Invasive procedures are performed at the bedside of critically ill patients with increasing frequency to avoid the risks, resources, and inconvenience of transportation to other areas of the hospital (1,2). Multiple studies have documented the high incidence of unexpected adverse events (as high as 68%) occurring during intrahospital transport of critically ill patients (3–5). With the development of safety systems and techniques, the morbidity of these bedside procedures is not higher than the morbidity of similar procedures performed in the operating room, emergency department, or angiography suite (6,7). Knowledge of anatomy, attention to detail, and understanding of potential pitfalls need to be mastered by the specialists involved in bedside procedures. Collaboration across specialties is crucial, as boundaries are continuously crossed and traditional turf make little sense in the age of technology.

Below, we will describe the following procedures, which can safely be performed at the bedside: open and percutaneous thoracostomy, thoracentesis, pericardiocentesis, diagnostic peritoneal aspiration and lavage (DPA/DPL), percutaneous tracheostomy, open and percutaneous cricothyroidotomy, percutaneous gastrostomy, abdominal pressure monitoring, and percutaneous vena cava filter (VCF) placement (8). Routine procedures such as central venous and arterial catheterization will be described in other chapters. The described procedures are selected from a myriad of possible bedside procedures. Collaboration across specialties is crucial, as boundaries are continuously crossed and traditional turf make little sense in the age of technology.

The percutaneous technique is safe for patients who do not have risk factors for intrathoracic adhesions (e.g., previous thoracic operation, empyema, clotted hemothorax, etc.). A 28-Fr or 32-Fr chest tube is adequate according to the size of the patient and does not cause excessive pain (12). For the drainage of simple pneumothorax, smaller tubes (14-Fr or 18-Fr “pigtail catheters”) may be used (13).

The site of placement is chosen and prepared. The most common site is at the intercostal space above the nipple (usually the fourth intercostal space) and at the midaxillary line. The diaphragm can elevate up to the nipple in expiration, and for this reason, lower placement of chest tubes is not safe and may risk injury to the diaphragm and intra-abdominal organs. Adequate local analgesia is key because tube thoracostomy is a painful procedure (Fig. 35.1). The entire track, including the periosteum, should be infiltrated and not just the subcutaneous tissue. Recalling that the upper safety limit of administration lidocaine with epinephrine is 7 mg/kg, or maximum of 500 mg total dose, it is safe to inject almost 50 cc of 1% solution.

A needle, covered by a plastic sheath and connected to a fluid-filled syringe, is inserted through the skin with the intent to hit the underlying rib. Once the rib is felt, the needle is slightly withdrawn and then redirected immediately over the rib to avoid injury to the neurovascular intercostal bundle that travels under each rib. Under continuous suction the syringe and needle are slowly advanced until air or blood is aspirated. This indicates that the needle has entered into the pleural space. The needle and syringe are withdrawn, and the plastic sheath left in place. A guidewire is inserted into the sheath (Fig. 35.2). If there is any resistance during advancement of the guidewire, the procedure should be repeated from the beginning. With the guidewire in place, the plastic sheath is removed. A 2-cm skin incision is made, and sequential dilatation with three consecutive dilators is done over the guidewire. Following this, the chest tube, loaded on a plastic guide, is estimated on computed tomographic imaging. Fluids of other cause (hydrothorax, chylothorax, etc.) are drained according to volume and patient symptomatology.

Following trauma, the chest tube output is used as an indication for operation. A thoracotomy is offered if the output is more than 1,500 mL shortly after placement or if output of more than 200 mL/hr persists over 4 to 6 hours after placement (11). However, these are not absolute criteria. One must remember that chest tubes (no matter the size) are not reliable drains of intrathoracic blood secondary to clogging, kinking, or misplacement. A hemodynamically unstable patient who is bleeding in the chest should be taken to the operating room even with lower than the above chest tube outputs.

### Indications

Fluid or air that remains undrained into the pleural cavity may cause infection, lung collapse, or entrapment, and therefore needs to be drained. A pneumothorax is usually drained if it exceeds 15% to 20% of the hemithoracic volume or causes hemodynamic instability (9). Smaller pneumothoraces may be safely observed, even when the patient is on positive pressure ventilation (10). There is no universally accepted volume threshold for the drainage of a hemothorax. Usually, all hemothoraces of penetrating traumatic cause are drained. Hemothorax after blunt trauma is drained if more than 200 mL of blood is in the thoracic cavity, as found by blunting of the costodiaphragmatic angle on erect chest radiograph or

### Technique

#### Percutaneous Thoracostomy

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placed over the guidewire into the chest. The plastic guide and guidewire are withdrawn, and the chest tube is left in place. If available, and time permitting, dynamic or static sono-graphic guidance is recommended to identify the ideal insertion location as well as assess the thickness of the chest wall. This can allow for optimal placement of the thoracostomy tube for hemothorax evacuation (more posterior and caudal) and guide needle depth (14,15).

Securing the chest tube is a very important part of the procedure. The tube is tied to the skin with a 0 nonabsorbable suture. A separate suture should be placed as a purse-string around the tube and left untied. This suture will serve to close the incision once the chest tube is removed. The tube should also be taped to the skin. Extra precautions should be taken to have the chest tube and its connection to the drainage bottles secured to avoid inadvertent partial or complete removal. Usually, 20 cm H₂O negative suction is applied at least for the first 48 hours although there is no evidence that this shortens the period of placement or decreases the rate of residual pneumothorax compared to water seal.

Open Thoracostomy

The site of placement is marked as above. A 4-cm incision is made parallel to the ribs. Blunt dissection follows through the subcutaneous tissue and muscle. The clamp is finally inserted into the pleural space in a controlled way over the rib underlying the skin incision (Fig. 35.3). It is then opened wide to spread the muscles and enlarge the tract. This is an important step since the novice tends to make the skin incision large but the intermuscular tract too small, resulting in difficulty with tube insertion. There is no reason to “tunnel” the track to the rib above the skin incision. Tunneling causes more pain, makes the procedure more difficult, and offers no benefit.

A finger is inserted to explore for the presence of adhesions at the site of insertion (Fig. 35.4). Then, the chest tube is guided by a clamp into the opening and toward the superior and posterior hemithorax (Fig. 35.5). The clamp is removed, and the tube is secured as discussed above.

Removal of Chest Tubes

Removal takes place when there is no air leak and fluid output is less than 2 mL/kg per 24 hours. The patient is asked to inspire maximally and hold the breath or perform a Valsalva maneuver. With one hand against the chest wall, the physician briskly pulls the chest tube with the other hand and immediately ties the purse string to seal the insertion site. The site is dressed. If a purse-string suture is absent, it is important to apply occlusive dressing to prevent air entry into the chest.

Pitfalls and Complications

A misplaced chest tube may not drain adequately. Do not assume that air or fluid will be drained because a chest tube is in place (16). Confirm correct placement with a chest
radiograph, and have a low threshold to replace or add a chest tube if the symptoms are not relieved, hemodynamic instability persists, or drain output ceases abruptly. A chest tube may cause more harm than benefit if inserted improperly. Injury to the intercostals vessels or lung may cause significant bleeding. The chest tube should then be removed and on rare occasions, the bleeding site explored if the hemorrhage continues. Intraparenchymal placement (diagnosed by computed tomography) may cause a persistent air leak. The tube should be removed and a replacement inserted. The leak usually seals spontaneously. The chest tubes should be securely tied and taped to the skin and checked daily. Accidental removal of a tube equals a sloppy technique. Infection is the most common related complication. Poor aseptic technique, long duration of the tube in the chest, and no antibiotic prophylaxis (one dose before tube placement) are associated with this complication (9). Significant undrained hemothorax (estimated at more than 400 mL) should be managed by thoracoscopic evacuation or intrathoracic thrombolysis (17,18).

**DIAGNOSTIC PERITONEAL ASPIRATION (DPA) AND LAVAGE (DPL)**

**Indications**

The most common reason for a DPA/DPL is for the diagnosis or exclusion of intra-abdominal injury. A count of more than 100,000 red blood cells/mm$^3$ or 500 white blood cells/mm$^3$ or the presence of bile, enteric content, or high-amylase fluid in the effluent of the lavage are considered indications for an operation following abdominal trauma (19). However, these criteria are oversensitive and frequently lead to nontherapeutic operations. Furthermore, these cell counts are valid for blunt but not for penetrating trauma. Portable ultrasonography and the liberal use of helical computed tomography have limited the usefulness of DPL. Currently, DPA/DPL is used only on rare occasions due to lack of appropriate technologic resources or due to major physiologic instability that precludes patient transport to computed tomography (20). Another indication for DPL may be to detect bowel injury in patients with an unreliable abdominal physical examination, since CT scan may miss intestinal infarction and perforation. Aspiration or paracentesis of the abdomen is also performed to diagnose and treat ascites.

**Technique**

**Percutaneous Insertion of Peritoneal Catheter**

A 0.5-cm skin incision is placed under the umbilicus (or over it in the presence of pregnancy, pelvic hematoma, or a lower midline operative scar). A sheathed needle is introduced with direction toward the pelvis. The needle is connected to a fluid-filled syringe and advanced slowly. When the flow of fluid becomes unobstructed, the needle is in the peritoneal cavity (Fig. 35.6). Needle and syringe are withdrawn, and the plastic sheath is left in place. A guidewire is introduced through the sheath, which is then removed (Fig. 35.7). A dilator is placed over the guidewire and withdrawn. Then, the DPL catheter is introduced and the guidewire is removed (Fig. 35.8). Aspiration is performed first (DPA) and is considered positive if 10 mL of gross blood is aspirated. If the DPA is negative, 1 L of normal saline is infused (DPL). By lowering the normal saline bag below the level of the body, the lavage fluid returns into the bag; the fluid is sent for analysis. It is not necessary to recover the entire 1 L.

A simpler DPL system includes only a catheter fed over a trocar. The trocar and catheter are introduced in a controlled and slow fashion into the abdomen. Two points of resistance are felt as the trocar passes through the anterior fascia and the peritoneum. As soon as the tip of the trocar passes the second point of resistance—and is presumably into the abdomen—the catheter is fed over it toward the pelvis and the trocar is removed. Experience is needed to perform this technique to prevent trocar injury of abdominal contents.
Open Technique for Peritoneal Catheter Insertion

A 2- to 4-cm skin incision is performed under or over the umbilicus. The fascia is visualized and retracted. The fascia is then incised and the peritoneal cavity entered (Fig. 35.9). Under direct observation a DPL catheter is introduced toward the pelvis (Fig. 35.10). Sometimes sutures are placed in the fascia to close the perforation. Although theoretically safer, the open technique does not offer any advantage over the percutaneous
technique. It takes longer to perform and may potentially be complicated in obese patients. I recommend the percutaneous technique routinely, although the choice of technique is based on operator preference.

Pitfalls and Complications
The introduction of needles and catheters in the abdominal cavity carries the (very low) risk of injuring the bowel or vessels. The procedure needs to be performed by physicians experienced with the procedure, as the procedure is not frequently performed (21). Once-useful cell counts need to be viewed with caution, as the indications for surgical exploration after abdominal trauma have changed and many injuries are managed nonoperatively. Infusing the lavage fluid but being unable to retrieve it is not uncommon. Slight reposition of the catheter may help.

CRICOTHYROIDOTOMY

Indications
Cricothyroidotomy is a true emergency and should be reserved for those patients who cannot be intubated orally or nasally or have lost a pre-existing oral airway and are unable to be oxygenated or ventilated. Because the cricothyroid membrane is superficial in relation to the skin, it should be selected as the easiest point—even if suboptimal—for the most timely insertion of a life-saving airway.

Technique
Open Cricothyroidotomy
A vertical incision is made directly overlying cricothyroid membrane (Fig. 35.11). This incision is preferred over a horizontal or collar-type incision because it can be extended over the trachea and decreases the likelihood of bleeding from injury to the anterior jugular veins, which run close to the midline of the neck. After sharp incision of any soft tissue between the skin and cricoid cartilage, the cricothyroid space is identified by palpation (Fig. 35.12). Any bleeding at this point is ignored, as the immediate goal is to establish an airway as soon as possible. A pointed clamp is introduced through the cricothyroid membrane and opened to dilate the space (Fig. 35.13). Experienced surgeons may choose to use a scalpel to incise the membrane, though this may risk injuring the cartilage or posterior wall. The thyroid cartilage is retracted upward and anteriorly with a tracheostomy hook. The tracheostomy hook is essential for this procedure. A no. 4 tracheostomy tube is introduced; if a tracheostomy tube is unavailable, a size 6 endotracheal tube may be inserted instead. The bleeding is controlled by sutures, electrocoagulation, or pressure.

FIGURE 35.11 Vertical incision at the cricothyroid space.

FIGURE 35.12 Digital identification of the cricothyroid space.

FIGURE 35.13 Dilatation of the cricothyroid membrane and insertion of the tracheostomy tube.
Percutaneous Cricothyroidotomy

A vertical incision is made. A hollow needle is introduced through the cricothyroid space (Fig. 35.14A,B) and a guide-wire is introduced through the needle (Fig. 35.14C), which is then removed. Dilation of the trachea takes place over the guidewire by introducing a dilator (Fig. 35.15A). Finally, a no. 4 tracheostomy tube is placed over a guiding dilator and the guidewire (Fig. 35.15B). The dilator and guidewire are removed, and the tube is left in place and secured to the skin.

Pitfalls and Complications

Despite the apparent simplicity of the technique, a cricothyroidotomy can become a challenging procedure, as the pressure to establish an airway in a dying patient is immense. Blood can obscure the field, creating additional difficulty. Incorrect identification of the cricothyroid space and placement of the incision above the thyroid cartilage is possible (22). Inadequate opening of the cricothyroid membrane and loss of valuable minutes while trying to insert the tracheostomy tube through a very narrow opening is again not uncommon. Injury to the thyroid and cricoid cartilage, vocal cords, or posterior tracheal wall and esophagus is additional intra-operative complications. The unfortunate combination of a procedure requiring the most experienced person and the lack of time to have such a person present will unavoidably be the cause for complications (23).

There is controversy about the need to convert the cricothyroidotomy to a tracheostomy at a later stage. Previous standard teaching recommended that a tracheostomy should be performed because cricothyroidotomy is associated with a higher degree of tracheal stenosis if left in place for a long time. However, more recent studies have repeatedly refuted this and find no need for incising the trachea twice (24–26). Our personal practice is to leave cricothyroidotomies in place for as long as they are needed to ventilate the patient without converting to a tracheostomy.

PERCUTANEOUS TRACHEOSTOMY

Indications

A tracheostomy is performed in patients who cannot be safely extubated or have failed extubation. Decrease in airway resistance and improved pulmonary toilet are considered major advantages of tracheostomy over orotracheal intubation. An added advantage is the removal of tubes from the patient's
mouth, allowing better oral hygiene and the ability to speak through fenestrated tracheostomy tubes. The technique for open tracheostomy will not be described because it is a procedure that should be performed strictly by surgeons and preferably in the operating room. The percutaneous technique is safe, easy to teach, and can be routinely performed at the bedside (27,28).

**Technique**

Multiple methods of percutaneous tracheostomy have been reported but one, described by Ciaglia, is the most widely used, validated by multiple articles from different groups, and described below (29,30). Ideally, the neck is hyperextended by placing a pillow under the patient's shoulders but can be left in the neutral position if cervical spinal precautions are required. After preparation of the neck, the site of incision is selected to the midpoint between the cricoid cartilage and sternal notch, which corresponds to the second or third tracheal cartilage. The procedure is usually performed under bronchoscopic guidance, though some have reported success without visualization (31). The bronchoscope is introduced through the existing endotracheal tube, and the tube is pulled to the level immediately below the vocal cords. A 2-cm vertical incision is made, and the subcutaneous tissue and pretracheal muscles are bluntly dissected until the trachea is palpated (Fig. 35.16). Care must be taken to avoid injuring the anterior jugular veins or thyroid gland during this dissection. A needle (with or without its sheath) connected to a fluid-filled syringe is introduced. Aspiration of bubbles into the syringe indicates entry into the trachea, also confirmed by the bronchoscope (Fig. 35.17). The needle is pushed in 2 mm farther since the sheath is shorter than the needle. The needle and syringe are removed, and the sheath remains in place. The syringe is placed back on the sheath and air aspirated to confirm that the sheath remains in the airway and has not dislodged during removal of the needle. A J-tipped guidewire is introduced through the sheath into the trachea, and the sheath is then removed (Fig. 35.18). The track is dilated by a short firm dilator, following which a large curved dilator (Fig. 35.19), fed over a guiding tube, is introduced over the guidewire. The large curved dilator has a mark to guide how deep it should be inserted into the airway. Now the trachea is adequately dilated to accommodate the tracheostomy tube. The curved dilator is removed, and the tracheostomy tube (usually a Shiley no. 8) is fed over a 28-Fr dilator, guided by the guidewire/guiding tube complex into the trachea (Fig. 35.20). Although we almost always use a no. 8 tracheostomy tube, on the rare occasions that a no. 6 is required, it will be fed over a 26-Fr dilator. The kit contains several sizes of dilators to accommodate different caliber tracheostomy tubes.
A single cannula tracheostomy tube will have the same internal diameter as a double cannula tube but a smaller external diameter making it easier for insertion. All these steps are visualized through the bronchoscope although during insertion of the curved dilator and tracheostomy, the force required to push the dilator may temporarily collapse the trachea for several seconds with poor visualization through the bronchoscope.

Finally, the guidewire, guiding tube, and curved dilator are removed and the tracheostomy tube is left in place. The bronchoscope is withdrawn from the endotracheal tube (which remains in place) and inserted into the newly placed tracheostomy tube to confirm correct placement by visualizing the carina. The cuff of the tracheostomy tube is inflated, and the tube is connected to the ventilatory circuit. Chest movement, airway pressures, oxygen saturation, and end-tidal carbon dioxide are additional methods to confirm that the tracheostomy is correctly placed and working. It is only at this time that the endotracheal tube may be removed. The tracheostomy tube is sutured and taped in place. Of note, the track created by the percutaneous technique is tight and matures rapidly around the tube. Therefore, if the tube needs to be exchanged or downsized, this can be safely performed after 5 days, as opposed to 8 to 10 days usually recommended with the open technique.
Pitfalls and Complications

Loss of airway is the most important concern (32). It can occur by unrecognized pretracheal or paratracheal placement of the dilators, which dilate the soft tissues instead of the trachea, leading to placement of the tracheostomy tube outside of the trachea. Bronchoscopic guidance is key to avoid this, and although we do not consider it necessary for experienced surgeons, we encourage most physicians to use it. Also, the endotracheal tube should not be removed before the very end of the procedure and only after correct placement of the tracheostomy tube is confirmed bronchoscopically and/or by unobstructed introduction of a suction catheter through the tube, normal chest movements, and expected ventilatory parameters. The bronchoscope may be used to suction blood clots, which can cause major airway occlusion, and also to obtain sputum cultures if indicated.

Bleeding is usually not a problem, and we routinely do not use electrocoagulation. On occasion, however, injury to an anterior vessel or the thyroid gland may cause bleeding through the wound. Superficial bleeding is usually easily controlled with digital pressure or simple suture ligation. It is very rare that bleeding will persist, and under such circumstances the incision should be enlarged and the wound explored at the bedside or ideally in the operating room.

Tube dislodgement may be a catastrophic complication, particularly if it occurs early after the operation (33). For this reason, the tube should be secured in place with tracheal ties and/or skin sutures. Morbidly obese patients with particularly thick necks may need longer tracheostomy tubes.

PERCUTANEOUS GASTROSTOMY

Indications

A gastrostomy is required for patients who cannot be fed through the mouth because of inability to safely swallow, obstructing lesions of the pharynx or esophagus, or extensive neck operations. Although short-term nutrition can be offered through a nasogastric tube, nonoral enteral access is preferred for mid- to long-term nutrient deliver.

Technique

The epigastrium and left upper quadrant are prepared. The procedure starts with an esophagogastroscopy and insufflation of the stomach. Maximal inflation of the stomach apposes it to the anterior abdominal wall. An appropriate site of placement is selected by applying digital pressure on the skin, which is seen through the gastroscope as an indentation to the stomach. Transillumination should also be confirmed at the selected site of placement. It is often helpful to dim the ambient lighting in the room. A long needle covered by a plastic sheath is introduced through the skin and abdominal muscles into the stomach (Fig. 35.21). The needle is withdrawn and the plastic sheath left in place. A snare is introduced through the working port of the gastroscope. A guidewire is inserted into the stomach through the plastic sheath and grasped by the snare (Fig. 35.22). The gastroscope, snare, and guidewire are then withdrawn out of the mouth. The guidewire is disengaged from the snare and tied to the tip of the percutaneous gastrostomy tube. A 1-cm incision is made on the skin, and the guidewire is pulled. In this way, the gastrostomy tube is also pulled back into the mouth, through the esophagus and stomach, and out through the skin (Fig. 35.23). The gastroscope is reintroduced into the stomach to confirm correct placement of the tube, to confirm hemostasis, and to ensure that the mushroom tip is not pulled too tight. In most adults, the distance...
from the stomach to the skin is between 2.5 and 3.0 cm. The gastrostomy tube should be snug, but still be able to freely rotate. Once appropriate tension has been adjusted, the tube is secured to the skin. It can be used for medications and enteral nutrition within 3 to 4 hours (34,35).

Pitfalls and Complications

It is necessary to confirm that there are no vessels and no intervening hollow viscera (such as the colon or small intestine) between the stomach and anterior abdominal wall. The indentation created by digital pressure should be clearly evident by the gastroscope, and transillumination at that site should always be confirmed (36). In this way, bleeding or inadvertent injuries are usually avoided.

Infection of the wound should be recognized early and can be minimized with strict sterile technique. Usually, the tube does not need to be removed. The infection is treated by opening the wound and administering antibiotics. Some suggest that the initial tract should not be “tight” and that a larger skin wound from the beginning prevents infection (37). We do not agree and always create a small wound that is only large enough to accommodate the tube.

Tube dislodgement may occur either if the stomach is under tension (e.g., on a patient with hiatal hernia or with adhesions) or because the tube was not secured adequately and was inadvertently pulled (38). Both complications are usually preventable and should be avoided by recognizing that the anatomy is not favorable for a gastrostomy.

ABDOMINAL PRESSURE MONITORING

Indications

Patients with risk of developing abdominal compartment syndrome (ACS) should have intra-abdominal pressures measured routinely. Abdominal hypertension, the elevation of pressure in the abdominal cavity due to bleeding, visceral swelling, or gaseous distention leads to compromise of cardiac output, tissue perfusion, and ventilation, all eventually resulting in death if untreated (39). Early recognition of intra-abdominal hypertension (IAH) before the development of full-blown ACS (hypotension, oliguria, and high airway pressures) is recommended. Multiple methods have been described to monitor the intra-abdominal pressure. The most widely accepted method is the measurement of bladder pressure because of the logical assumption that the intraperitoneal pressure is transmitted on the bladder wall (Fig 35.24). The normal intra-abdominal pressure (IAP) in a critically ill patient is approximately 5 to 7 mmHg. IAH is defined by increasing severity: Grade 1: IAP 12 to 15 mmHg, Grade 2: IAP 16 to 20 mmHg, Grade 3: IAP 21 to 24 mmHg, and Grade 4: IAP >25 mmHg; however, ACS is defined as sustained IAP > 20 mmHg combined with new organ dysfunction (40).

Technique

Recent bladder repair is an absolute contraindication to this procedure. With the patient lying flat and under aseptic technique, a three-way stopcock is connected to a syringe and pressure monitor. Twenty-five milliliters of saline are injected into the bladder, and the stopcock is opened toward the pressure monitor (41). It is important to level the monitor in advance, so that the 0 mark corresponds to the midaxillary line (40). The universal standard is to express the IAP in mmHg and measure the pressure at end expiration with the patient completely supine (41). Complete relaxation (with sedatives or even sometimes paralytics) is required, as agitation or pain may falsely elevate IAP recordings.

Pitfalls and Complications

The most dangerous pitfall is the exclusive reliance on bladder pressure measurements. Clinical examination should always be the principal reason for continued observation or immediate decompression. Bladder pressure measurements should only support the clinical diagnosis of ACS. Spuriously high measurements may occur when the patient is inadequately sedated or when improper technique is used to obtain measurements. It is imperative to adhere to the standardized technique described above.
PERICARDIOCENTESIS

Indication

The pericardial space can accommodate large volumes of fluid if accumulation occurs over a long period of time; however, cardiac tamponade develops with even small quantities of fluid if it accumulates rapidly. Pericardiocentesis is indicated to treat tamponade or diagnose the nature of chronic fluid (42). The latter is performed under ultrasonographic guidance. The former will be described below, although pericardiocentesis for traumatic tamponade is rarely useful. Unless the patient is in a remote area with difficult access to a trauma center, pericardiocentesis is not indicated; rapid thoracotomy or sternotomy to control the bleeding is the preferred treatment.

Technique

With the patient supine, a standard pericardiocentesis kit or, in true emergencies, a central line kit can be used. A hollow needle is inserted approximately 1 cm below the costal margin, slightly to the left of the midline, and directed at the left shoulder. The needle is advanced slowly under the rib (Fig. 35.25). Electrocardiographic monitoring is possible by attaching an alligator clip to the needle. ST-segment elevations indicate contact of the needle with the epicardium. Aspiration of fluid or blood obviously indicates that the needle is in the pericardial sac. Aspiration of blood relieves the pericardial tamponade, and a guidewire is inserted through the needle. Using a Seldinger technique, a catheter is inserted and used to withdraw further fluid or blood over time, if needed. With wide availability of portable ultrasound machines, emergent tapping of pericardial space may be safer than the previously used “blind” technique as described above (43).

Pitfalls and Complications

Pericardiocentesis is a potentially dangerous technique, if performed blindly (44). When done by radiologic guidance for stable conditions, little risk if involved. When performed under emergency situations for presumed cardiac tamponade, there is risk of injuring the heart, particularly if the clinical diagnosis of tamponade is not correct and the space between the pericardium and epicardium is very narrow. Additionally, misplacement of the needle—most typically under the heart—is not unusual. As mentioned previously, blind pericardiocentesis for traumatic injury purposes has been nearly abandoned in hospital settings.

PERCUTANEOUS INFERIOR VENA CAVA FILTER PLACEMENT

Indications

Inferior VCF use has met an explosive growth for the prophylaxis of pulmonary embolism (45). The evidence supporting its effectiveness is contradictory, and is another interesting example of how standard of care is formed in the absence of solid evidence (46). Absolute indications for filter placement are as follows: recurrent pulmonary embolism despite anticoagulation, contraindications to anticoagulation in the presence of pulmonary embolism or proximal deep venous thrombosis, and complications of anticoagulation prompting its cessation. Relative indications include polytrauma patients at high risk for venous thromboembolism, critically ill patients with tenuous respiratory status in whom even a small pulmonary embolism may prove detrimental, and large free-floating venous clot.

Multiple types of permanent filters exist, although lately removable filters are used with increasing frequency and in many institutions predominantly or exclusively (47). The Gunther Tulip (COOK, Bloomington, IN) retrievable VCF consists of four main struts, each bearing a hook at the inferior end. On the superior joint of the four struts is attached a small hook, which is used for retrieval. It is inserted through a sheath with an outer diameter of 8.5 Fr. The Recovery (Bard, Tempe, AZ) RVCF is based on a bi-level design with six stabilizing arms and six anchoring legs and is introduced through a 9-Fr sheath. The G2 (COOK, Bloomington, IN) RVCF is a recently developed system consisting of 12 nitinol wires forming a two-level structure with six legs and six arms similarly to the Recovery system. All of the above devices are MRI compatible. Two techniques are dominant in performing filter insertion at the bedside and will be described below: the fluoroscopic-guided and the endovascular ultrasound–guided techniques.

Technique

Fluoroscopy Guided

After a screening duplex ultrasound is performed to examine for femoral venous clots, portable fluoroscopy is used to define the L2–4 lumbar region. The site of venous access is selected—typically the left or right femoral vein—and venous cannulation is performed using a Seldinger technique. A 4- or 5-Fr angiographic catheter is advanced over a guidewire into the inferior vena cava and up to the second lumbar vertebra. Contrast material is injected, and the cava is imaged to delineate its anatomy and size. In particular, the renal veins are defined as the landmark below which the filter should be placed. After venography is completed, the pigtail catheter is exchanged for the sheath, which is inserted over a dilator. The
sheath is positioned under the renal veins, and the filter carrier system is advanced into the sheath. The filter is then deployed, completion venography is performed, and the sheath is withdrawn. The filter sits caudal to the renal veins (Fig. 35.26).

**Intravascular Ultrasonographic–Guided**

Insertion is usually performed through a right femoral vein approach. A micropuncture is made in the vein using a 4-Fr catheter, and a 0.035 wire is introduced. An 8-Fr sheath is inserted into the inferior vena cava, and the IVUS (In-Vision Gold, Volcano Corp, Rancho Cordova, CA) is advanced over the wire through the iliac venous system up to the level of the right atrium. Then, it is slowly withdrawn to evaluate the inferior vena cava in a retrograde fashion. The right renal artery and bilateral veins are visualized, and the maximum diameter of the vena cava is measured. After a second puncture in the right common femoral vein, the delivery sheath for a VCF is introduced over a 0.035 guidewire. The sheath and then the VCF are advanced to the level of the renal veins. Deployment is performed under direct IVUS visualization. Confirmation of correct placement below the renal and above the iliac veins is established ultrasonographically. The catheters and sheaths are removed and direct pressure held over the femoral puncture sites. A postinsertion plain radiograph is routinely performed to verify correct placement at the L2–4 level. This technique is valuable in patients at risk for renal failure due to avoidance of radiocontrast dye (31).

**Pitfalls and Complications**

The potential for complications starts with the venous access. Access complications (the same as any central venous access) include bleeding, hematoma, pseudoaneurysm, arteriovenous fistula, hemopneumothorax, and cardiac dysrhythmias. Misplacement outside the IVC or at an incorrect location is a common complication of insertion and has been reported to be as high as 4.6% (48). Locations for filter misplacement include renal veins, gonadal veins, or unintended suprarenal placement. Insertion site venous thrombosis and vena cava occlusion are potential complications of filters. Access via the internal jugular or subclavian vein results in a lower incidence of thrombosis when compared to femoral access. Cava1 thrombosis rates do not appear to vary significantly among the available filters. Some reports show very high rates of caval thrombosis (up to 25%) while others for the same filter are much lower (49). Two explanations for this disparity are different patient populations (i.e., trauma versus malignancy) and provider related. It is expected that with the increasing use of retrievable VCFs, the rate of caval thrombosis will decrease. Pulmonary embolism in the presence of an IVC filter has been reported in 3% to 7% of patients after filter placement in series >50 patients (50). Guidewire entrapment occurs during placement of central venous and pulmonary artery catheters as well as during catheter exchanges. Attempts at removal of an entrapped item can lead to filter displacement and vessel damage when excessive force is applied. Straight guidewires should be used for all new central venous catheters in patients with indwelling IVC filters.

**Key Points**

- Unexpected adverse events are common during intra-hospital transportation of critically ill patients.
- Bedside performance of procedures such as thoracostomy, thoracentesis, pericardiocentesis, DPA, tracheostomy, cricothyroidotomy, gastrostomy, VCF placement is safe and effective.
- Proper Seldinger technique is important for many bedside procedures.
- Traditional large caliber chest tube thoracostomy (36 to 40 F) offers no advantages over smaller size tube thoracostomy (14-F “pigtail”).
- Percutaneous tracheostomy has many advantages over open tracheostomy and should be performed with bronchoscopic guidance whenever possible.

**References**