# What size chest tube? What drainage system is ideal? And other chest tube management questions

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Chest tubes and their accompanying pleural drainage units continue to present challenging questions regarding their optimal use. Appropriate chest tube size selection to accommodate the clinical situation is key, especially in the setting of large pleural air leaks lest a tension pneumothorax ensue. Connection of an appropriate pleural drainage unit to the chest tube is equally important to obviate impeding airflow after successful evacuation by the chest tube. Large-bore chest tubes are generally required for patients with pneumothoraces, regardless of etiology, if the patient is mechanically ventilated, or for patients requiring drainage of viscous pleural liquids such as blood. Smaller bore tubes may be adequate in patients with limited production of pleural air or of free-flowing pleural liquid. Chest tubes may be removed successfully at either end expiration or end inspiration, and potentially as soon as ≤200 mL/fluid output per day is achieved. Additional prospective studies are needed to provide evidence-based answers to the many questions remaining regarding chest tube placement, ongoing management, and removal.

**Keywords**

chest tube, pleural drainage unit

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**Abbreviations**

**PDC** pleural drainage catheter
**PDU** pleural drainage unit
**SSP** secondary spontaneous pneumothorax

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Despite a long history of clinical use, the role and management of chest tubes and accompanying pleural drainage devices remain incompletely defined. The multitude of materials from which chest tubes are made, and design variations incorporated in chest tubes and pleural drainage units (PDUs), and the host of clinical indications for their use, contribute to practice variation in using these devices. Such variation has been documented in recent surveys of practice habit in the management of spontaneous pneumothorax [1] and of malignant pleural effusions [*2*].

Two common questions asked by the clinician when incorporating a chest tube and a PDU are what size chest tube to select and what PDU to use. These two issues and several issues addressed recently in the literature are the focus of this article.

## What size chest tube?

Various sizes of chest tubes are now available, with manufacturers providing numerous prepackaged kits for chest tube placement that often contain smaller bore chest tubes. Chest tubes are placed for various conditions including pneumothorax, parapneumonic effusion and empyema, recurrent symptomatic pleural effusions, and hemothorax. A myriad of available chest tube choices may lead to inappropriate tube size selection. Key to chest tube size selection is the flow rate of either the air or the liquid that can be accommodated by the tube. The Fanning equation determines the flow of moist gas with turbulent flow characteristics through a chest tube ($v = \pi^2 r^5 P/fl$, where v is the flow, r is the radius, l is the length, P is the pressure, and f is the friction factor) [3–6]. The internal diameter (bore) of the tube and, less so, the tube length, are the critical flow determinates. Given the variety of liquids and accompanying pleural debris that may be drained by a chest tube, no single formula for flow of these many materials exists. However, the principle determinates of airflow through a tube, bore, and length are logically key determinates of flow for various pleural liquids including blood and pus. Chest tube selection must take into account not only what material is being drained but also its rate of formation. Ongoing production of more viscous fluids such as blood, particularly if being generated rapidly, requires a larger bore tube than for a similar volume of air produced.

Patients with bronchopleural fistulas in the setting of chest trauma, thoracotomy, and acute respiratory distress syndrome may have air leaks ranging from less than 1 L/minute to as large as 16 L/minute [4,7,8]. Patients with spontaneous pneumothoraces, especially those requiring mechanical ventilation, may also have large air leaks. Daily experience indicates that 16 L/minute is not a fixed upper limit for air leak volume, with larger leaks possibly occurring in any mechanically ventilated patient with a persistent bronchopleural fistula, as in postoperative pneumonectomy stump dehiscence. Appropriate chest tube size selection is therefore key to prevent tension pneumothorax development [9•].

Management of spontaneous pneumothorax has been quite heterogeneous including chest tube selection [1]. The recently published American College of Chest Physicians' Delphi consensus guideline provides direction regarding the appropriate size chest tube to be selected in spontaneous pneumothorax patients [10••]. Initial chest tube placement and hospital admission is the preferred management of an unstable patient with a large (≥3 cm lung collapse) primary spontaneous pneumothorax, or any secondary spontaneous pneumothorax (SSP) patient with a large pneumothorax or with clinical instability. Primary spontaneous pneumothorax patients suitable for chest tube placement should have a small-bore chest tube (catheter ≤14 Fr) or a 16 to 22-Fr chest tube placed. SSP patients, because of their underlying lung disease, may be at greater risk of a large air leak or may require mechanical ventilation, potentially contributing to a large air leak. Hence, stable SSP patients not at risk for a large air leak (not mechanically ventilated) who are chest tube candidates should have a 16 to 22-Fr chest tube placed. Smaller tubes (≤14 Fr) may be acceptable in select patients. Unstable SSP patients and SSP patients on mechanical ventilation should have a 24 to 28-Fr chest tube placed because of their risk for larger air leaks [10••].

Pneumothorax ranks second to rib fractures as the most common manifestation of traumatic chest injury and is noted in 40 to 50% of patients with chest trauma [11–13]. As many as 20% of patients with chest trauma or multiple trauma have an accompanying hemothorax [14]. Generally, traumatic pneumothoraces should be treated with chest tube placement, particularly if the patient is mechanically ventilated [11–13,15]. Given the potential need for both air and blood evacuation, a large-bore tube (28–36 Fr) is recommended [16•,17•].

Iatrogenic pneumothoraces are commonly caused by transthoracic needle aspiration, subclavian vein catheterization, and thoracentesis [18,19]. Management including when to incorporate a chest tube is quite variable, and is complicated by insufficient tracking and reporting of these events [20]. A current text of pulmonary medicine suggests observation and oxygen supplementation for patients not mechanically ventilated with minimal symptoms and a limited (<15%) pneumothorax. If the patient has more than minimal symptoms or a larger pneumothorax (>15%), simple aspiration is recommended [21]. Notably, patients with CT evidence of emphysema in the area of a transthoracic lung needle biopsy developing a pneumothorax require chest tube placement significantly more often than patients without emphysema (27% with evidence versus 9% without evidence, $P < 0.01$) [22••]. Hence, initial chest tube placement of a small-bore catheter (≤14 Fr) and foregoing observation is recommended in such patients [16•]. Safe outpatient management incorporating a Heimlich or similar one-way valve after chest tube placement may be pursued in such patients with an iatrogenic pneumothorax [23,24]. Mechanically ventilated patients sustaining an iatrogenic pneumothorax may develop a bronchopleural fistula and a tension pneumothorax [25]. Such patients require placement of a larger bore chest tube [9•,17•], ideally at least ≥28 Fr.

When and what size chest tube to incorporate in the setting of parapneumonic effusions and empyema, recurrent symptomatic effusions, malignant effusions, and hemothorax continue to be incompletely defined. As noted, fluid (compared with air) within the pleural space requires larger bore tubes (≥28 Fr), especially if the fluid is particularly viscous, as with blood or clotting blood. Several recent guidelines provide direction to chest tube use including size selection in the setting of malignant effusion [26••] and in parapneumonic effusion and empyema [27••]. Key in malignant effusions and in parapneumonic effusions and empyema is considering the use a of small-bore catheter. Smaller bore tubes are particularly successful, with success on par with large-bore tubes in the setting of recurrent, symptomatic, malignant pleural effusions both for fluid drainage and for the administration of sclerosing agents [26••].

As outlined, smaller bore catheters are a reasonable choice in many pneumothorax settings and in some patients requiring pleural liquid drainage. Commercially available pleural drainage catheters (PDCs, or chest tubes) were assessed recently and were found to have significantly different airflow rates [9•] As predicted by the Fanning equation presented earlier, commercially available PDCs handle lower flow rates than larger bore PDCs, with some notable exceptions (Table 1). Eight-French PDCs have mean flow rates of 2.6 to 5.5 L of air per minute. However, 8-Fr thoracentesis PDCs handle significantly ($P < 0.05$) lower flow rates than their 8-Fr pneumothorax PDC counterparts made by the same manufacturer. Interestingly, the lengths of both the thoracentesis PDCs tested are shorter than their comparable pneumothorax PDCs of the same internal bore, which should enhance flow rates. The reduced flow rates in the thoracentesis PDC are likely the result of proximal catheter equipment found on the thoracentesis catheters im-

**Table 1. Pleural drainage catheter description and mean flow rates in liters per minute ± standard deviation**

| Model | Manufacturer | Size | Description | Suction level, cm $H_2O$ –10 | –20 | –40 |
|---|---|---|---|---|---|---|
| AK-01500 | Arrow* | 8.0 Fr × 16 cm | Pneumothorax kit | 3.3 ± 0.1 | 4.9 ± 0.2 | 7.5 ± 0.1 |
| AK-01000 | Arrow | 8.0 Fr × 12 cm | Pleura-seal thoracentesis kit (three-way stopcock and self-sealing valve) | 2.3 ± 0.1 | 3.4 ± 0.1 | 5.4 ± 0.1 |
| Argyle Safety Pneumothorax | Argyle | 8.0 Fr × 10 cm | Safety pneumothorax system | 3.5 ± 0.1 | 5.5 ± 0.1 | 8.1 ± 0.1 |
| Argyle Safety Thoracentesis | Argyle | 8.0 Fr × 8.5 cm | Turkel safety thoracentesis system (catheter with side port/three-way stopcock and self-sealing valve) | 1.5 ± 0.0 | 2.6 ± 0.0 | 4.0 ± 0.1 |
| C-TPTS-8.5-7.5-FSNS | Cook† | 8.5 Fr × 7.5 cm | Emergency pneumothorax set | 4.3 ± 0.1 | 6.5 ± 0.2 | 10.0 ± 0.3 |
| C-TPT-100 | Cook | 9.0 Fr × 29 cm | Pneumothorax set | 3.8 ± 0.4 | 6.4 ± 0.5 | 10.5 ± 0.9 |
| C-UPTP-1400-WAYNE | Cook | 14.0 Fr × 29 cm | Pneumothorax set | 8.1 ± 0.1 | 12.8 ± 0.3 | 19.7 ± 0.4 |
| AK-01600 | Arrow | 14.0 Fr × 23 cm | Percutaneous cavity drainage catheterization kit (curved catheter with sidearm port) | 10.2 ± 0.1 | 16.8 ± 0.1 | 25.0 ± 0.2 |
| AK-01601 | Arrow | 14.0 Fr × 23 cm | Percutaneous cavity drainage catheterization kit (straight catheter with sidearm port) | 10.3 ± 0.1 | 16.8 ± 0.1 | 25.9 ± 0.1 |
| C-TQTS-1600 | Cook | 16.0 Fr × 41 cm | Quick chest tube set | 9.3 ± 0.0 | 14.8 ± 0.6 | 21.1 ± 0.2 |
| C-TQTS-2400 | Cook | 24.0 Fr × 41 cm | Quick chest tube set | 17.5 ± 0.1 | 28.1 ± 0.1 | 45.0 ± 0.1 |

*Mississauga, Ontario, Canada. †Bloomington, IN. Arranged in predicted increasing flow rates as would be predicted by the catheters French and length. Those with the smallest French size and, less important, longer length would be expected to have the lower flow rates. (See text for details regarding the Fanning equation for flow rates).

peding airflow. Use of thoracentesis PDCs as pneumothorax drainage devices should be adopted cautiously. Perhaps more concerning are the significantly ($P < 0.05$) lower mean airflow rates delivered by larger bore (16 Fr, 14.8 L/minute) and smaller bore (14 Fr, 12.8 L/minute) Cook (Bloomington, IN) PDCs compared with the 14-Fr Arrow (Mississauga, Ontario, Canada) PDCs (16.8 L/minute). Greater length of the Cook PDC as well as potential differences in the PDC bore size, perhaps not reflected by the manufacturer-reported bore sizes, and different PDC construction materials permitting catheter collapse under negative pressure may account for these observed differences. These differences in airflow rates may not be recognized by a clinician selecting a PDC based simply on bore size, and may be key in larger air leak settings [9•].

## What drainage system is ideal?

Once a chest tube is placed, depending on the clinical indication, a PDU may be attached to provide suction or a water seal to prevent the backflow of air into the pleural space. Similar to chest tube management issues, the appropriate use of PDUs, including suction, is well delineated in the American College of Chest Physicians spontaneous pneumothorax guideline [10••] and is less well defined for traumatic and iatrogenic pneumothoraces [16•,17•]. Most important, one does not want to select the correct size chest tube for a pneumothorax only to compromise efficient air evacuation by selecting a PDU incapable of accommodating the airflow. Less defined is the role of PDU-generated suction in the setting of pleural liquid collections as found in malignant pleural effusions [26••], parapneumonic effusions, empyema [27••], and hemothorax.

Pleural air and free-flowing fluid will generally drain from the chest without need for suction. If the pleural air or liquid is not responding adequately to gravity (non-suction) water seal drainage, suction may be applied. The American College of Chest Physicians spontaneous pneumothorax guideline suggests attaching the chest tube to a water seal device with or without suction as acceptable in most spontaneous pneumothorax patients [10••]. Concerns regarding the use of suction for pneumothorax or pleural liquid removal and the possibility of reexpansion pulmonary edema are beyond the scope of this discussion, and the reader is referred to several other sources [3,17•,28–35].

Although single-bottle and two-bottle PDU systems are available [5,36], today's readily available and widely used commercial PDUs in the United States use the three-bottle (compartment) system [9•]. The same resistance considerations in choosing a chest tube need to be considered for the connecting tubing and the multicompartment drainage device comprising the PDU [3,8,9•,25,37]. No formula analogous to the Fanning equation exists to determine flow rates for commercially available PDUs. This is likely the result of the relatively complex structure of the three-bottle (compartment) system. Commercial products condense the three-bottle system into a convenient, mobile single module of variable design. The three compartments sequentially, include the collection bottle to trap liquid material and other debris from the patient's pleural space and to allow pleural air to pass through the next two compartments, the water seal bottle to prevent airflow back to the patient's pleural space and to detect an air leak (bronchopleural fistula), and the manometer bottle to regulate the amount of negative pressure transmitted back to the patient from the wall suction device (or equivalent suction source). The manometer bottle may use a water column or a dry system (spring-loaded valve system) to down-regulate the wall suction applied. Commercial packaging of PDUs and of chest tubes provides no flow rate information for either air or liquids [9•]. This absence of information leaves the clinician unable to compare flow characteristics of these devices and choose objectively the optimal device fitting the clinical situation.

The only available assessments of commercial PDUs were published in the 1980s [8,37]. The evaluated devices are no longer available. A current assessment of commercially available devices notes that PDUs differ considerably in their accommodated flow rates and in the accuracy of delivered negative pressures. The airflow rate capabilities of the PDU assessed at −20 cm water pressure vary widely, with mean values ranging from 10.8 to 42.1 L/minute (Table 2) [9•]. The Argyle Sentinel Seal (Sherwood Medical, Tullamore, Ireland) PDU has the lowest flow rate at 10.8 L/minute. This average flow is substantially less than may be encountered in various clinical situations and could lead to the development of a tension pneumothorax. Several PDUs deliver less than 16 L/minute (discussed earlier) at −10 cm water pressure (Table 2), but all PDUs except the Sentinel Seal deliver greater than 16 L/minute at −20 cm water pressure.

Inaccuracy of delivered pressure to the pleural space by a PDU if too negative could damage the underlying lung and mediastinal structures including the heart and pericardium and, if unexpectedly less negative, can lead to inadequate fluid or air removal. Although many significant differences in assessed commercial devices are found, they are of little clinical importance given the limited absolute magnitude of the inaccuracies [9•].

Instead of a complex PDU, simple one-way valve systems incorporating easily collapsible rubber tubing housed in a rigid plastic tube with entrance and exit ports are available and are often included in commercial pneumothorax kits. The Heimlich valve is such a device. Using such a device may allow home management (discussed later), but with clear patient instructions regarding device orientation and maintenance to avoid complications including tension pneumothorax [38,39].

## Other recently addressed chest tube management questions

Ongoing controversy surrounds the question of whether "prophylactic" antibiotics should be used in patients with a chest tube. Given that the majority of such patients have a chest tube in place before antibiotics are administered, this may be more appropriately termed presumptive antibiotic treatment. The majority of publications deal with chest tubes placed in trauma-related circumstances, with the controversy addressed in part by two key recent publications. The evidence-based guideline publication by Luchette *et al.* [40••] and the accompanying editorial by Wilson and Nichols [41••] point out the many confounding variables that have yet to be assessed completely, including geographic location (operating room, emergency department, etc.) of tube placement, patient acuity at time of tube placement, personnel placing the tube (surgeon versus nonsurgeon), choice of antimicrobial agent, and duration of therapy. Regardless, the guideline makes a level III recommendation (lowest level of overall evidence support), stating there is sufficient class I (prospective, randomized, double-blinded study) and class II (prospective, randomized, nonblinded) data to recommend prophylactic antibiotic use in patients receiving a chest tube after chest trauma. A first-generation cephalosporin should be used for no longer than 24 hours. The available data suggest there may be a reduction in the incidence of pneumonia but not empyema [40••]. The role, if any, of antibiotics in patients receiving a chest tube for nontrauma-related issues is not addressed by the guideline. However, given the often more controlled circumstances of chest tube

**Table 2. Pleural drainage unit (PDU) models, manufacturers, and mean PDU flow rates in liters per minute ± standard deviation**

| | | Suction level, cm $H_2O$ | | |
|---|---|---|---|---|
| Manufacturer | PDU | −10 | −20 | −40 |
| Atrium Medical Corporation (Hudson, NH) | Atrium Ocean 2002* | 25.4 ± 1.3 | 40.7 ± 0.3 | No −40 setting |
| | Atrium 3600† | 20.5 ± 0.8 | 34.0 ± 0.8 | 42.8 ± 0.0 |
| | Atrium 3612† (pediatric device) | 11.5 ± 1.3 | 20.3 ± 0.6 | 32.4 ± 0.0 |
| Sherwood Medical (Tullamore, Ireland) | Argyle Aqua-Seal* | 25.9 ± 0.4 | 42.1 ± 1.0 | No −40 setting |
| | Argyle Thora-Seal III* | 26.2 ± 0.5 | 39.6 ± 1.2 | No −40 setting |
| | Argyle Sentinel Seal* | 6.3 ± 1.2 | 10.8 ± 0.6 | No −40 setting |
| Deknatel, Inc. (Fall River, MA) | Pleur-evac A-6000† (code no. A-6000) | 20.5 ± 0.8 | 33.1 ± 0.6 | 50.5 ± 2.3 |
| | Pleur-evac SAHARA† (Code no. S11000FS) | 12.5 ± 1.0 | 20.5 ± 1.0 | 35.6 ± 1.9 |

*Water device: pressure regulation by water column. †Dry device: pressure regulation not by water column. PDU, pleural drainage unit.

placement in most nontrauma settings, antibiotics seem unwarranted except for empyema and parapneumonic effusions.

The minimum daily volume of chest tube fluid output before tube removal seems established by convention, not evidence, with significant variation [42•]. Younes *et al.* [42•] found in 139 prospective, randomized post-thoracotomy patients (and validated in 91 subsequent patients) no difference in drainage time, hospital stay, fluid reaccumulation rates, and thoracentesis rates among those patients with their tube removed at a daily tube threshold fluid output rate of ≤100 mL/day, ≤150 mL/day, or ≤200 mL/day. Hence, an increased threshold to 200 mL/day for tube removal did not affect adversely drainage, hospitalization time, or overall cost, nor did it increase the likelihood of fluid reaccumulation in this postsurgical procedure patient group. Such prospective randomized studies in medical patients with recurrent benign or malignant pleural effusions undergoing sclerosis are needed given the potential impact on hospital length of stay and overall procedure cost.

Whether to remove a chest tube at the end of inspiration or the end of expiration is a common question. The randomized assessment of Bell *et al.* [43•] of 102 chest tube removals in 69 trauma patients found no difference in post chest tube removal pneumothoraces rates using either method (end inspiration, 8% occurrence; end expiration, 6%). The presence of hemothorax, history of thoracotomy or thoracoscopy, previous lung disease, or chest tube duration did not affect pneumothorax recurrence.

## Conclusions

Chest tubes and PDUs are invaluable and frequently used clinical tools. However, many questions remain unanswered regarding their optimal use. Additional well-done, prospective randomized studies are required to assess many aspects of their use, particularly regarding their timely and appropriate removal. In the meantime, clinicians must be ever vigilant to choose initially the correct-size tube and appropriate PDU to suit the clinical condition prompting chest tube placement, especially in situations with high-volume airflow or viscous pleural fluid production.

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