Interventional Pulmonology Procedures in the Intensive Care Unit

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KEYWORDS

• Intensive care unit • Interventional pulmonology • Procedures

KEY POINTS

- Interventional pulmonologists (IPs) can play a large role in providing care in the intensive care unit (ICU) through various procedures and interventions.
- The performance of percutaneous tracheostomy and endoscopic gastrostomy can be safely performed by trained IPs.
- Central airway obstruction and massive hemoptysis remain common problems seen in the ICU with a large armamentarium available.

INTERVENTIONAL PULMONOLOGY PROCEDURES IN THE INTENSIVE CARE UNIT

The intensive care unit (ICU) is often a fast-paced, high-acuity location in the hospital in which many opportunities exist for the interventional pulmonologist (IP) to help their colleagues. The gamut of IP procedures may be performed within the ICU, oftentimes depending on local practice patterns and facility support/expertise. In general, the most common procedures are related to therapeutic airway and pleural interventions. We plan to review and summarize the most common ICU procedures that may be performed by IPs.

Percutaneous Dilatational Tracheostomy

Introduction

Tracheotomy has been a procedure that humans have been performing since ancient Egypt when 2 tablets from 3600 BC depicted a lancet entering the neck of a seated person.[1] However, not until Chevalier Jackson developed the surgical open tracheotomy did it find a place in modern clinical practice again.[1] In 1955, C. Hunter Shelden described the first method for percutaneous tracheostomy tube placement in neurosurgical patients, but it was associated with a high rate of complications.[2] In 1985, Pasquale Ciaglia and colleagues developed and popularized the percutaneous method that used the seldinger technique to facility different caliber devices to progressively dilate the airway.[3] Since its development, percutaneous dilatational tracheostomy (PDT) tube placement has been one of the most utilized procedures in the ICU for respiratory failure.[4] The performance of PDT has been successfully and safely by numerous specialties, including IPs.[5]

Indications

Indications for PDT can vary but are usually as an alternative method for prolonged mechanical

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Abbreviations	
CAO	central airway obstruction
ETT	endotracheal tubes
ICU	intensive care unit
IP	interventional pulmonologist
LOS	length-of-stay
PDT	percutaneous dilatational tracheostomy
PEG	percutaneous endoscopic gastrostomy
PUG	percutaneous ultrasound-guided
SEMS	self-expanding metal stents
TXA	tranexamic acid

ventilation or relief of an upper airway obstruction. Indications for PDT often include:

- Prolonged mechanical ventilation
- Upper airway obstruction
- Patient comfort and safety
- Secretion management/Pulmonary toilet
- Failed extubation

Contraindications

While PDT is safe and effective, some patients may have contraindications and the procedure should either be aborted or performed surgically. Absolute contraindications include infection at the insertion site and operator inexperience. Relative contraindications include irreversible coagulopathy, inability to palpate anatomy, anatomic abnormalities (goiter, lack of hyperextension), hemodynamic instability, significant ventilator support (ie, fraction of inspired oxygen>50%, positive end expiratory pressure>12 cm H20, inability to tolerate apnea), emergent procedure, and recent neck or cardiothoracic surgery.[1]

Anatomy

As part of the pre-procedural evaluation, assessment of anatomy is a key to a successful procedure and minimization of complications. Careful palpation and evaluation of the thyroid cartilage, cricoid cartilage, cricothyroid membrane, and first through third tracheal rings should be done prior to the procedure (Fig. 1). Palpation and ultrasound examination for any vascular structures close to the insertion site can also be performed to avoid accidental puncture.

Preoperative/pre-procedure planning

Prior to performing PDT, a review of the patient's history and physical examination should be done. Timing is determined by the underlying etiology of the patient's respiratory failure and when recovery/extubation may be achieved. These discussion points are helpful to review with the primary ICU team and often evaluated in a multidisciplinary fashion. When it comes to early versus late tracheotomy in the ICU, studies have demonstrated no significant differences in hospital length-of-stay (LOS), 28-day mortality, or post-hospital discharge destination, but there is a difference in duration of mechanical ventilation and ICU LOS.[6]

Fig. 1. Preoperative landmarks from top to bottom: thyroid cartilage, cricoid cartilage, first tracheal ring, second tracheal ring, and sternal notch. (*From* Lerner AD, Yarmus L. Percutaneous Dilational Tracheostomy. Clin Chest Med, 2018 Mar; 39(1):211–222.)

During pre-procedural physical examination, the ability of the neck for appropriate extension should be investigated as hyperextension is often needed to ensure proper positioning and successful tracheostomy tube placement. If available, ultrasound can be used to help identify key landmarks and identify possible vascular structures that may not be easily palpated. Laboratory testing may be variable but can include international normalized ratio, partial thromboplastin time, prothrombin time, complete blood count including platelet level, and blood urea nitrogen. If a coagulopathy is recognized, correction of this coagulopathy should occur, or alternative methods to managing the airway and/or coagulopathy should be considered. Patients with difficult anatomy or irreversible coagulopathy should be likely being considered for surgical tracheotomy. Lastly, review of the patient's respiratory status and vitals should be evaluated and insertion should be delayed if the patient is unstable.

Preparation and patient positioning

All materials should be collected and available prior to positioning and sedation. Once all materials are available, the patient head is placed in hyperextension, which is usually done with a shoulder roll behind the scapula. Special attention is taken to ensure the head is not “floating” and has adequate support. The neck should again be palpated for tracheal landmarks and ultrasound can be used again to ensure no vascular structures while in the hyperextended position. The patient should be sedated and pre-oxygenated with a fraction of inspired oxygen of 1.0. Neuromuscular blockade can be utilized once adequate sedation is achieved. The neck should be cleaned and draped in typical sterile fashion. Staff for the procedure should include the physician performing the procedure, a bronchoscopist, respiratory therapist, and bedside nurse.

Procedural approach

Once adequate sedation, paralysis, and position are achieved, lidocaine with epinephrine is injected into the subcutaneous tissues (Fig. 2A). A 1 cm vertical or horizontal incision is made through the skin and superficial fascia (Fig. 2B). The subcutaneous tissue is investigated and the tracheal rings are palpated. A bronchoscope is then inserted into the endotracheal tubes (ETTs) and used to help retract the ETT to the level of the cricoid cartilage. Trans-illumination from the bronchoscope can aid in selecting a site prior to performing the incision (prior to Fig. 2B) but can also be performed after the incision is made to confirm appropriate positioning (Fig. 2C) and guide needle trajectory.

A finder needle is next inserted through the midline incision and through the anterior tracheal wall (Fig. 3A), taking care not to puncture the posterior membrane of the trachea (Fig. 3B). A J-tipped wire guidewire is inserted through the seldinger needle ensuring it travels caudally toward the carina (Fig. 3C, D).

The needle is then removed and a short 14F punch dilator is used to start dilating the tract (Fig. 4A, B). The punch dilator is removed and a single tapered dilator is placed over the wire and used to dilate the tract to the proper diameter (Fig. 4C, D).

The dilator is removed leaving the J-tipped wire and guiding catheter. The tracheostomy tube with loading dilator is passed over the J-tipped wire and guiding catheter and inserted into the trachea (Fig. 5A). The loading dilator, J-tipped wire, and guiding catheter is removed (Fig. 5B) and the bronchoscope is retracted from the ETT and placed into the newly placed tracheostomy tube.

Once proper positioning within the airway is confirmed, the bronchoscope is removed, the cuff is inflated, and the tracheostomy tube is connected to the ventilator. Additional confirmation of proper placement can be performed with return of adequate tidal volumes and appropriate end-tidal carbon dioxide levels. The tracheostomy tube is finally secured to the neck with sutures and tracheostomy ties.

Post-procedure care

The wound should be kept clean and dry. It is recommended that within the first week, the outer cannula not be removed to allow the tract to mature and to avoid premature closure of the tract during tracheostomy tube exchange. If accidental decannulation occurs in the first 7 d, there should not be an attempt to replace the tracheostomy tube due to the lack of maturity of the cutaneous-tracheal tract.[7]

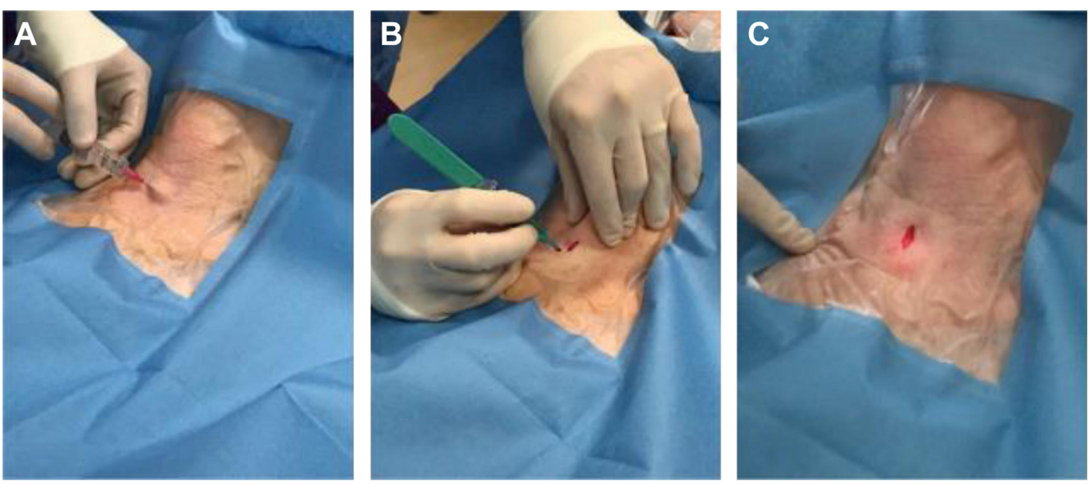

Fig. 2. (*A*) Subcutaneous injection of lidocaine with epinephrine; (*B*) One cm vertical incision; (*C*) transillumination using the bronchoscope following blunt dissection. (*From* Lerner AD, Yarmus L. Percutaneous Dilational Tracheostomy. Clin Chest Med, 2018 Mar; 39(1):211–222.)

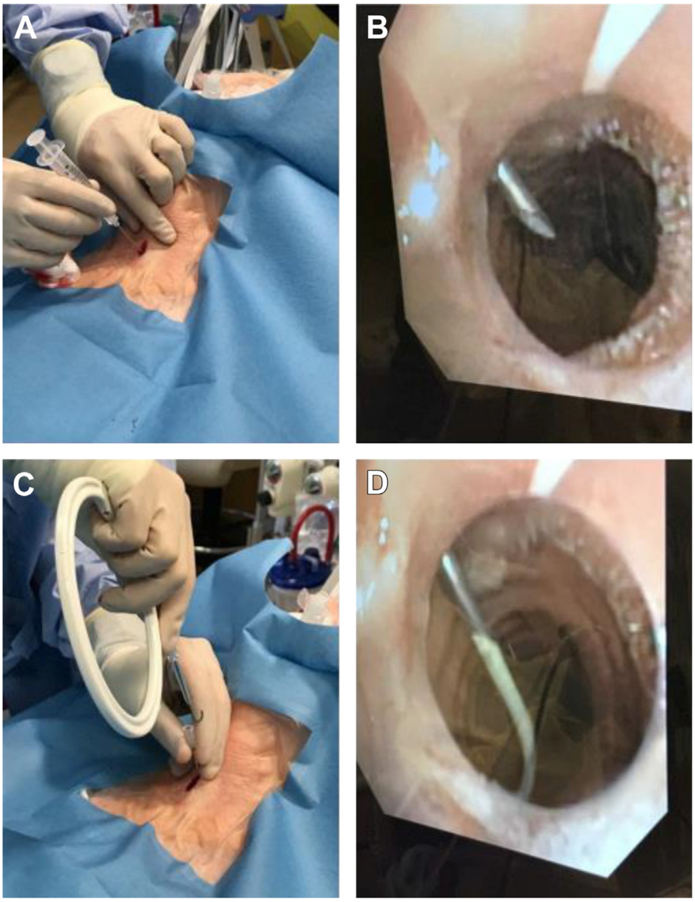

Fig. 3. (*A*) Insertion of introducer needle with (*B*) endoscopic view. (*C*) Insertion of guidewire with (*D*) endoscopic view. (*From* Lerner AD, Yarmus L. Percutaneous Dilational Tracheostomy. Clin Chest Med, 2018 Mar; 39(1):211–222.)

Tracheostomy tube cuff pressures should be maintained between 20 and 25 mm Hg.[7] The first tracheostomy tube exchange typically occurs between 7 and 14 days to allow for the cutaneous-tracheal tract to mature. Other indications for tracheostomy tube exchange include reduction in size moving toward decannulation, to alleviate malposition, cuff leak, granulation tissue formation, and as routine care.[1]

Complications

Complications are often grouped into early versus late with regards to their timing or peak incidence.[8] Early complications usually arise within the first week of tracheostomy tube placement. These complications include bleeding, infection, posterior membrane injury, tracheostomy tube obstruction, pneumothorax, pneumomediastinum, and early decannulation. Late complications are usually categorized by their anatomic locations in relation to the stoma, such as suprastomal, stomal, and infrastomal.[8] Suprastomal complications are usually related to tube placement or friction and include subglottic stenosis, tracheal stenosis, and granulation tissue formation.[9,10] Stomal complication include fracture of the tracheal rings causing a fixed obstruction and granulation tissue.[8] Infrastomal complications include tracheal stenosis, tracheomalacia, granulation tissue, trachea-esophageal fistula, and tracheo-innominate fistula.[11]

SUMMARY

PDT has grown in favor within many ICUs as a safe and effective procedure. There are very few absolute contraindications to PDT and many can be safely accomplished even if relative contraindications are present. Procedural experience and expertise are the keys to successful placement and management of complications. A thorough review of the patient's history and physical examination is needed prior to insertion. Once placed, tracheostomy tube care should include the prevention of infection and monitoring for early and late complications that can arise.

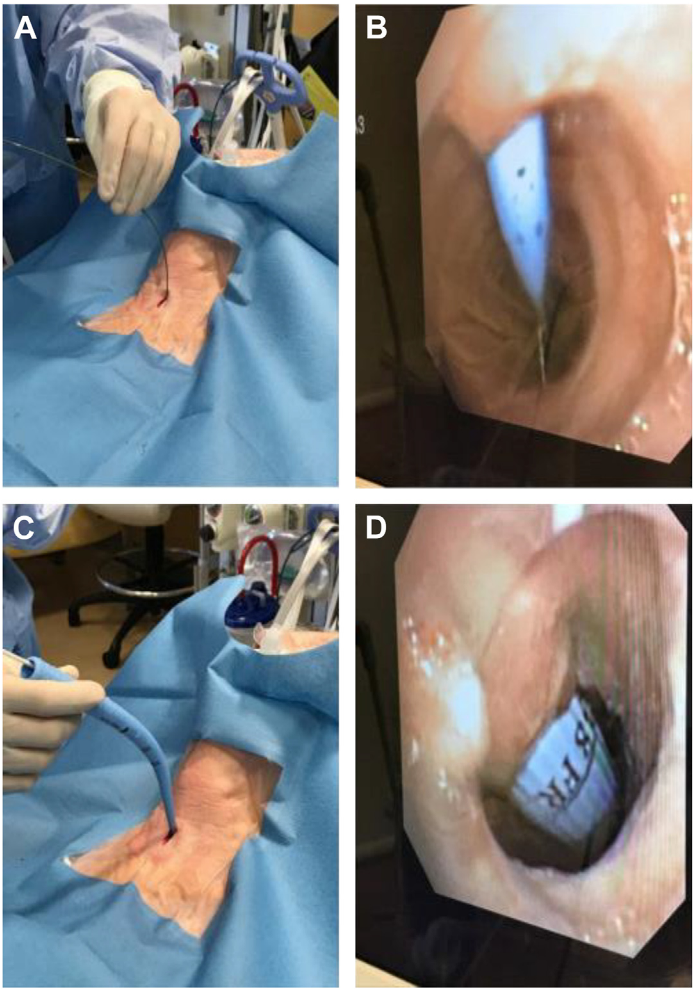

Fig. 4. (*A*) Insertion of a 14F dilator over wire and (*B*) endoscopic view. (*C*) Insertion of dilator and (*D*) endoscopic view. (*From* Lerner AD, Yarmus L. Percutaneous Dilational Tracheostomy. Clin Chest Med, 2018 Mar; 39(1):211–222.)

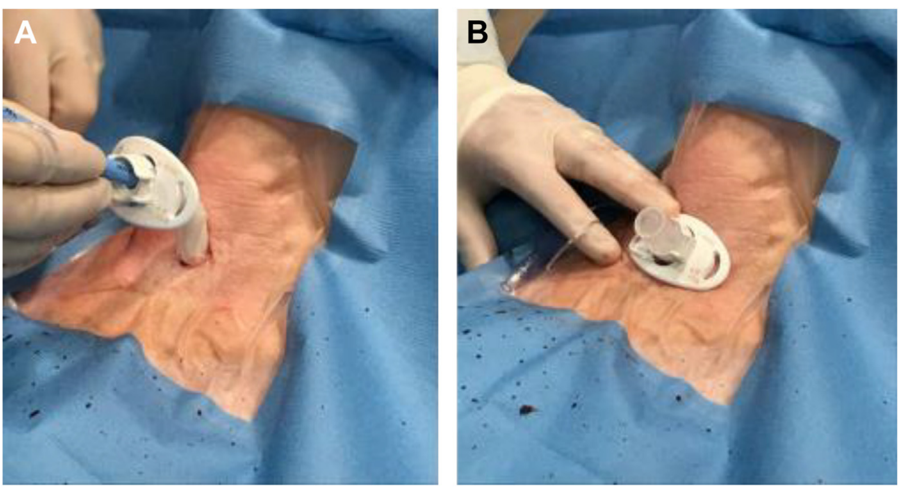

Fig. 5. (*A*) Insertion of tracheostomy tube over introducer. (*B*) Tracheostomy tube in final position. (*From* Lerner AD, Yarmus L. Percutaneous Dilational Tracheostomy. Clin Chest Med, 2018 Mar; 39(1):211–222.)

CLINICS CARE POINTS

- Timing of tracheotomy is controversial and depends on the patient and clinical scenario.
- No difference in hospital LOS, 28-day mortality, or post-hospital discharge destination but a difference in duration of mechanical ventilation and ICU LOS.
- Use of ultrasound can aid in selection of a puncture site and avoidance of vessels.
- Complications can still happen even for experienced proceduralists so be prepared for complications as they arise.

Percutaneous Endoscopic Gastrostomy Tube

Percutaneous endoscopic gastrostomy (PEG) tube is often the preferred route for nutritional support in patients with a functional gastrointestinal system and for those who require long-term support.[12] The first PEG tube insertion was described by Gauderer in 1980 when placing gastrostomy tubes in children and adults with minimal morbidity and mortality.[13] Due to the low cost, less invasive nature, and no need for general anesthesia in most cases, PEG is often considered a better choice for long term enteral access compared to surgical gastrostomy tube placement.[12] When comparing enteral feeding to para-enteral feeding, enteral feeding provides stimulation and less compromise of the gut defense barrier and less risk of bacterial translocation and subsequent bacteremia.[14,15] While PEG placement has typically been performed by surgeons and gastroenterologists, literature exists supporting the performance of PEG tube placement by IPs.[16]

In attempts to provide additional access to other providers and improve costs associated with ICU stay and PEG tube placement, interest has expanded in percutaneous ultrasound-guided gastrostomy tubes (PUG) in the ICU. In a study by Reis and colleagues, 25 consecutive patients underwent PUG tube placement with a technical success rate of 96%.[17] Two major complications occurred, 1 with coffee ground emesis and hypotension in the setting of restarting anticoagulation and the other was bleeding from the puncture site. Similar complication rates were seen in the non-PUG patients (received a standard PEG tube or interventional radiology placed percutaneous gastric feeding tube) enrolled in the study.[17]

Indications

The primary indication for PEG tube placement is to provide nutritional support and meet the metabolic requirements for patients with inadequate oral intake.[12] There are several patient populations that can benefit from a PEG tube due to the risk of malnutrition associated with their disease process including the following indications:

- Critical illness
- Dementia
- Malignancy (head and neck cancer, esophageal cancer, cerebral tumor, etc.)
- Reduced level of consciousness
- Congenital anomaly
- Acquire defect (trachea-esophageal fistula)
- Short bowel syndromes
- Facial trauma
- Stroke
- Motor neuron disease
- Multiple Sclerosis

Contraindications

Contraindications for PEG tube placement are similar to many other endoscopic procedures. Contraindications for PEG tube placement include; serious coagulopathy that cannot be reversed, hemodynamic instability, ascites, peritonitis, esophageal obstruction/disease that will not permit safe passage of a gastroscope, infection over the insertion site, peritoneal carcinomatosis, interposed organs such as liver or colon, partial or complete gastrectomy, gastric outlet obstruction, peritoneal dialysis, or severe portal hypertension with gastric varices.[12]

Preoperative/pre-procedure planning

A thorough review of the patient's history and physical examination should be done prior to the procedure. The anterior abdomen should be evaluated for infection or other contraindications to insertion. Available imaging should be reviewed and if needed, ultrasound can be used to identify structures and to evaluate for possible ascites. Patients should be nothing by mouth (NPO) for at least 8 h prior to the procedure.

Prep and patient positioning

Typically, when performed in a combined fashion in the ICU, PEG tube insertion is completed after PDT and the airway is secured. The patient is maintained in the same supine position with care taken to not dislodge the newly placed tracheostomy tube during patient preparation. Equipment needed is a gastroscope with typical insufflation capabilities, video tower, and PEG tube insertion kit.

Procedural approach

Prior to beginning the procedure, ensure that the patient continues to have adequate sedation and neuromuscular blockade (if utilized for PDT). The gastroscope is inserted into the oropharynx and guided into the esophagus while insufflating. Careful attention is taken to examine the esophagus while advancing to the stomach. Once the gastroscope has entered the stomach, the stomach is next insufflated to bring the wall of the stomach into close proximity with the abdominal wall. Trans-illumination is next used to locate the lateral/anterior edge of the stomach for puncture and insertion. The proceduralist performing the PEG tube insertion should use their finger to push on the insertion site to ensure 1:1 indentation. The inability to obtain appropriate trans-illumination and one-to-one indentation should raise concern at that approach, as likely an inappropriate site for puncture. Once a proper site is selected, the area is prepped and draped in typical sterile fashion. One percent lidocaine is administered to the skin and subcutaneous tissues. A 1 cm incision is made to help facilitate placement of the PEG tube. Next, a finder needle with overlying catheter is inserted into the incision and guided into the stomach under direct endoscopic view. Once puncture of the stomach is achieved, the catheter is left in place and the needle removed. A looped guidewire is placed into the catheter and advanced into the stomach. A snare is then placed through the working channel of the gastroscope and used to grasp the looped wire. The gastroscope is removed bringing the wire through the esophagus and out of the patient's mouth. The PEG tube is then attached to the looped wire and pulled back down into the stomach under gentle traction. The PEG tube is then pulled through the abdominal wall ensuring not to pull the PEG tube completely through or to cause excessive tension of blanching of the gastric wall. The gastroscope is again advanced into the stomach to ensure satisfactory positioning. The PEG tube is secured to the abdominal wall and cut to the proper length. The gastroscope is retracted and the procedure concluded.

Percutaneous ultrasound-guided gastrostomy tube

One of the limiting factors in some institutions is access to equipment, specifically a gastroscope. Within the last 4 to 5 years, a percutaneous PUG tube insertion kit has been developed and used successfully when compared to conventional PEG tube placement.[18] While similar is overall approach (a feeding tube pulled through the oropharynx and out through the abdominal wall) there are a number of differences between the PEG and the PUG.

The initial setup for a PUG is very similar to a PEG, including sedation, sterile preparation of the insertion site, and so forth. However, instead of inserting a gastroscope to facilitate placement, previously placed enteral access (orogastric tube or nasogastric tube) is utilized to insufflate the stomach. Next, a balloon catheter with a magnetic tip is inserted into the oropharynx and advanced distally through the esophagus and into the stomach. A handheld magnet is placed over the stomach to allow magnetic coaptation. Approximately 20 to 30 cc of saline is used to inflate the balloon, which is directly visualized under ultrasound. Once visualization is confirmed, local anesthetic is applied and an 18-gauge finder needle is inserted and advanced to the balloon under ultrasound guidance (Fig. 6).

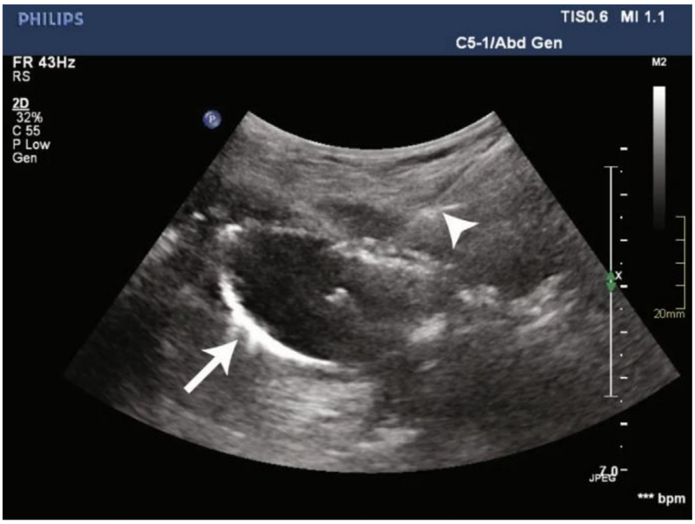

Fig. 6. Transabdominal ultrasound of the inflated orogastric balloon (*arrow*) within the gastric lumen. The orogastric balloon is being pulled against the anterior gastric wall via magnetic gastropexy. An 18-gauge needle (*arrowhead*) is advanced through the abdominal wall into the orogastric balloon, creating the gastrostomy tract. (Accorsi, F., Chung, J., Mujoomdar, A. et al. Percutaneous ultrasound gastrostomy (PUG): first prospective clinical trial. Abdom Radiol 46, 5377–5385 (2021). https://doi.org/10.1007/s00261-021-03200-x.)

Once the balloon is punctured and return of saline is noted, the guide wire is then advanced into the balloon. The balloon is deflated and then retracted out through the oropharynx. A gastrostomy tube is loaded onto the wire and pulled back through the esophagus and through the stomach. A small incision is made around the wire and the gastrostomy tube is pulled through the stomach and abdominal wall. The gastrostomy tube is cut and secured in typical fashion.[19]

Complications

PEG tube placement is a relatively safe procedure, but complications can still occur. Below are a list of complications that can be reported with PEG tube placement, grouped into minor and major:[20,21]

Major complications Bleeding, visceral organ puncture/injury, necrotizing fasciitis, buried bumper syndrome, tumor seeding, and ileus, volvulus.

Minor complications Granuloma formation, pneumoperitoneum, gastric outlet obstruction, site infection, tube dislodgement, peristomal leak, ulcerations, and tube blockage.

SUMMARY

PEG tube insertion is generally a safe procedure and performed frequently in critically ill patients to aid in recovery. Percutaneous insertion is preferred over surgical given it can be done at bedside and generally uses less sedation. There are few absolute contraindications but a pre-procedural evaluation is necessary to ensure patient safety. Classically, a PEG tube is inserted with the aid of a gastroscope for direct visualization in the stomach to ensure proper placement, but recently PUG tubes have proven to be a viable option for those who do not have access to a gastroscope. Complications can occur even when done by experienced clinicians, but patient preparation/selection and proper technique will help aid in avoiding complications.

CLINICS CARE POINTS

- Due to lower costs and less invasive nature, PEG tube placement is preferred over surgical.
- Even though very few absolute contraindications exist, a pre-procedural evaluation is necessary to ensure the patient is an appropriate candidate.
- An option for ultrasound guided gastrostomy tube placement exists (PUG) for those who do not have access to the necessary equipment.
- Complications do occur and will sometimes take a multi-modal/team approach to correct, reverse the complication.

Massive Hemoptysis

Introduction

Massive hemoptysis is a life-threatening condition that historically had a very high mortality rate, up to 75% in patients with over 600 mL in less than 24 h.[22] In 1978, Garzon demonstrated that emergent surgical management via open thoracotomy reduced the mortality rates to less than 20%.[23] However, with continued improvement of medical imaging, the advent of flexible bronchoscopy, and new Interventional Radiology techniques; the mortality rate for massive hemoptysis has continued to decrease even more.[24]

The definition of massive hemoptysis has historically been difficult to define and can have a wide range. Classically, massive hemoptysis has been defined as 300 to 600 mL per 24 h or 3 episodes within a 1 w period.[25–27] Given this wide range, the diagnosis can instead be made mostly on clinical factors, such as the ability to maintain airway patency, the patient's underlying physical reserve, the briskness of bleeding, and overall clinical stability.[24] Any hemoptysis that causes hypoxemia requiring mechanical ventilation, transfusion, or shock should be considered life-threatening and quick action should be taken to control the airway and bleeding. The cause of death in massive hemoptysis is almost never from hemorrhagic shock, but rather from asphyxiation.[24]

The lungs have 2 blood supplies that bleeding can arise from, the pulmonary arteries and bronchial arteries. In most cases of life-threatening hemoptysis, approximately 90%, arise from the high-pressure bronchial arteries.[28] These branches typically arise directly from the aorta, which is why they are such a high-pressure system.[28] Causes of massive hemoptysis can vary widely and include etiologies, such as malignancy, bronchiectasis, infections, vascular complications, vasculitis, anticoagulation, coagulopathies, and trauma.[29]

Preoperative/pre-procedure planning/localization

Most patients with massive hemoptysis require immediate transfer to an ICU for further stabilization and pre-operative management. Airway stabilization and control/isolation of hemorrhage are the keys prior to any intervention. If the side of bleeding is already known, the patient can be placed in the lateral decubitus position with the bleeding side down.[29] Intubation can be live saving but may be quite difficult in the setting of massive hemoptysis as visualization of many normal structures within the airway (even supraglottic structures) can be challenging. While the initial urge to perform intubation with a double lumen tube to help isolate the bleeding side may occur, it should be discouraged. The placement of double lumen tubes is often difficult for mainly anesthesiologists that routinely place them in controlled settings. The addition of airway bleeding, a more uncontrolled and less elective intubation, and likely less experienced operators is often fraught with potential problems. Additionally, once double lumen tubes are placed, the small inner diameters often result in the inability to offer any therapeutic interventions within the airway. As a result, larger, single-lumen ETTs are recommended to enable passage of therapeutic bronchoscope and other tools to help control bleeding. In cases where flexible bronchoscopes or tools are not readily available, selective intubation into the right or left main stem can help isolate hemorrhage and protect the unaffected lung. A simple unilateral intubation may be the most life life-saving maneuver that an intensivist can perform in the setting of massive hemoptysis. If stability is achieved, localization of the bleeding site is crucial and either bronchoscopy or computed tomography imaging should be done to help identify the source of bleeding. Both flexible bronchoscopy and rigid bronchoscopy can be utilized to help localize/control the source of bleeding. Therapies delivered bronchoscopically include vasoactive medications, ablative therapies such as APC, and endobronchial blocker placement. Cryotherapy with a cryoprobe can often be used to help evacuate clot, but is almost never helpful in the immediate presentation of ongoing hemoptysis and airway stabilization. Interventional radiology should also be involved early within the presentation as they can often provide insight into potential bronchial artery embolization for more definitive therapy. If anticoagulants were given prior to the episode of hemoptysis, these should be reversed while stabilizing the patient.

Flexible bronchoscopy

Flexible bronchoscopy can be utilized with a fairly diverse armamentarium of tools to help localize, control bleeding, as well as the eventual removal of obstructing clots. Therapeutic bronchoscopes should generally be used as their working channel measures 2.8 mm in size or greater and can help facilitate removal of fresh blood, organized blood clot, and allow for the majority of therapeutic tools. Historically for active bleeding, ice cold saline, epinephrine, and ephedrine have been utilized to cause topical vasoconstriction. Conlan and colleagues reported a series of 12 patients who were treated with iced saline at 4°C with resolution of bleeding in all 12 patients.[30] Epinephrine and norepinephrine are also commonly used but there have been reports of vasospasm and arrhythmia.[31] If used, it is recommended to use smaller amounts, 5 to 10 mL, of a diluted, lower dose (1:10,000). Tranexamic acid (TXA) is an antifibrinolytic drug that has grown in use for control of hemoptysis since recent randomized trials have demonstrated its efficacy in helping to retard bleeding. TXA can be delivered intravenously or inhaled. Wand and colleagues randomized patients to nebulized TXA or placebo and found that the TXA group was more likely to have a decrease in hemoptysis and less likely to need further intervention.[32] When blood clots are unable to be removed with standard suction or other tools, clot extraction with a cryoprobe can be used to remove the clot *en bloc* (**Figs. 7** and **8**).

Endobronchial blockers can be utilized to block of areas of bleeding and preserve non-bleeding lobes in the same lung or contralateral lung. Endobronchial blocker sets often include a multiport airway adapter, endobronchial blocker, and attachments for suction and ventilation (**Fig. 9**).

Endobronchial blocker procedure

The endobronchial blocker and bronchoscope are lubricated liberally to aid in passage through the adapter and ETT. The blocker is passed through the blocker port and the bronchoscope is passed through the bronchoscope port on the multiport adapter. The bronchoscope is passed through the loop on the endobronchial blocker and the loop is tightened. The multiport adapter is attached to the ETT and ventilator tubing. The

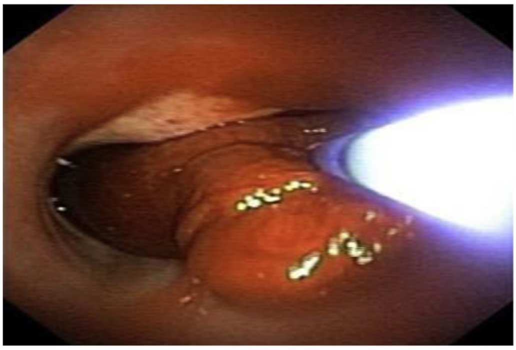

Fig. 7. Cryoprobe used to freeze and extract a large clot occluding the right-sided and left-sided mainstem bronchi and the trachea. (*From* Davidson K., Shojaee S.: Managing massive hemoptysis. Chest 2020; 157: pp. 77–88.)

Fig. 8. Blood clot retrieved via cryoprobe *en bloc* showing airway branching.

bronchoscope and blocker are advanced to the tracheobronchial tree as 1 unit. Once in the trachea, the bronchoscope and blocker are advanced to the area of confirmed bleeding. The loop is loosened and the blocker is advanced into position. The balloon is inflated and secured in place with the multiport adapter.

Rigid bronchoscopy

Rigid bronchoscopy offers some advantages over flexible bronchoscopy but requires expertise that may not be readily available, and often not in an immediate emergency that requires quick airway stabilization. Rigid bronchoscopy allows better access to the central portions of the tracheobronchial tree due to the large lumen of the rigid bronchoscope. This allows for easy passage of tools and scopes into the airway to control bleeding. The rigid bronchoscope can isolate a lung while providing ventilation to the contralateral lung via ventilating side ports (Fig. 10).[24,33] It also allows for easy clot evacuation with suction, forceps, and cryoprobe.[28] Although rigid bronchoscopy has some advantages over flexible, in a life-threatening situation, flexible bronchoscopy is easily accomplished and requires less coordination and specialized equipment.[33]

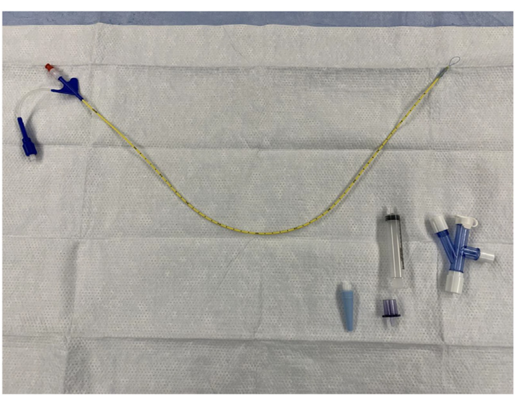

Fig. 9. Endobronchial blocker set with endobronchial blocker, multiport adapter, syringe, and adapters for suction and ventilation.

Fig. 10. Left-sided airways are secured, ventilation is maintained through the side ports of the rigid bronchoscope, and right-sided hemorrhage is controlled. (*From* Davidson K., Shojaee S.: Managing massive hemoptysis. Chest 2020; 157: pp. 77–88.)

SUMMARY

Massive hemoptysis is a life-threatening condition that historically had a high mortality. With the advancement of imaging, bronchoscopic techniques, surgical techniques, and interventional radiology, mortality has dropped to less than 20%. Airway stabilization is a key and may require intubation, which may be difficult in the setting of massive hemoptysis. Both flexible bronchoscopy and rigid bronchoscopy can be utilized for localization and control of bleeding. Techniques include adminstration of vasoactive medications, such as iced saline/epinephrine/TXA, thermal therapies, cryoprobe for clot removal, and endobronchial blocker placement. Deciding on which therapy to administer is often dependent on available equipment and expertise of the bronchoscopist.

CLINICS CARE POINTS

- Massive hemoptysis is a life-threatening condition and a multidisciplinary approach is usually needed to halt bleeding. Embolization is utilized frequently once localization is accomplished.
- Imaging and/or visualization is a key to help localize bleeding and to establish a care plan.
- Flexible bronchoscopic techniques include vasoactive medication administration (iced saline, epinephrine/norepinephrine administration, and TXA administration), removal of

clot, endobronchial blocker placement, and thermal therapies.

- Rigid bronchoscopy has advantages over flexible bronchoscopy, such as a larger working channel allowing more tools into the airway. It, however, requires additional equipment and expertise that may not be readily available.

Central Airway Obstruction

Introduction

Central airway obstruction (CAO) is defined as ≥50% obstruction of the trachea, mainstem bronchi, or bronchus intermedius.[34] The causes of CAO are often divided into malignant and non-malignant causes, with malignant causes being more common.[35] Some common etiologies of CAO are listed as follows:

- Malignant
  - Primary Carcinoma
  - Bronchogenic
  - Adenoid Cystic
  - Mucoepidermoid
  - Carcinoid
  - Metastatic carcinoma to the airway
  - Lymphoma
- Non-Malignant
  - Lymphadenopathy
  - Infectious
  - Vascular
  - Autoimmune
  - Iatrogenic
  - Hamartomas
  - Amyloid
  - Tracheomalacia
  - Bronchomalacia
  - Granulation tissue
  - Foreign object
  - Airway Stents
  - Blood clot
  - Goiter

An estimated 20% to 30% of patient with lung cancer will develop airway complications related to obstruction.[34] Malignant CAO is further divided into 3 main subtypes based on the anatomic presentation: intrinsic, extrinsic, and mixed.[36] Depending on the lesion type, location, and patient factors, there are a wide range of procedures that can be done to alleviate the obstruction.

Balloon dilation

Balloon dilation is a useful tool not only for primary dilation of a stenotic area but also to aid with stent deployment.[37,38] Ballon dilation can be done both with a flexible bronchoscope and/or a rigid bronchoscope. Depending on the segment/area in need of dilation, the proper size balloon is selected and inserted across the area of stenosis. The balloon is inflated with saline to a set atmosphere to achieve a selected diameter, in mm. Balloon dilation is often immediately effective for airway compression, but the results may be difficult to maintain. The main complications associated with balloon dilation are rupture of the airway, pneumothorax, pneumomediastinum, mediastinitis, and bleeding.[37]

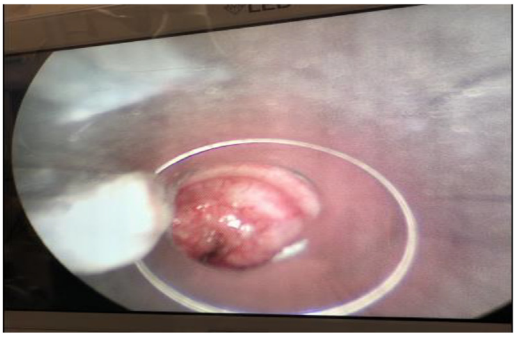

Fig. 11. Malignant airway obstruction seen through the barrel of a rigid tracheoscope approximately 3 cm below the vocal cords. Airway diameter was measured to be 2 mm.

Rigid coring and dilation

Rigid coring and dilation can be used in both malignant and non-malignant disease. It is a relatively quick way to obtain patency of the airway and has a high success rate, between 82% and 90%.[39] The bevel of the rigid bronchoscope is used, in a rotating motion, to core through tumor or to dilate an area of stenosis (Figs. 11 and 12). This can be done multiple times to dilate/core out tumor if needed. This is often used in conjunction with other modalities, such as balloon dilation, cryoprobe adhesion, stent insertion, and thermal therapies. The major risks with rigid coring or dilation

Fig. 12. Patent airway after mechanical coring of tumor and self-expanding covered metal stent insertion.

Fig. 13. Narrowed trachea from non-small cell lung cancer who presented with respiratory failure.

are damage to adjacent structure, perforation of the airway, and bleeding.[36]

Airway stents

Airway stents are hollow prosthetic devices that are placed in compressed or compromised airways to restore patency.[36] Airway stents come in many different shapes and sizes but typically fall into 1 of the 2 categories: silicone or self-expanding metal stents (SEMS).

Silicone stents Silicone stents can be straight, hour-glass, Y-shaped, and even custom built. They come in a variety of sizes and thicknesses and can be easily modified. Typically, silicone stents need to be deployed via a rigid bronchoscope (Figs. 13 and 14). Complications include migration, granulation tissue, mucus plugging, and erosion.[34,36]

SEMS can come fully covered or partially covered. Smaller sized stents can fit through the working channel of a flexible bronchoscope, but larger sizes will need to be deployed either with a rigid bronchoscope or fluoroscopically. SEMS generally have a favorable inner-to-outer ratio when compared to the silicone stents, and provide protection from tumor ingrowth and granulation tissue.[40] Complications from SEMS can include migration, granulation tissue, mucus plugging, and rarely perforation.

Ablative therapies

Depending on the type of obstruction, many different ablative therapies can be used to regain patency of the airway. Electrocautery, or electrosurgery, uses high-frequency electrical current to create heat allowing for cutting, coagulation, or vaporization of tissues through direct contact.[40] Argon plasma coagulation is a non-contact diathermy that utilizes ionized argon gas to conduct an electrical current between the probe and the tissue. It produces a more homogenous but superficial effect to achieve coagulation and tissue destruction.[41] Laser is another modality that can be used to cause coagulation, tumor destruction, and vaporization. The most common laser used to airway tumors is the Nd:YAG laser, which operates at a wavelength of 1064 μm.[40] Risk with thermal therapies include damage to the airway, bleeding, airway fire, air embolism, gas embolism, and inadvertent electrical shock if not grounded appropriately.[40,42] It is recommended to lower the fraction of inspired oxygen to less than 40% during thermal therapies, therefore its use in patients experiencing significant hypoxic respiratory failure may be difficult/unfeasible.

Cryotherapy/cryodebulking

Cryotherapy involves using a liquefied gas through a probe leading to rapid gas decompression and a resulting drop in temperature, a result of the Joule-Thomson Effect.[39] This can be used to cryo debulk tumors out of the airway by attaching the freezing probe to the tumor and rapidly pulling off pieces. Cryo-recanalization can be done by alternating

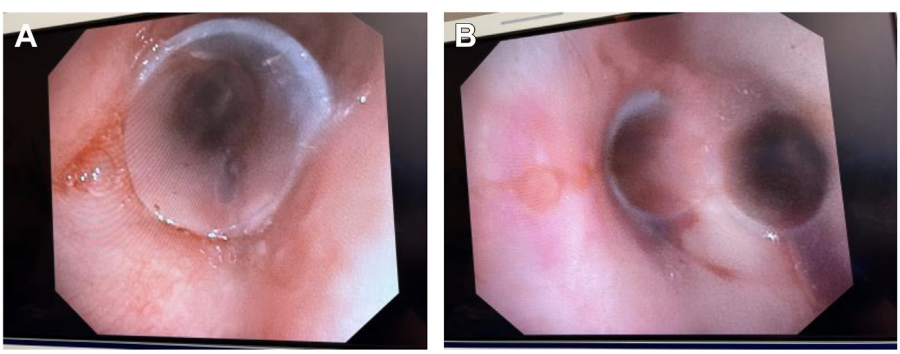

Fig. 14. Successful deployment of a silicone Y-stent to alleviate the distal tracheal obstruction. Tracheal limb of the Y-stent (*A*) and mainstem limbs of y-stent (*B*) shown earlier.

freezing and thawing cycles at overlapping intervals leading to sloughing of malignant tissue a few days after.[39] Risk associated with this modality are bleeding and damage to surrounding structures.

SUMMARY

There are numerous etiologies for managing CAO, with many techniques to help restore and maintain airway patency. Many of these interventions can be performed via flexible or rigid bronchoscopy. Debulking procedures, dilation, stent insertion, thermal therapies, and cryotherapy can be used alone or in combination to alleviate CAO.

CLINICS CARE POINTS

- Both flexible and rigid bronchoscopy, with a myriad of tools, can be used to regain airway patency.
- Success rates depend on the type of lesion, lesion location, and duration of obstruction.
- No single modality has proven to be more successful over the other for regaining airway patency.

DISCLOSURES

Dr T.L. Ferguson and Dr C.R. Gilbert have no significant disclosures related to this article.

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