Fr) pigtail catheters inserted using the trocar system. Patients on mechanical ventilation were excluded. Most patients (70%; n = 118) were successfully treated. Those that did not respond (30%; n = 50) underwent further management with either LBCT placement or video-assisted thoracoscopic surgery (VATS). The success rate was higher for patients with chronic obstructive pulmonary disease (COPD; 75%) and malignancy-associated pneumothorax (81%). The authors recommended treatment with LBCTs for infection-related secondary pneumothoraces related to Pneumocystis pneumonia and tuberculosis, and so forth, because less success was seen with smaller tubes (50%).

The BTS guidelines recommend consultation with a thoracic surgeon when an air leak persists for 48 hours after placement of a chest tube in patients with secondary pneumothorax.[20] In these patients, a persistent air leak may require VATS for underlying lung disease (eg, bullectomy), pleurodesis, or treatment with a Heimlich valve for a longer period before surgical intervention can be considered.

Traumatic pneumothorax

Although the data are scant, an increasing trend is occurring towards using SBCTs in the setting of a traumatic pneumothorax. One retrospective study compared the effectiveness of SBCTs and LBCTs in stable trauma patients.[28] Pneumothorax was the indication for 45% of the SBCTs and 69% of the LBCTs. Radiologists used image guidance (CT scan or ultrasound) to place small tubes (10–14 Fr; n = 131) using the Seldinger technique. Attending-supervised surgical residents placed large tubes without trocars (32–36 Fr; n = 71). Subsequent procedures were required in 14% of patients with SBCTs compared with 20% with LBCTs (P = not statistically significant). Complications included hemothorax (6% vs 4%) and empyema (3% vs 1%).

In another retrospective study of trauma patients over a 2-year period, 75 14-Fr pigtail catheters were placed for pneumothorax compared with 146 traditional chest tubes.[29] The tubes were inserted by surgery or emergency medicine physicians. The analysis noted a nonsignificant trend toward a higher tube failure rate in the pigtail catheter group compared with the chest tube group (11% vs 4%; P = .06). At this institution, small pigtail catheters were safe, able to be performed at the bedside, and became favored over traditional chest tube placement in the trauma setting for patients with pneumothorax. Additional prospective studies on chest tube size and character (pigtail vs straight) are required to make more definitive recommendations for patients with traumatic pneumothorax.

Pneumothorax in patients receiving mechanical ventilation

The type of chest tube required in patients on mechanical ventilation may depend on the cause of the pneumothorax. Traditionally, large-bore catheters have been favored because of the concern for an inability to evacuate large air leaks in patients receiving positive pressure ventilation. However, Lin and colleagues[30] reported their retrospective data on the management of 70 cases of pneumothorax in patients on mechanical ventilation. The authors reviewed placement of 12- to 16-Fr pigtail catheters inserted with ultrasound guidance via the Seldinger technique. The overall success rate was 68.6%; however, a significant

difference in the success rate was seen among patients with iatrogenic- versus barotrauma-related pneumothorax. Management of iatrogenic pneumothoraces with pigtail catheters had 87.5% success rate compared with only 43.3% success in managing barotrauma-related pneumothoraces (P<.001).

Iatrogenic pneumothorax

Iatrogenic pneumothorax is seen with CT-guided transthoracic needle biopsies, bronchoscopy, thoracentesis, central venous line placement, and other procedures.[17,19] It can be treated with simple needle aspiration. However, SBCTs are very effective for managing these patients. A study by Galbois and colleagues[25] showed a low failure rate for small (8 Fr) chest tubes, with a second chest tube required in 11% and VATS in 2% of 130 patients with iatrogenic pneumothorax. Another study showed a failure rate of 2% in 48 patients with iatrogenic pneumothorax, which was similar whether SBCTs (5 Fr, Seldinger technique) or LBCTs (14–20 Fr, trocar technique) were used.[23] One study examined the management of pneumothorax related to image-guided transthoracic needle biopsy,[31] in which SBCTs (8.5 Fr) were used to treat 191 patients. Of these, 93% had immediate reexpansion of the lung and were treated as outpatients with a Heimlich valve, and only 9% needed additional interventions, such as a larger-sized tube.

Pleural Effusions

Malignant pleural effusions

Chest tubes are primarily used in malignant pleural effusion for symptom relief and chemical pleurodesis. Traditionally, LBCTs were used to instill a sclerosing agent to prevent blockage of the tube.[32] However, substantial evidence has shown that small-bore catheters can be used effectively for chemical pleurodesis.[17] The BTS guidelines recommend placement of an SBCT (10–14 Fr) for drainage and pleurodesis of malignant pleural effusion.[33] Indwelling pleural catheters are indicated for trapped lung in which pleurodesis is likely to be unsuccessful.[34] Various agents have been instilled via SBCTs when attempting chemical pleurodesis. In a prospective study by Patz and colleagues,[35] SBCTs (14 Fr) were inserted with image guidance using the Seldinger technique in 106 patients with malignant pleural effusions. Doxycycline was compared with bleomycin for achievement of pleurodesis, with similar success rates (43% for doxycycline and 40% for bleomycin). The same group showed a higher success rate (72%) using talc pleurodesis instilled through SBCTs.[36] In a separate retrospective study examining chemical pleurodesis, 58 patients with SBCTs were compared with 44 patients with LBCTs.[37] Talc, doxycycline, bleomycin, and interferon alpha were used as sclerosing agents. The recurrence rate of the pleural effusion was similar (53% for SBCTs vs 51% for LBCTs) at 4 months, indicating no difference regardless of the size of chest tube chosen. A prospective study randomized 20 patients to receive LBCTs (32 Fr) and 23 to receive SBCTs for malignant effusions. Using iodopovidone as the sclerosing agent, the response rate was 90% for LBCTs and 87% for SBCTs at 3 months.[38]

A prospective, multicenter trial, the Second Therapeutic Intervention in Malignant Effusion trial (TIME2) recently compared patients undergoing talc pleurodesis using SBCTs (12 Fr) and those who received indwelling tunneled pleural catheters for management of their malignant effusions. Although the primary end point was dyspnea, an 89% success rate of pleurodesis was seen in the 54 patients who had talc slurry instilled via their SBCTs.[39] Similar outcomes were reported from another study.[40] These studies suggest that pleurodesis may be accomplished using SBCTs, while showing the efficacy of talc.

Parapneumonic effusion and empyema

The BTS guidelines recommend placement of a chest tube for empyema, complicated parapneumonic effusion with a pleural fluid pH less than 7.2, or multiloculated pleural effusions concerning for infection.[41] Despite the conventional practice of using LBCTs to drain thick purulent pleural fluid, the newest BTS recommendations support SBCTs (10–14 Fr) for empyema management when chest tubes are used. Ultrasound guidance for placement and routine flushing of the tubes are recommended.

The prospective, multicenter Multicenter Intrapleural Streptokinase Trial (MIST1) assessed the efficacy of intrapleural streptokinase in 405 patients with empyema or complicated parapneumonic effusion.[42] The primary outcome was the combined frequency of death and surgery, and secondary outcomes included length of hospital stay and change in chest radiograph and lung function at 3 months. No difference was seen in the percentage of patients who died or required surgery, regardless of the chest tube size placed for empyema (36%–44% with tubes <10 Fr and >20 Fr). Most of the small chest tubes were placed using the Seldinger technique and large ones were placed via blunt dissection. The secondary outcomes were also similar; however, patients who received larger tubes had significantly higher pain scores.
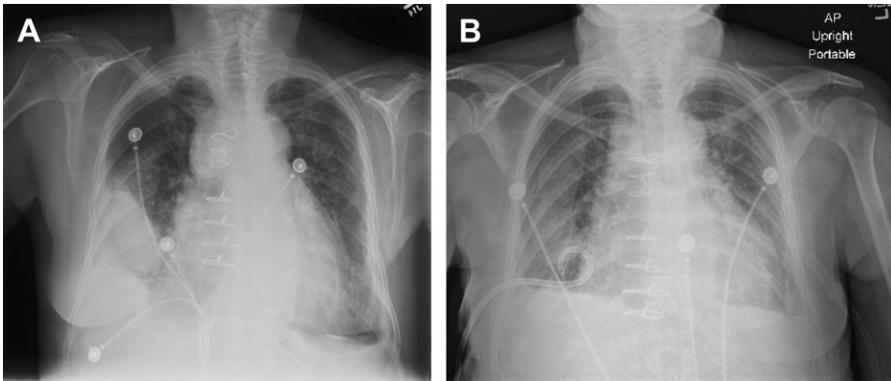
Fig. 6. Chest radiograph showing (*A*) loculated right pleural effusion. (*B*) The effusion resolved after placing a small pigtail chest tube.

In a recent prospective, multicenter, double-blind, randomized controlled MIST2 trial assessing the effectiveness of intrapleural tissue plasminogen activator (tPA) and DNase, most patients received SBCTs (<15 Fr).[43] A significant improvement in the pleural drainage, decreased surgical referral, and shorter hospital stay were seen in the group of patients that received tPA plus DNase as opposed to the groups not receiving combined treatment, showing the efficacy of dual therapy and supporting the use of small chest tubes for the initial management of empyema. Another study showed a 79% success rate using SBCTs (8–14 Fr) for drainage of empyema.[11] However, some studies have reported a higher failure rate with SBCTs.[26,44] Sometimes, image-guided small-bore catheters have been used when large bore tubes fail, especially for the drainage of loculated effusions (**Fig. 6**).[6,45]

Hemothorax
Hemothorax is the presence of blood in the pleural space, and is characterized by a pleural fluid hematocrit of at least 50% of the peripheral blood hematocrit. A chest tube is typically placed to quantify the rate of bleeding and to evacuate the pleural space. It may help to decrease the bleeding through apposition of parietal and visceral pleura.[17] Traditionally, LBCTs have been placed to facilitate drainage and prevent clots and thick fluid from inhibiting complete evacuation. However, SBCTs are increasingly placed successfully for patients with chest trauma, including those with hemothorax.[28,29]

Postoperative use of chest tubes
Since the description of their postoperative use by Lilienthal in 1922,[46] chest tubes are commonly placed during cardiothoracic surgical procedures to evacuate pleural effusions and pneumothorax (**Fig. 7**). Traditionally, LBCTs were used to prevent

clogging, because the tube blockage can lead to tension pneumothorax, inaccurate assessment of ongoing blood loss in the pleural space, and sepsis. However, small Blake drains (Ethicon Inc, Somerville, NJ, USA) are now being used because they are less painful and more flexible. The Blake drains are silicone tubes with a solid core center and 4 channels or flutes along the side. They exert constant suction over the entire length of the fluted portion of the drain, leading to efficient drainage of the fluid. They are connected to a pleural drainage unit with suction or water seal.

In a survey of 108 cardiothoracic surgeons and 108 nurses,[47] almost all surgeons observed chest tube clogging associated with adverse patient outcomes. Most surgeons (86%) reported that concern for clogging is why they use LBCTs. Approximately 70% of the surgeons would routinely place more than one large chest tube when clogging was anticipated. Only 33% used small-bore Blake drains routinely.
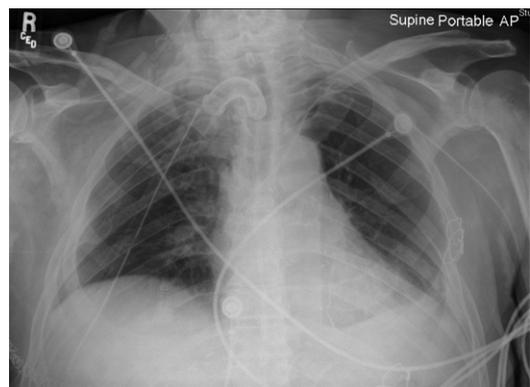
Fig. 7. Chest radiograph showing a straight LBCT placed during a surgical procedure (right lung transplant in a patient with a tracheostomy tube).

In a different study, 150 patients undergoing coronary artery bypass surgery were randomized to 24-Fr Blake drains or 32-Fr plastic or 32-Fr silastic chest tubes.[48] No tube was found to be superior, although all of these chest tubes were large-bore.

SUMMARY

Several types and sizes of chest tubes are available. Although chest tubes range in size (6–40 Fr) and shape (straight tubes vs pigtail catheters), small-bore tubes (<14 Fr) are effective for most pleural processes. Various types of pneumothorax and malignant and infected complicated pleural effusions have been successfully managed with SBCTs. Benefits of the smaller size include patient comfort and ease of placement. Most tubes can be placed using ultrasound guidance and the Seldinger technique. Although LBCTs may be necessary for barotrauma-associated pneumothoraces in mechanically ventilated patients and in the postoperative setting, abundant literature supports a paradigm shift towards the more routine use of SBCTs for managing pleural disease.

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