Interventional Bronchoscopy in During Mechanical Ventilation

Samuel Evans, MD, FACP, FCCP

Introduction

- Bronchoscopy and airway procedures represent a large portion of the interventional pulmonology that occurs in the ICU.
- The complementary roles of intensivists and interventional pulmonologists are highlighted in the management of critically ill patients both intubated and non-intubated.
- We will review novel methods to alleviate respiratory failure from central airway obstruction, manage life threatening hemoptysis and foreign body aspiration, and hasten recovery from pneumothorax with persistent air leak.

Central Airway Obstruction

- Central airway obstruction (CAO) occurs when a blockage of airflow develops in the trachea and/or mainstem bronchi due to a primary lung cancer, metastatic malignancy, or benign disease.
- Because CAO is a challenging disease both for patients to live with and for clinicians to manage, many patients may present acutely in respiratory failure and require intensive care unit (ICU) admission.
- One estimate suggested that 20–30% of lung cancer patients may develop CAO.

Ernst A, Feller-Kopman D, Becker HD, et al. Central airway obstruction. Am J Respir Crit Care Med 2004;169:1278-97. 10.1164/rccm.

Central Airway Obstruction

- Therapeutic bronchoscopy utilizing flexible and/or rigid methods to treat CAO due to endoluminal tumor, extrinsic compression, or both.
- While many Bronchoscopic ablative therapies and management algorithms exist for CAO, there is no standardized treatment approach.
- Management decisions are based upon multiple factors, including patient's clinical status, CAO cause, available equipment, and operator experience and preference.

BS Benn J Thoracic Dis 2021 Aug: 13(8): 5135-5138

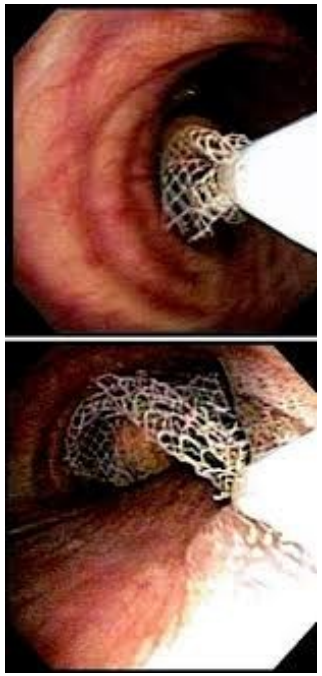
Central Airway Obstruction

- In patients with respiratory failure due to CAO interventional Bronchoscopic procedures can often hasten the time to liberation from mechanical ventilation.

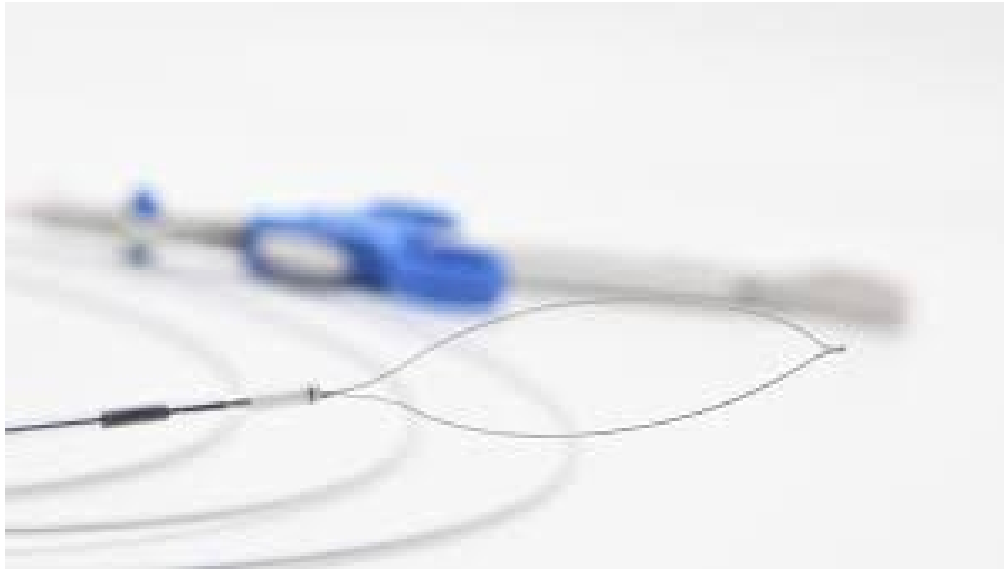
Evans SJ, Allen RL, Aghili SS, and Chan AL. “Bronchoscopic Management of an Endobronchial Primary Paraganglioma.” Journal of Bronchology. Spring 2003. Volume 10; p118-121.

Methods to Relieve Airway Obstruction

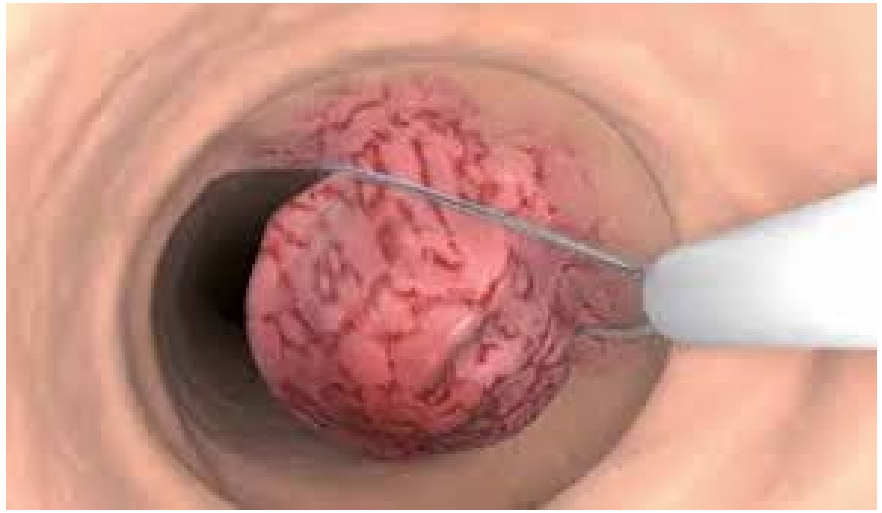
- Forceps and baskets (Foreign Body)
- Snare
- Tumor Ablation+Stenting (Tumor)
- GPA Tracheal Stenosis (Radial Cuts)
- APC Ablation
- Cryoablation
- Endocut/Cauterizing snare
- Balloon Bronchoplasty



SNARE

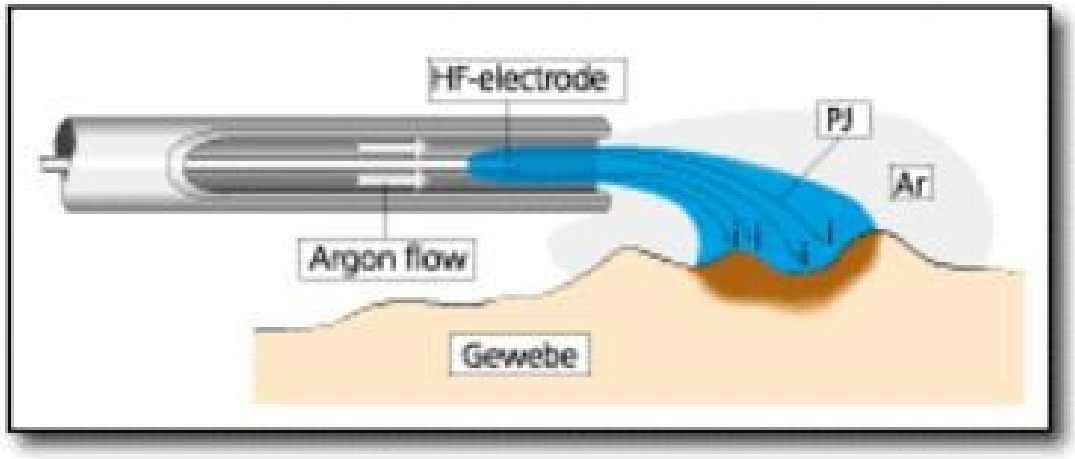


- Cauterizing Snare



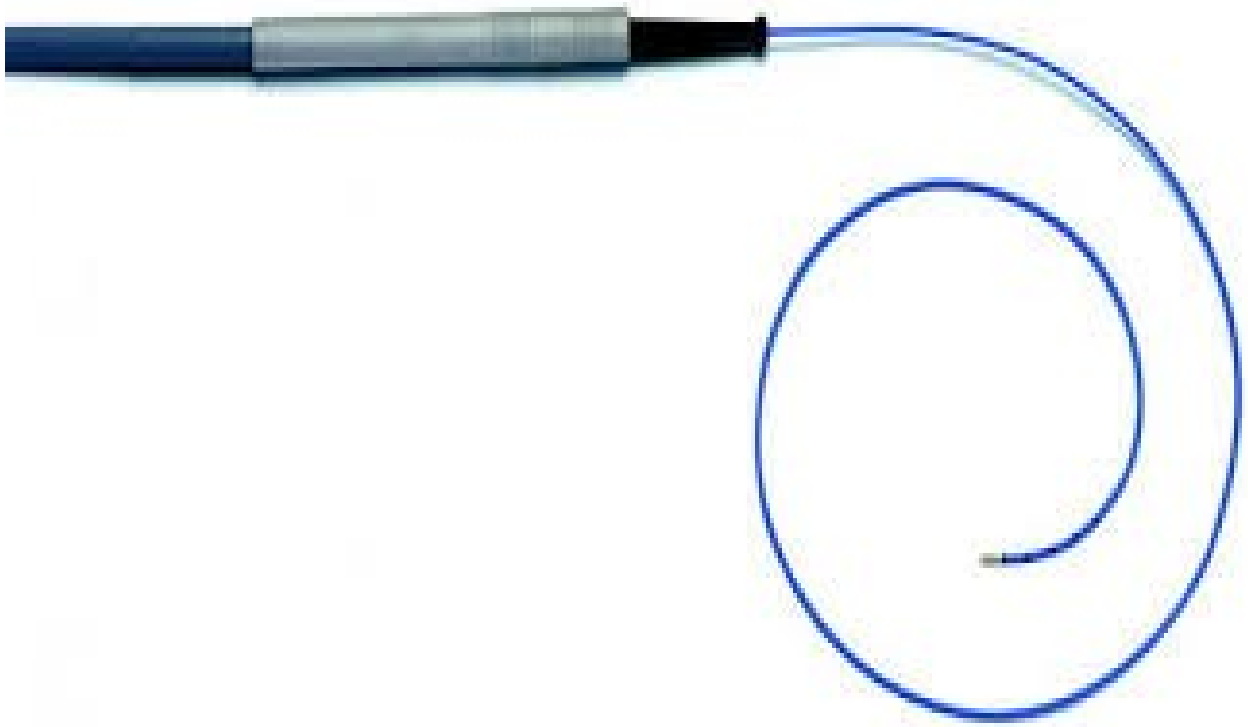
A[illegible] Plasma [illegible]agulation

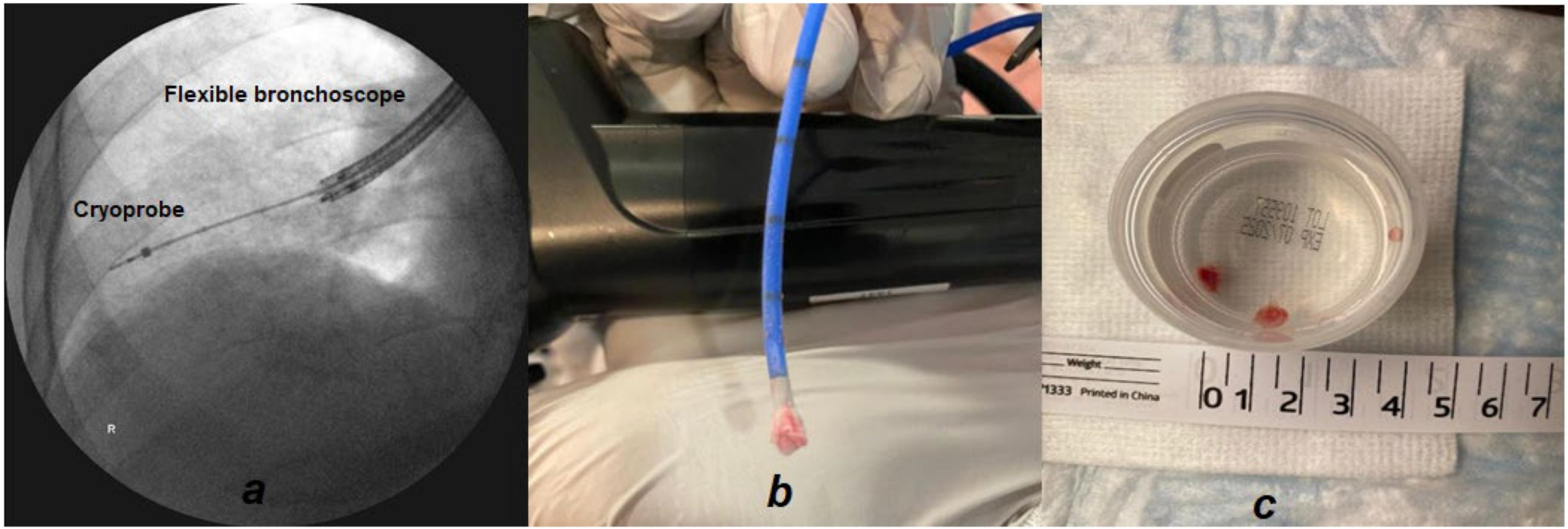
- A jet of Argon gas passed over an electrode resulting in an arc of plasma resulting in thermal injury to the treated tissue
- Depth of penetration 1 to 4mm depending on duration of therapy
- Excellent at photocoagulating – optimal choice for bleeding lesions
- Can be used for tumor debulking



Cryotherapy

Cryoprobe




Flexible bronchoscope
Cryoprobe
R
a
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0 1 2 3 4 5 6 7
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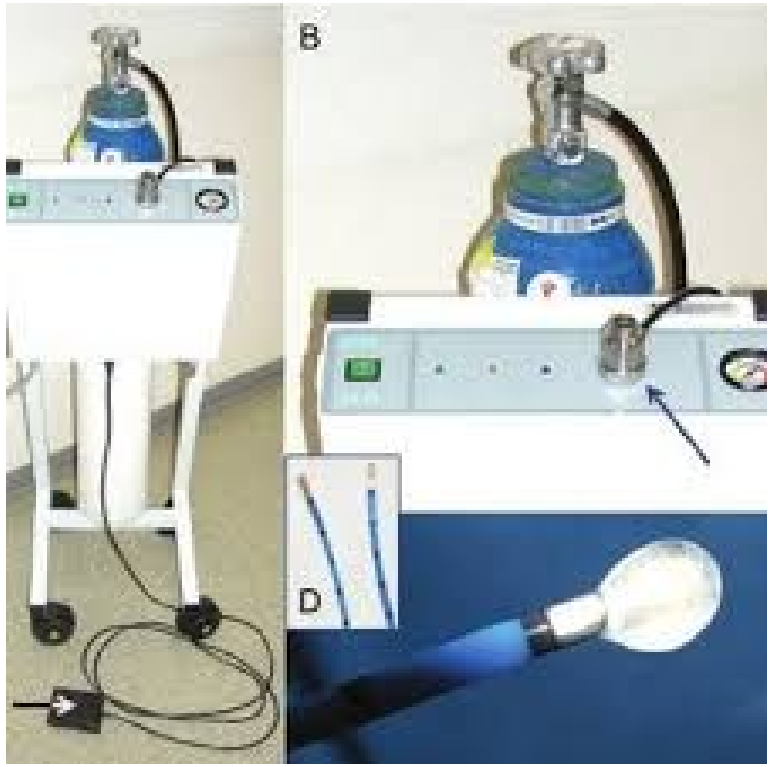
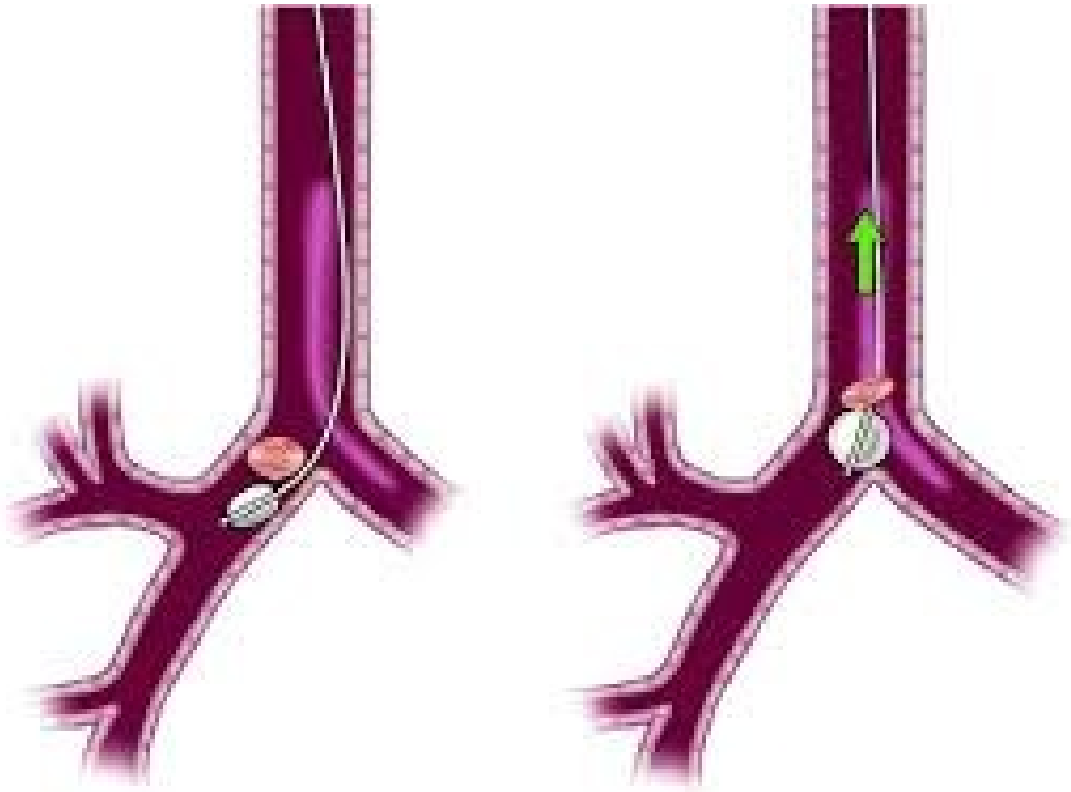
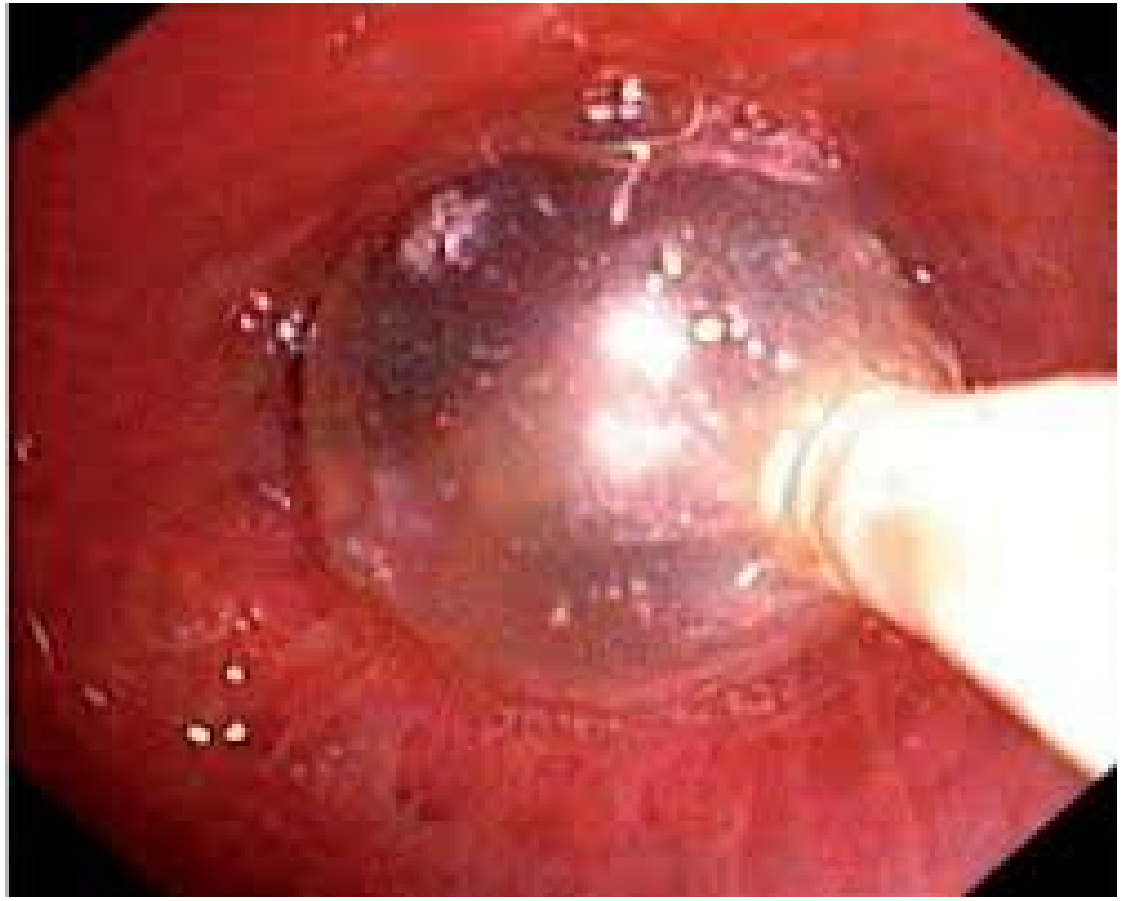
Cryotherapy

- Cryoprobe – a type of catheter with a tip which freezes to tissue or objects to either devitalize the tissue or adhere to the object.
- Excellent for removal of mucous plugs, aspirated organic material (anything which would freeze and adhere to the probe). Not as effective with metallic/plastic foreign bodies
- Can be used to debride tumor using freeze/thaw cycles but effect is delayed or forceable debridement when tumor is adhered to the probe
- Very large piece of tumor can be removed with attendant risk of hemorrhage.

C bination
C/Cryo/Cautery







Central Airway Obstruction

- The AQuIRE (ACCP Quality Improvement Registry, Evaluation, and Education) registry established a threshold for restoring the airway to at least 50% patency for a therapeutic bronchoscopy to be considered technically successful.
- In this registry, overall technical success was 93%, ranging from 90–98% at the different participating centers.
- The complication rate was 3.9% (45/1,115 total procedures) and was increased with urgent and emergent procedures and for patients with an American Society of Anesthesiologists (ASA) score >3.

Ost DE, Ernst A, Grosu HB, et al. Chest 2015;147:1282-98. 10.1378/chest.14-152

Central Airway Obstruction

- Another single center study looking at 2008 patients treated with multiple therapeutic modalities over 13 years showed a similarly high success rate, with 93% of patients having immediate restoration of airway patency post bronchoscopic procedure.
- Therapeutic bronchoscopy facilitates patient liberation from MV and transfer out of the ICU for patients with malignant CAO.
- A study examined the role of laser bronchoscopy in 17 patients with inoperable lung cancer requiring MV for acute respiratory failure.
- Laser bronchoscopy treatment of endoluminal CAO in 9 patients allowed for earlier removal from MV and facilitated further medical treatment compared to 8 patients with CAO due to extrinsic disease.

Stanopoulos IT, Beamis JF, Jr, Martinez FJ, et al. Laser bronchoscopy in respiratory failure from malignant airway obstruction. Crit Care Med 1993;21:386-91

Evans SJ, Allen RL, Aghili SS, and Chan AL. “Bronchoscopic Management of an Endobronchial Primary Paraganglioma.” Journal of Bronchology. Spring 2003. Volume 10; p118-121.

Central Airway Obstruction

- A similar study of 12 inoperable lung cancer patients with CAO found that 9 were successfully extubated from MV post therapeutic bronchoscopy.

Murgu S, Langer S, Colt H Respiration 2012;84:55-61.

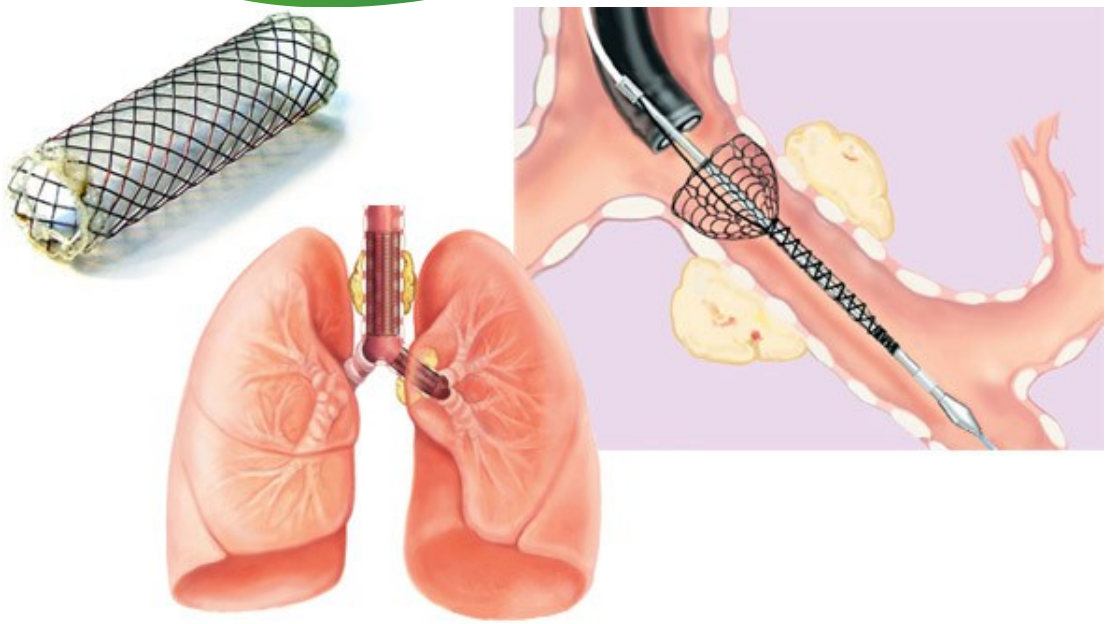
Airway Stenting:

- Rigid versus flexible fiberoptic bronchoscopy
- Large near obstructing tracheal or central tumors often best addressed with rigid bronchoscopic coring or vv ecmo.
- Some stent delivery systems (silicone) cannot be placed with fiberoptic bronchoscope.
- Jet ventilation may be required with rigid bronchoscopy.
- Larger tumors, I will use an ETT, more peripheral ones an LMA, advantage of the ETT is ability to mainstem intubate if uncontrollable bleeding occurs

Airway Stenting

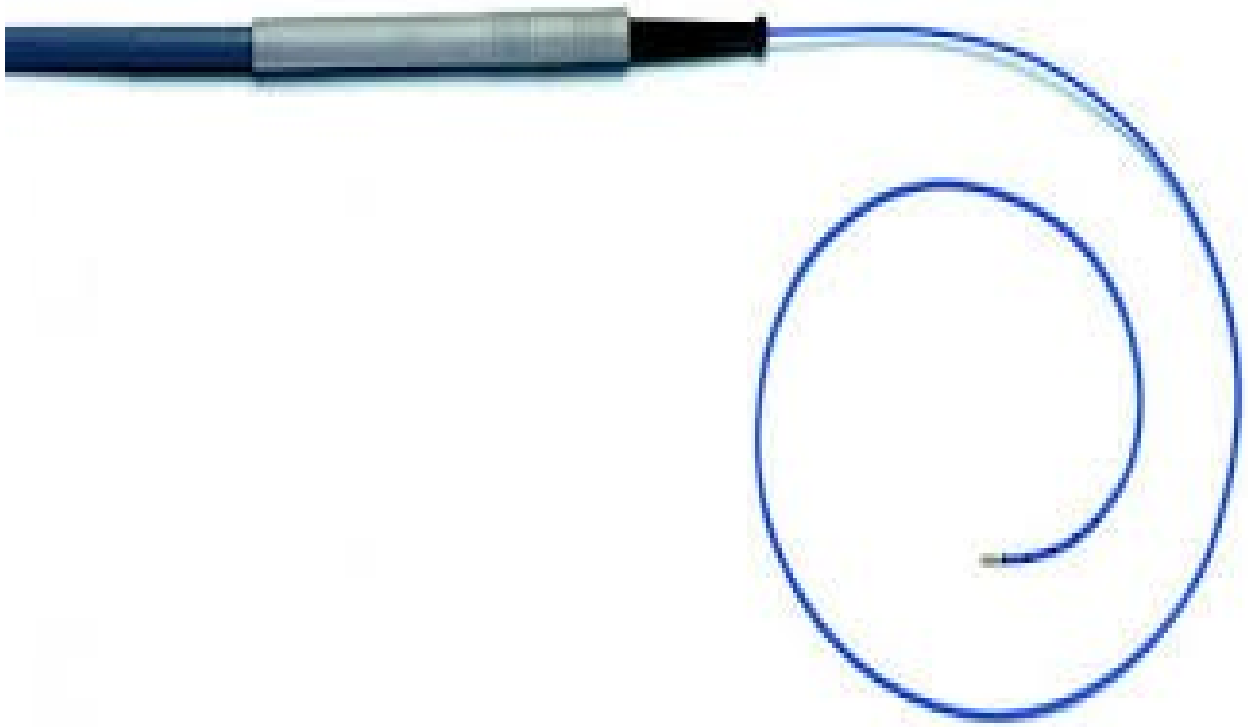
- Best used for malignant diagnoses but has rare applications in benign disease as well (tracheomalacia).
- Several types of stents, materials and delivery systems have been developed.
- Some stent delivery systems (silicone) cannot be placed with fiberoptic bronchoscope.
- Self expanding metal stents.
- Silicone stents.
- The number of lung cancer patients needing of benefitting from stents is quite small.

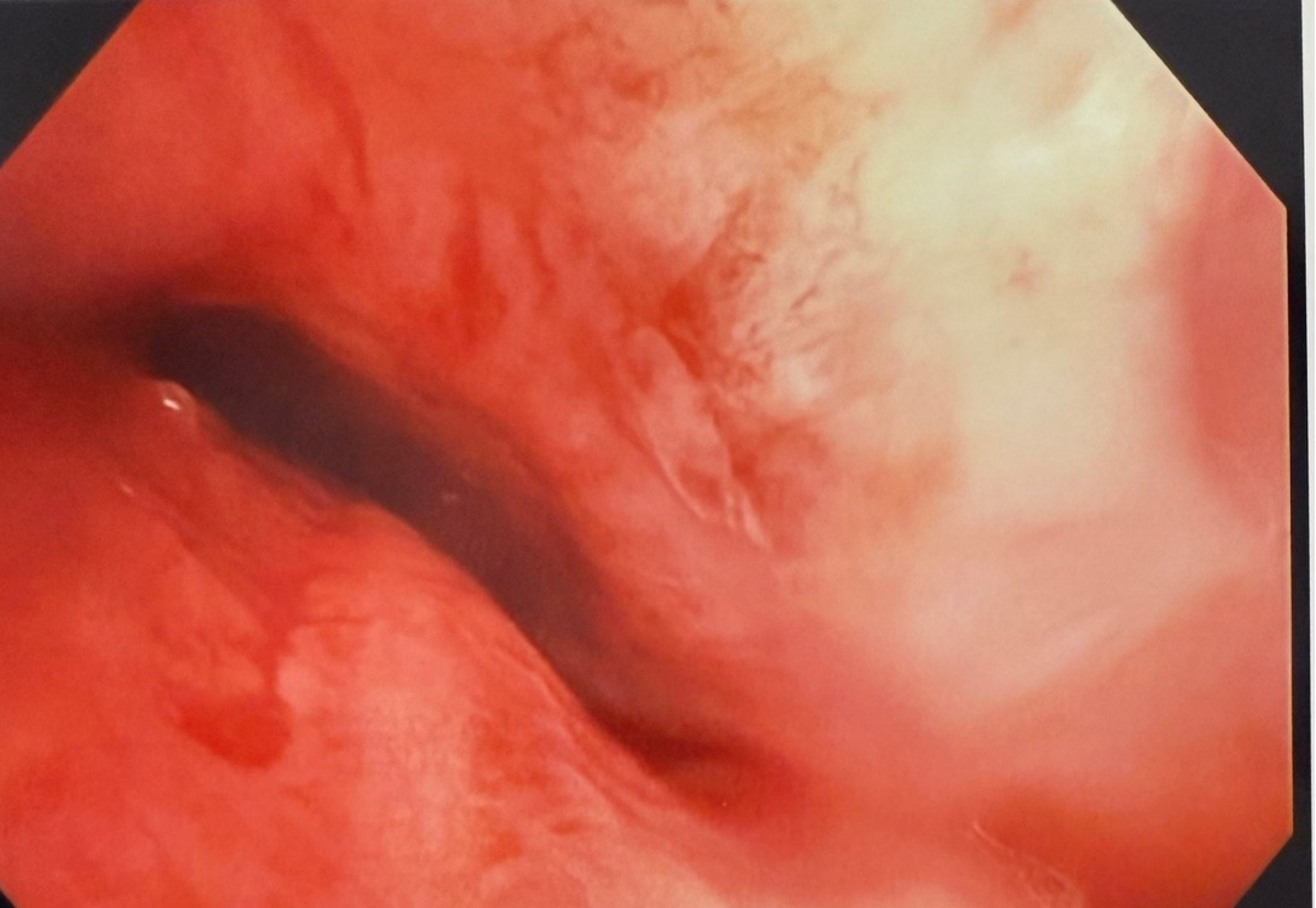
Airway Stenting

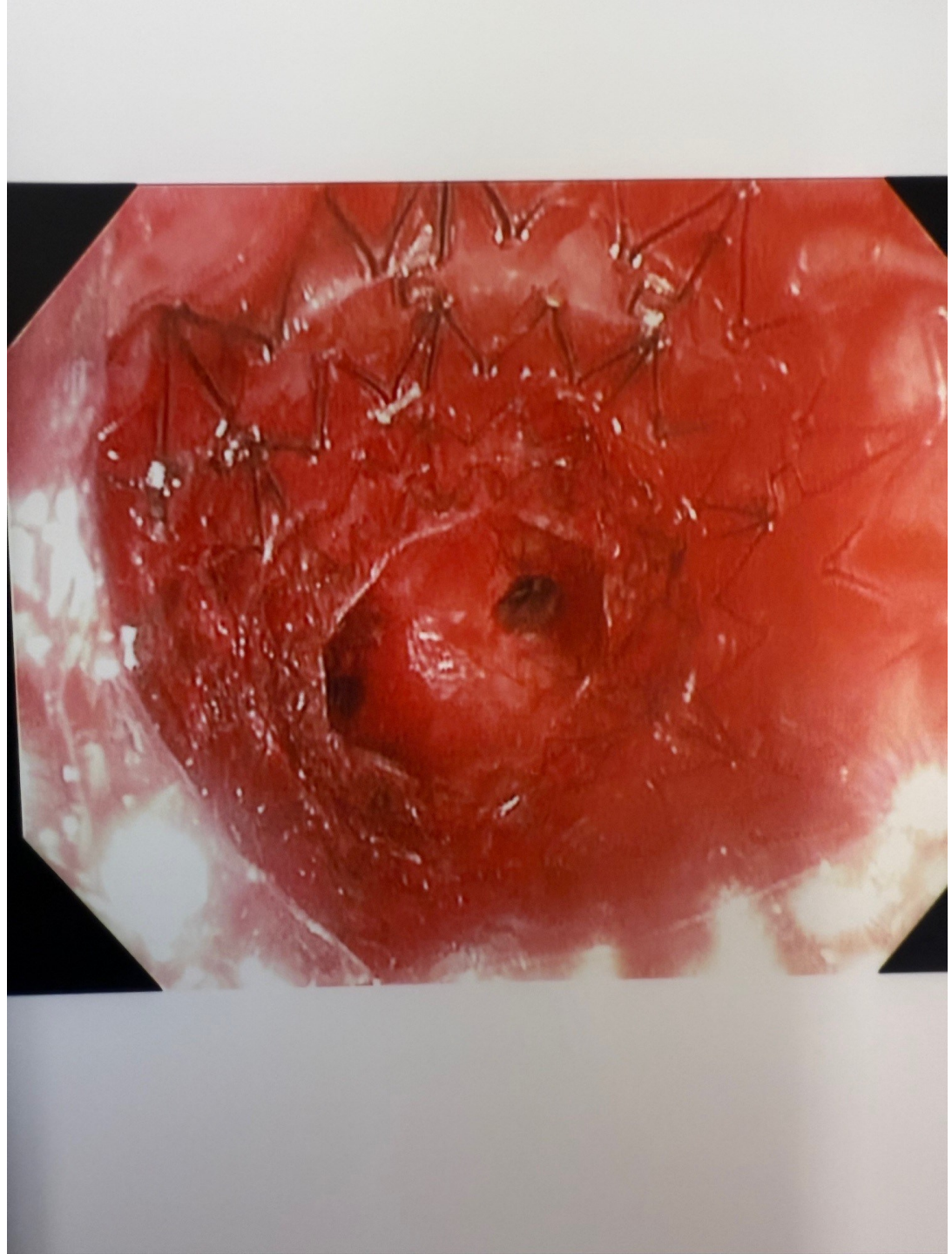


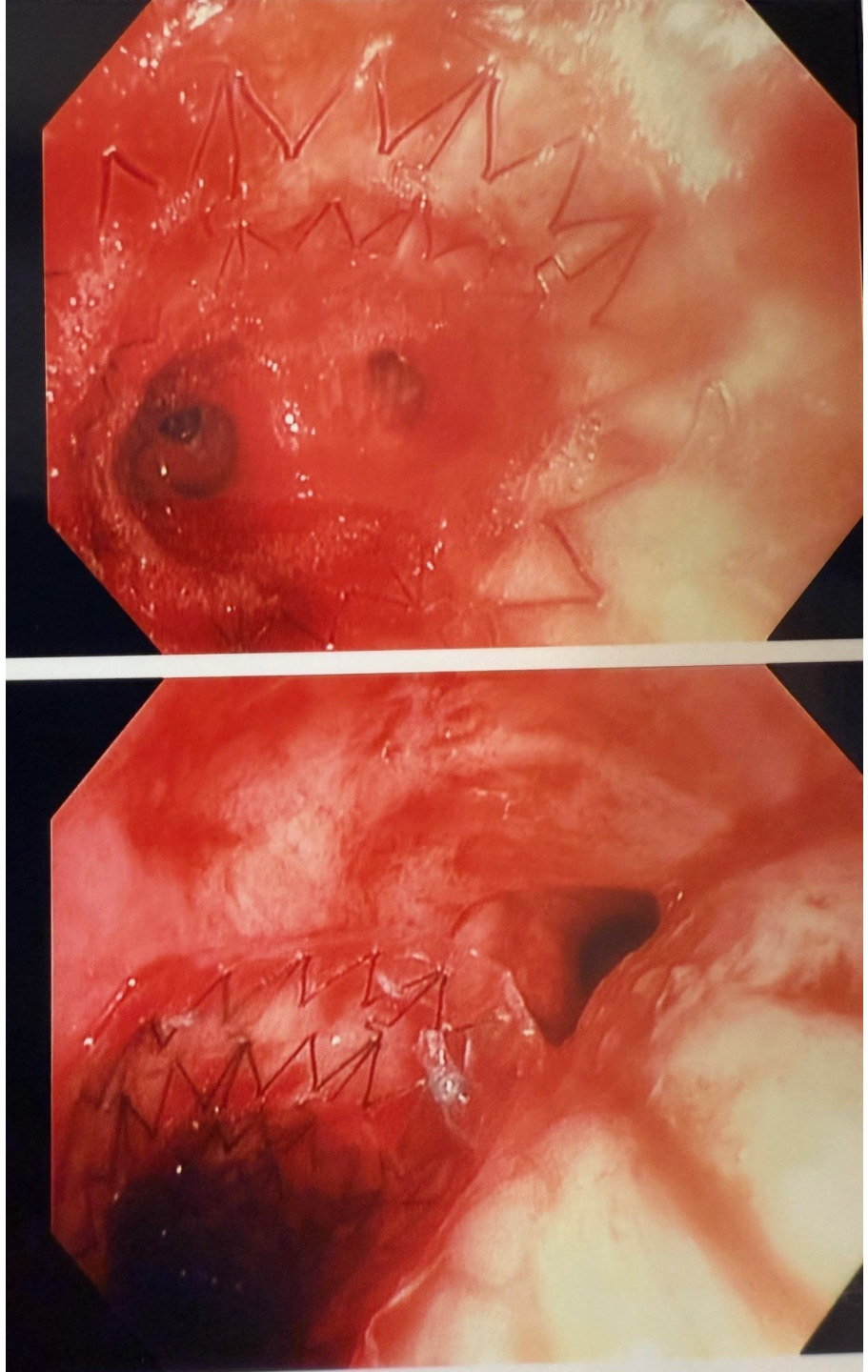
- The goal is to open an airway to functional lung
- Often, lung distal to the airway lesion is replaced with tumor or of too little volume to significantly palliate symptoms
- Excellent in the right patient but probably best performed at centers with experience.
- Placement often requires some tu
  debulking

Cryoprobe



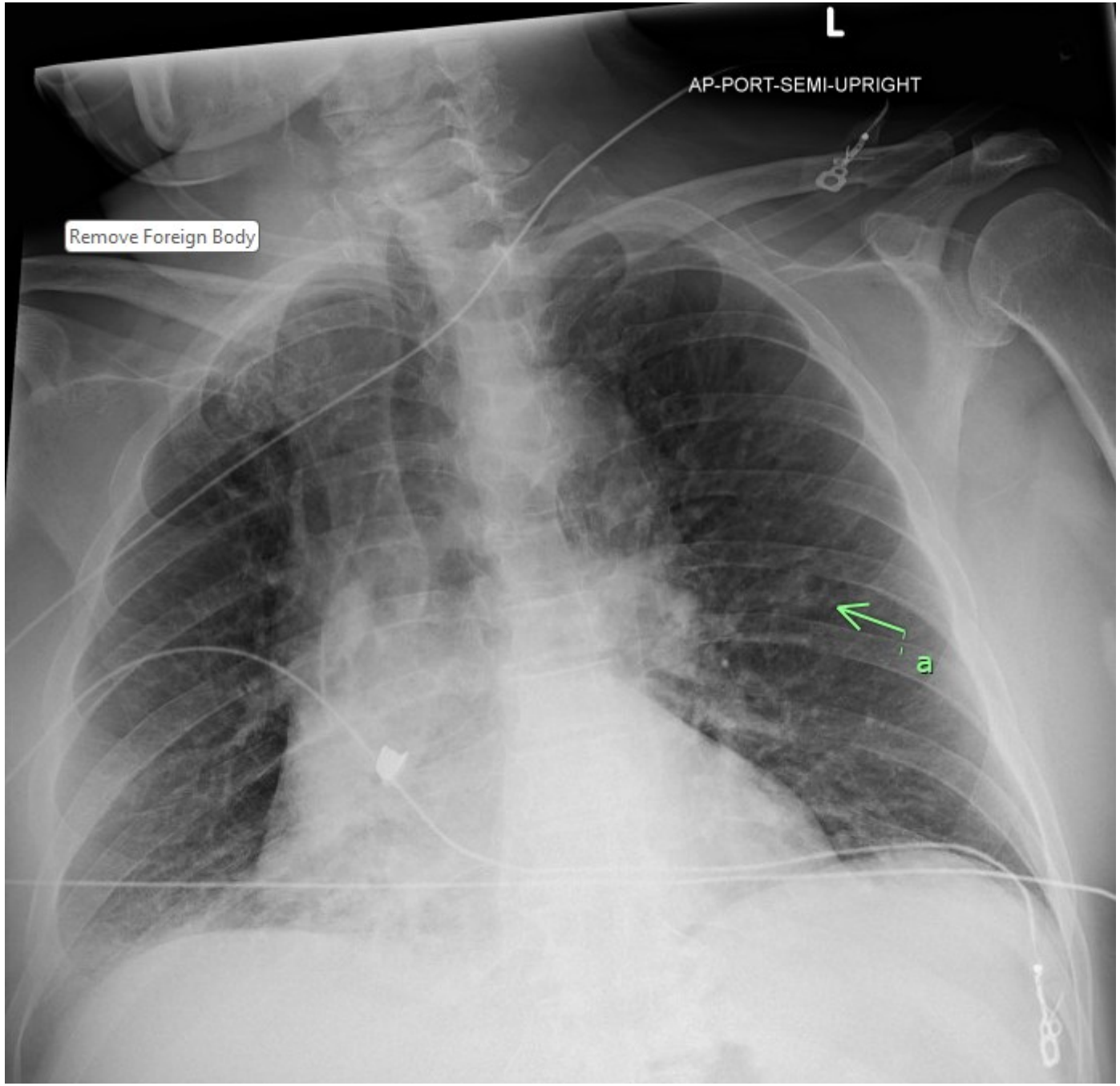






Remove Foreign Body

- Forceps
- Basket
- Snare
- Cryo
- Balloon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Remove Foreign Body
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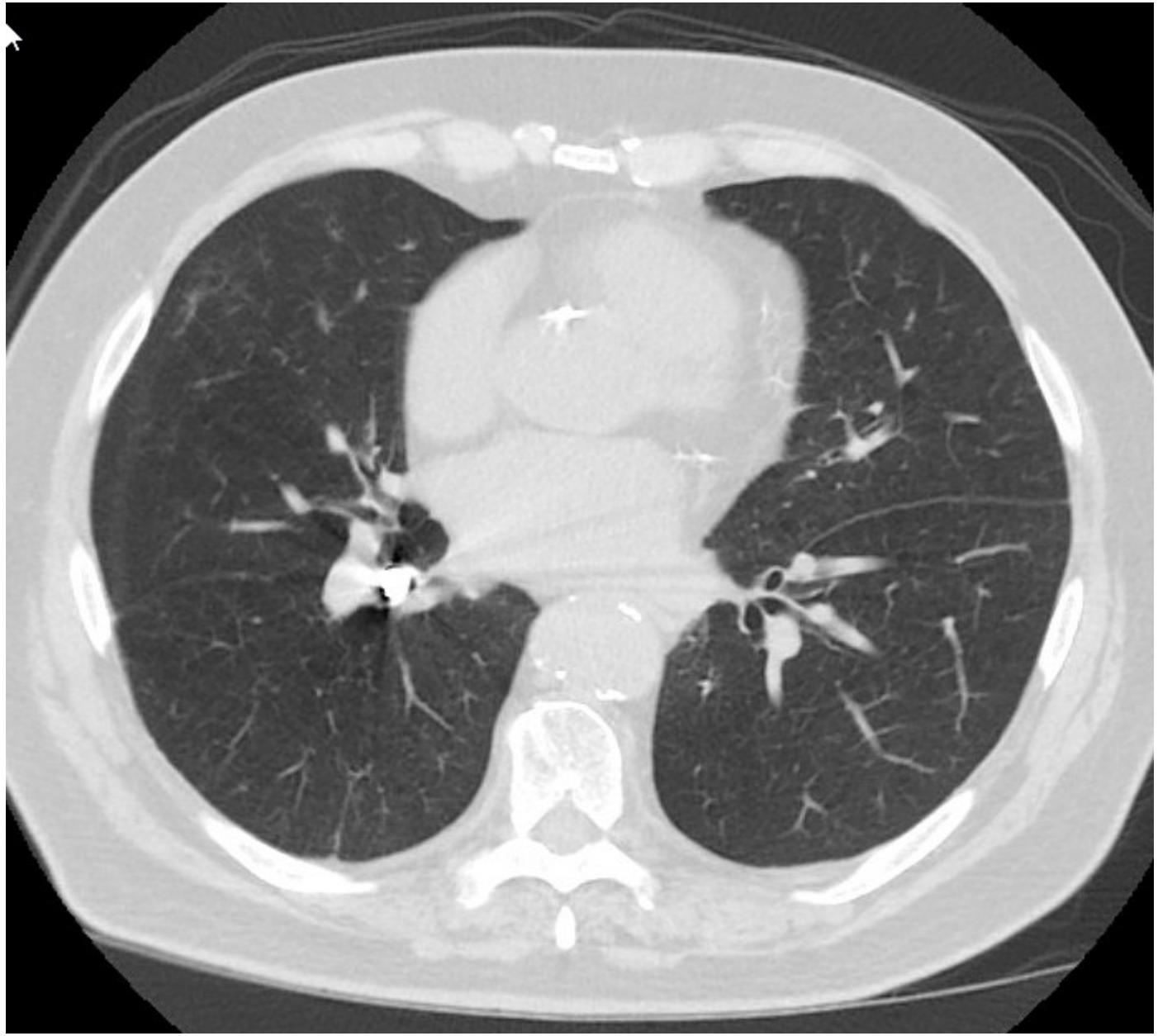
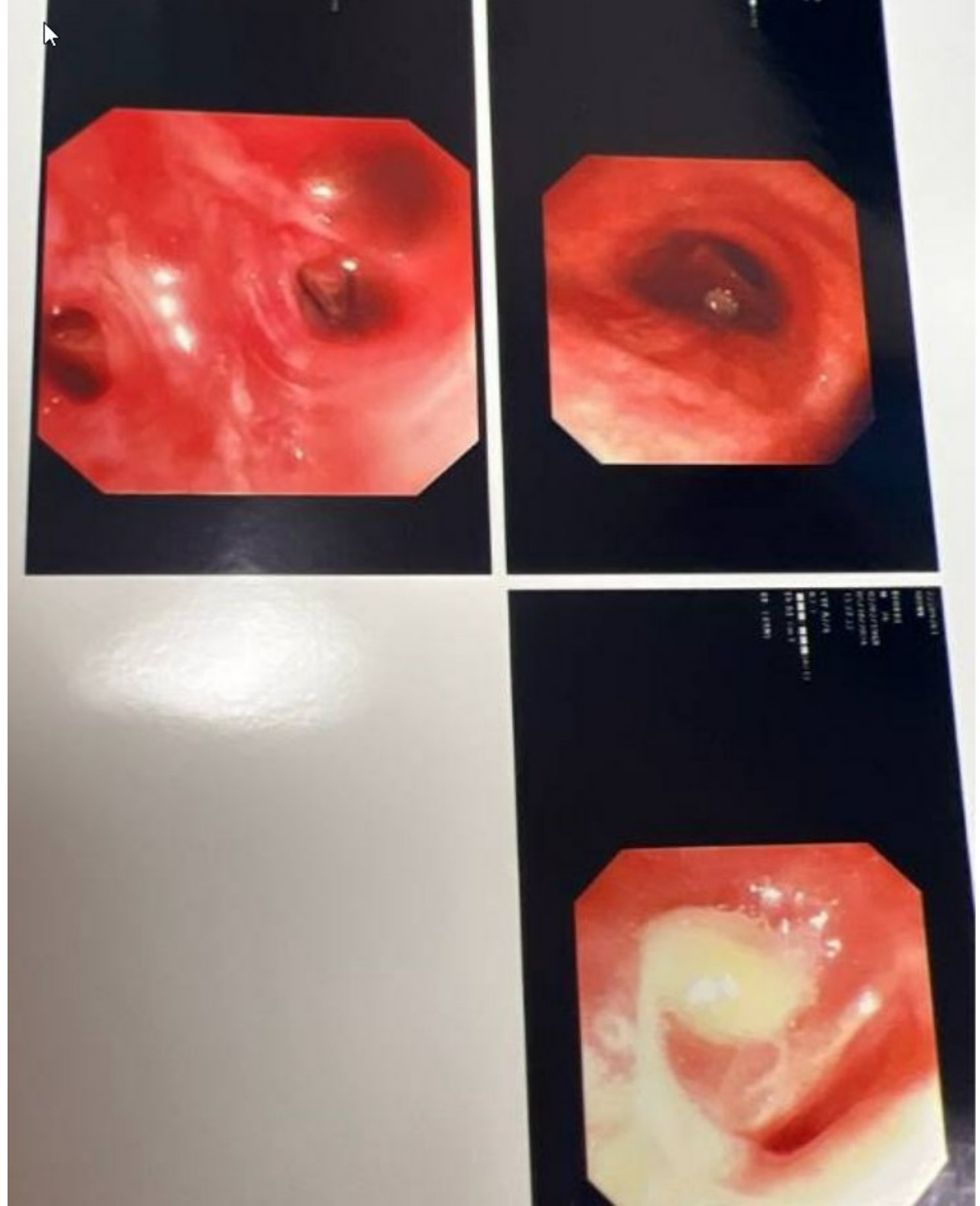
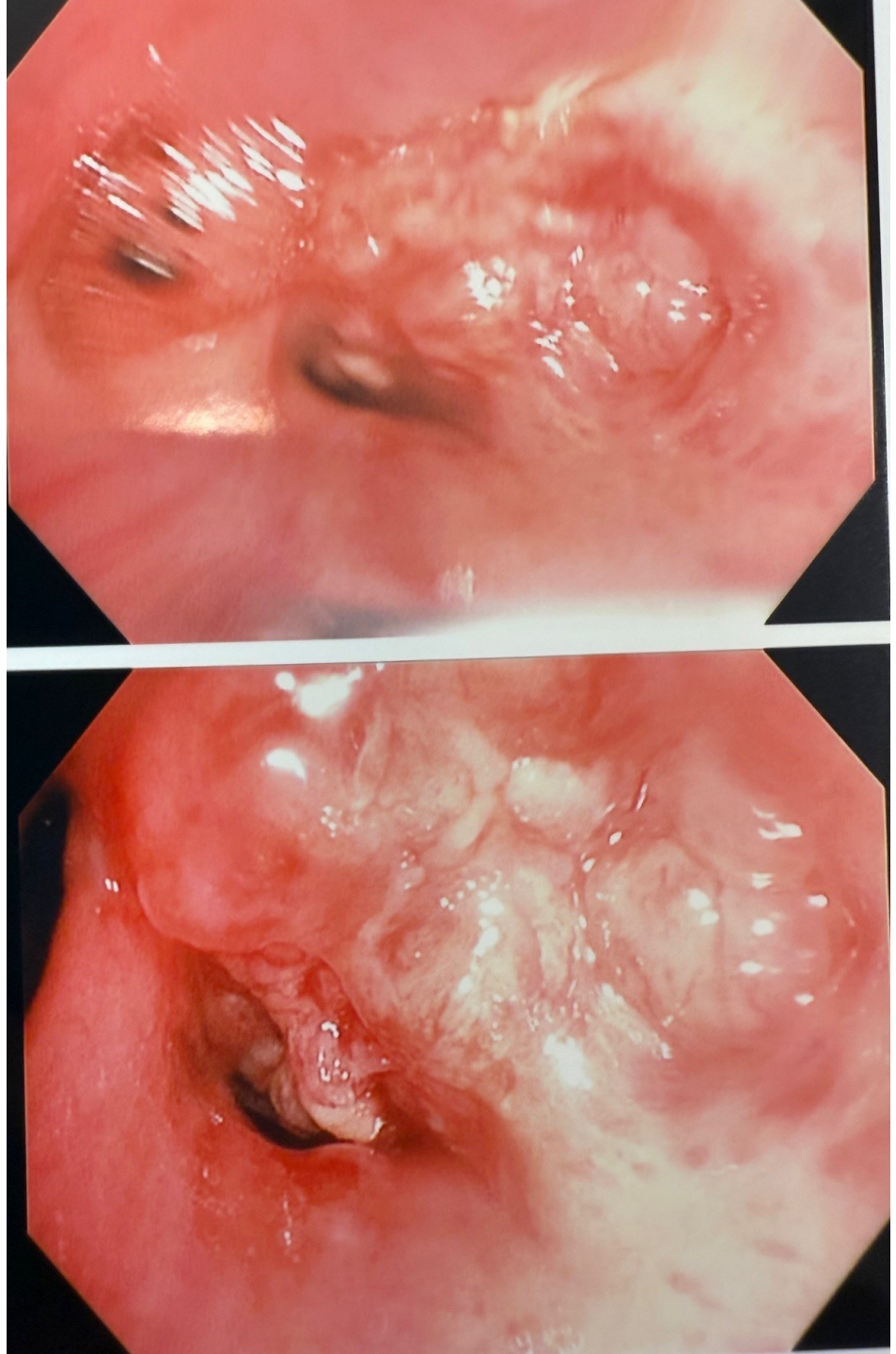
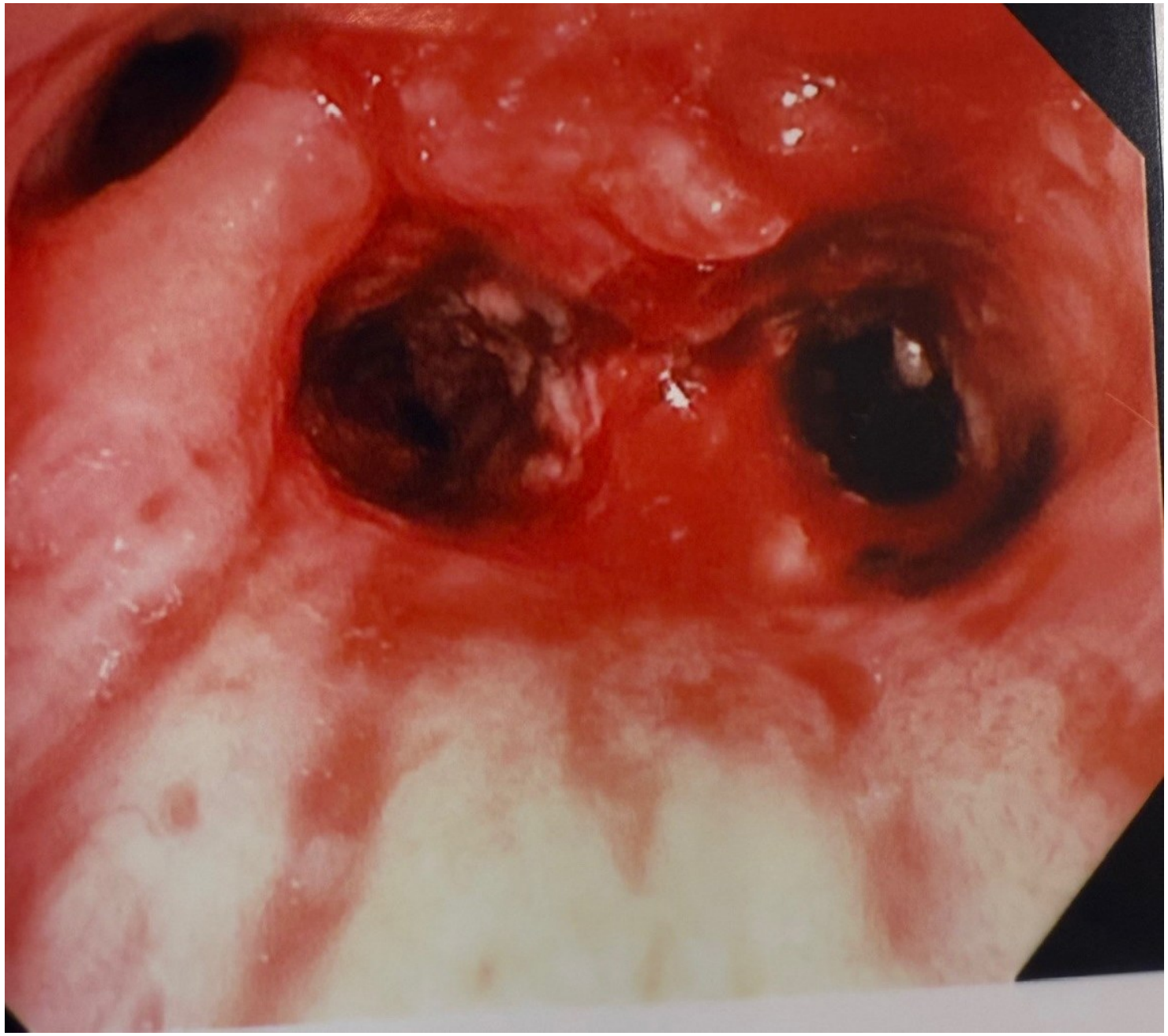




Distal RBI Tumor
Occluding RML, RLL



Post APC Ablation with
Balloon Bronchoplasty



Hemoptysis

- Hemoptysis, the expectoration of blood from the respiratory tract, can be challenging to manage for even the most experienced clinicians.
- The presentation varies, ranging from mild, blood-tinged mucus to serious and potentially life-threatening hemorrhage.
- A number of different etiologies exist.
- A variety of techniques are used to treat life-threatening hemoptysis, including bronchoscopy, bronchial artery embolization (BAE), and surgical intervention.
- Ultimately, management of this condition requires a multi-disciplinary team approach, including ICU physicians (intensivists), radiologists, pulmonologists, interventional radiologists, and thoracic surgeons.

Hemoptysis

- Several descriptors for the degree of hemoptysis exist in the literature with massive as the most commonly used term for severe hemoptysis.
- The exact criteria for “massive” hemoptysis has not been standardized, with volumes of blood loss used to characterize the condition ranging from 100 mL in 24 hours to greater than 1 L
- Others have argued that the severity of hemoptysis should be based not only on the amount of expectorated blood but also by the clinical context.

Hemoptysis

- Calculating the volume of lost blood may be difficult and inexact.
- Given that the average anatomic dead space of the lung is approximately 150 mL, even a small to moderate volume of blood can quickly overwhelm the lung's ability to oxygenate and ventilate.
- In patients with chronic lung disease, the physiologic dead space is increased.
- Pre-existing heart failure, emphysema, or pulmonary hypertension may compromi… patient's ability to compensate for e… volumes of bleeding in the trache… …al tree (lack of pulmonary reserve).

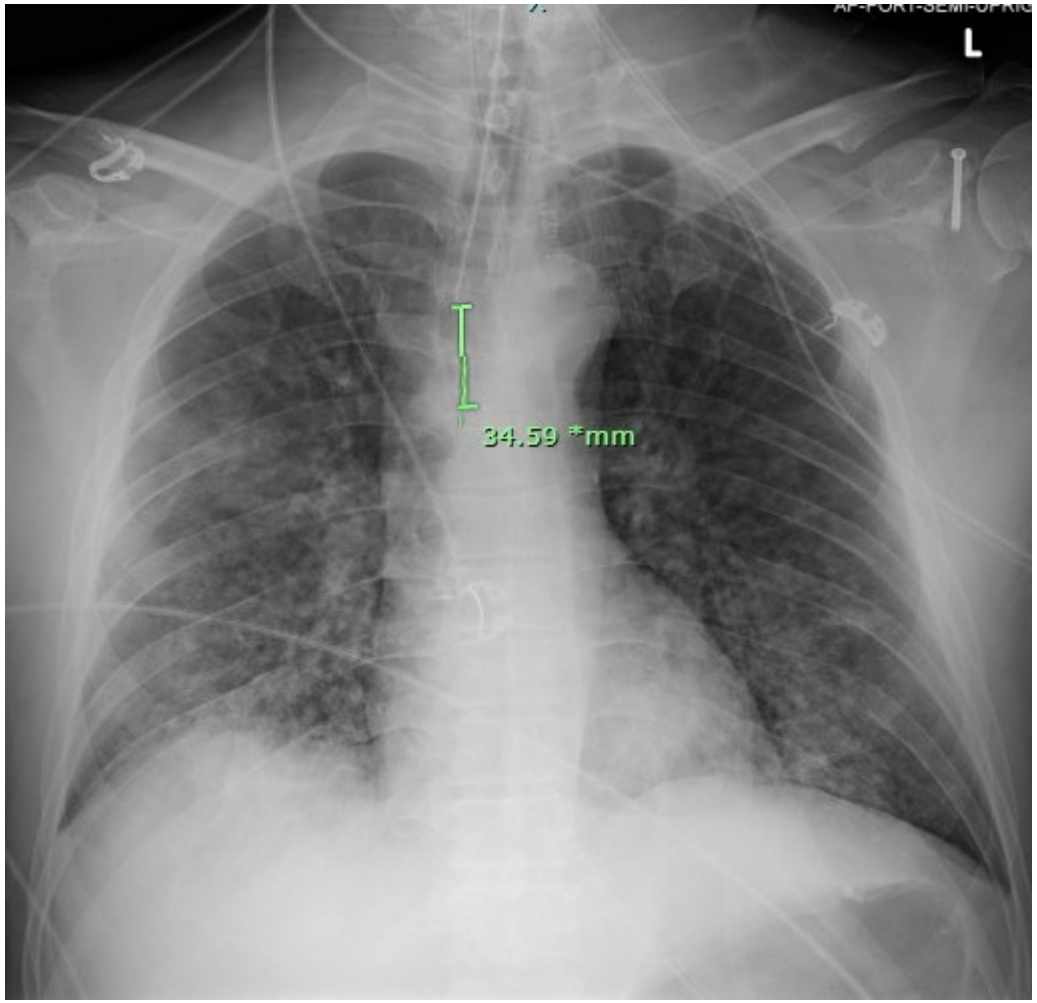
Hemoptysis

- Bronchoscopy is an essential intervention for the management of life-threatening hemoptysis.
- It can be used for both diagnostic and therapeutic purposes and can be done rapidly at the bedside in the ICU setting. Bronchoscopy can aid in lateralizing the site of bleed, but its sensitivity in determining the cause of bleeding is low (8%).
- In the setting of life-threatening hemoptysis, bronchoscopy can provide some therapeutic options for temporizing the bleeding prior to definitive management.
- Importantly, bronchoscopy is useful for suctioning of blood and clots from the unaffected lung in order to improve gas exchange.

Revel MP, Fournier LS, Hennebicque AS, et al. Can CT Replace Bronchoscopy in the Detection of the Site and Cause of Bleeding in Patients with Large or Massive Hemoptysis? AJR Am J Roentgenol 2002;179:1217-24.

Hemoptysis

- 47 yo male smoker with Histoplasmosis Lung infection (noncompliant with posaconazole) and severe hemoptysis leading to hypoxemic respiratory failure and intubation.
- Patient underwent bronchoscopy X8 to clear the airways of clot.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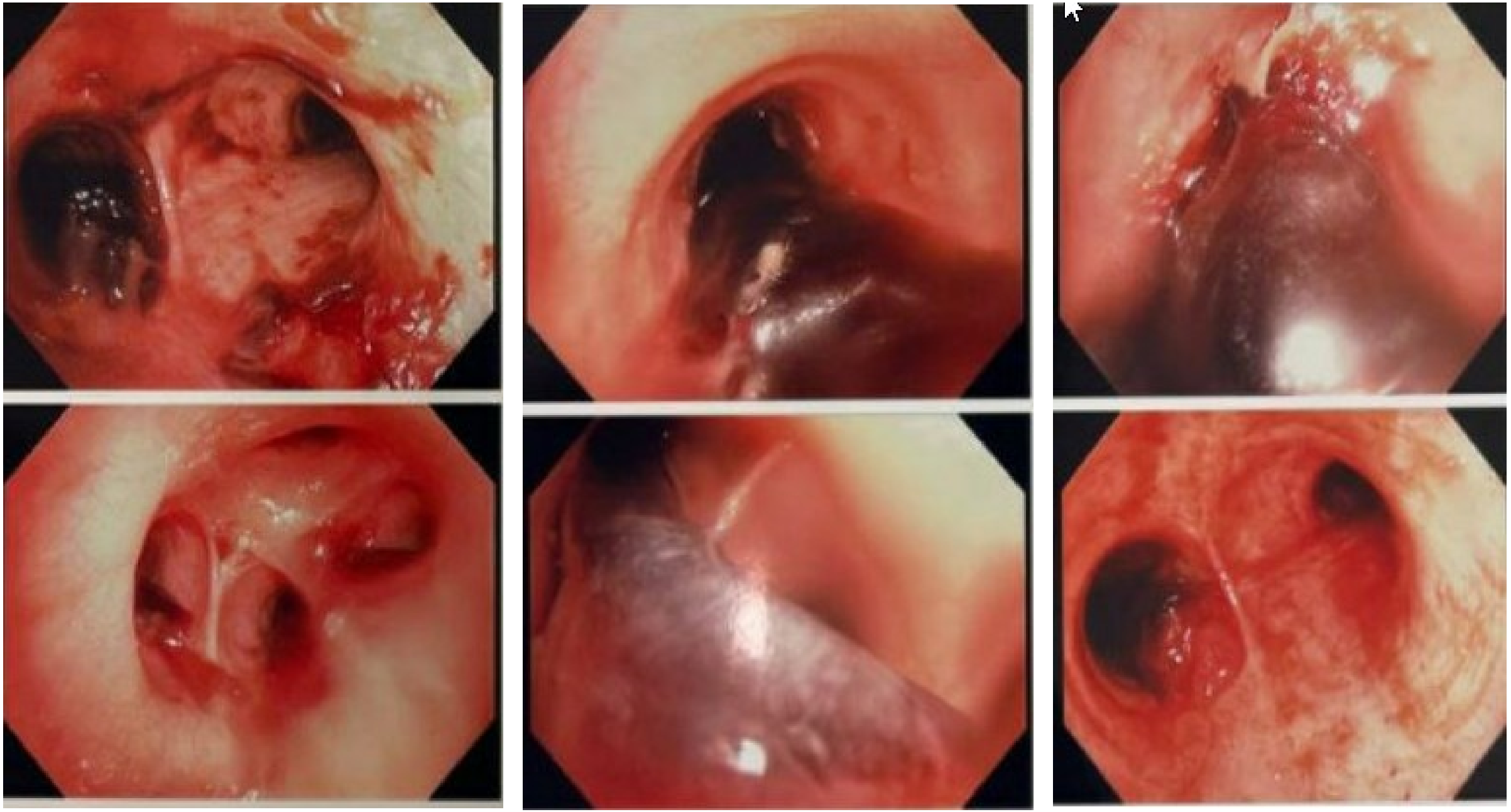
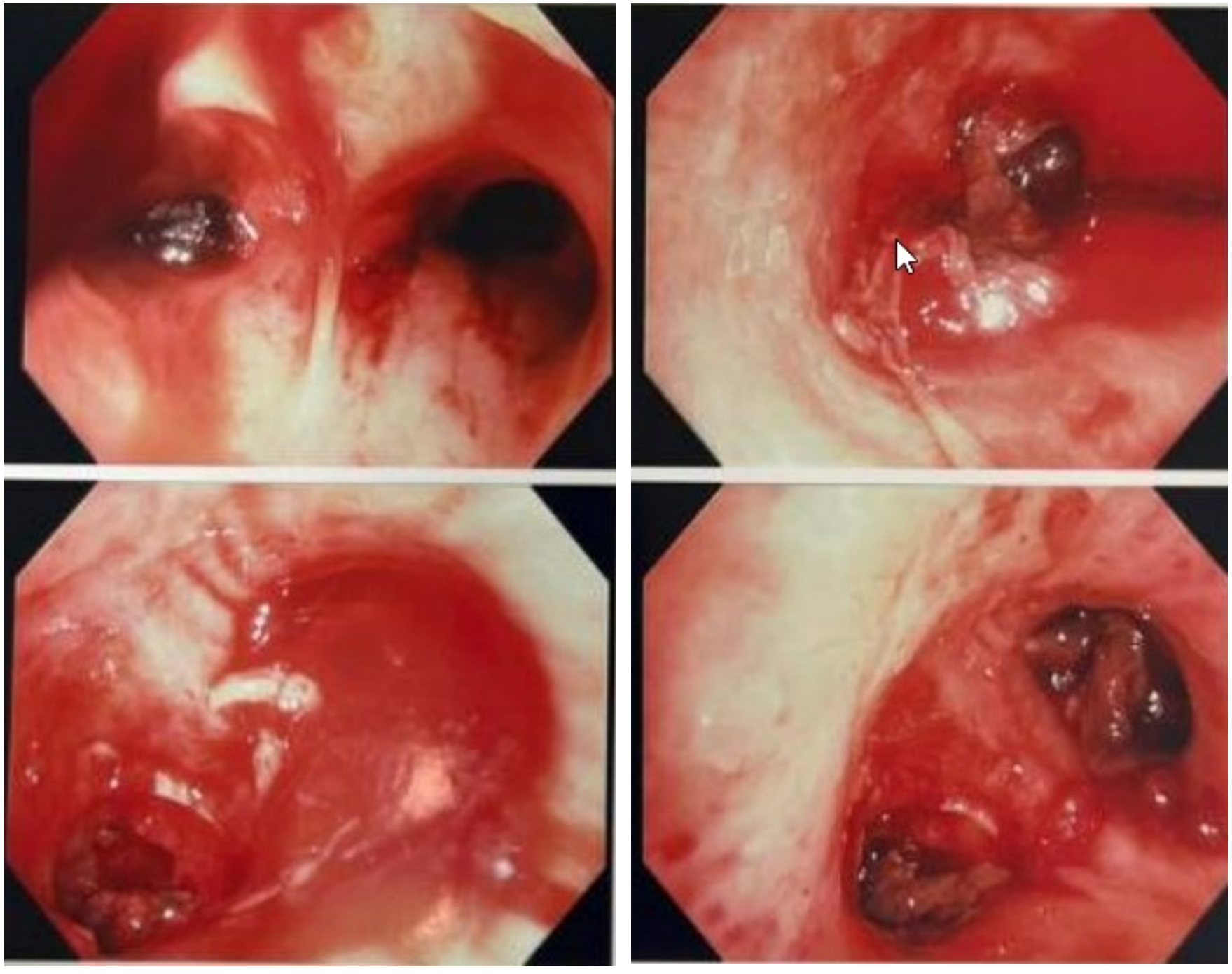
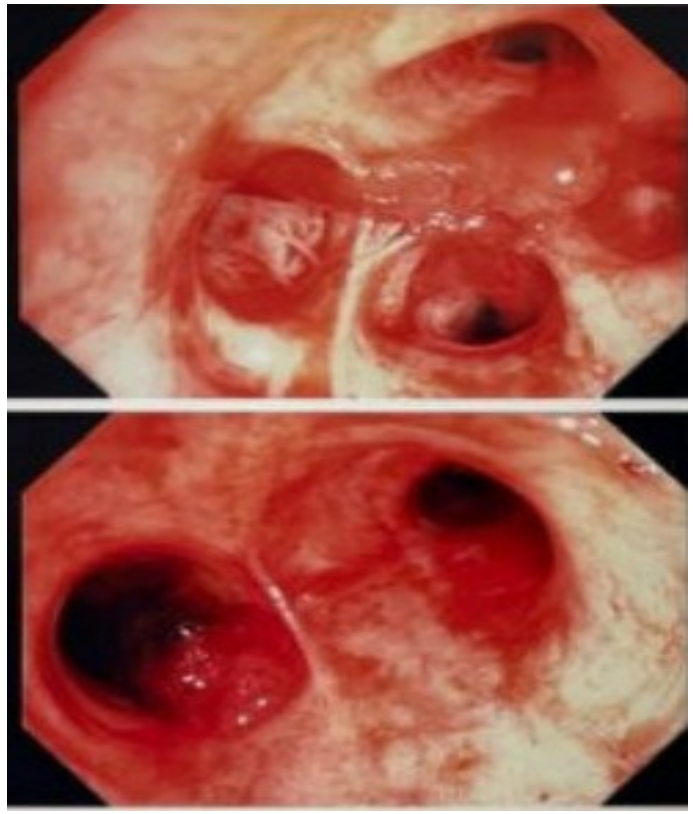




Remove Old Blood CLots

- Surgical Waste Management
- More Powerful than Usual Wall Suction

Post Procedure



Hemoptysis

- The pulmonary vascular supply consists of two distinct systems: the bronchial and pulmonary arteries.
- Ninety-nine percent of blood flow to the lungs is provided by the pulmonary arteries, which participate in gas exchange.
- The bronchial arteries supply nutrients to the pulmonary system and do not interact directly with the alveolar units/gas exchange.

Hemoptysis

- The source of bleeding in 90% of cases of life-threatening hemoptysis is the bronchial arteries, with the remaining 10% of cases originating from a pulmonary artery (PA) or an unidentified source of bleeding.
- Many pathological pulmonary conditions can alter the anatomy of the bronchial arterioles, which can increase the risk of rupture and subsequent pulmonary hemorrhage.
- Pulmonary hypertension, chronic infecti
  bronchiectasis, malignancy and v
  can all create an environment
  blood flow from the pulmon ies to
  the bronchial circulation, l g to
  hypertrophy, hypervascu tion, and
  collateral vessel format

Hemoptysis

- Mortality rates from massive or life-threatening hemoptysis range widely and can be as high as 50–100%.
- Hemoptysis cases predominantly involve adults, with males being more than twice as likely to be affected.

Crocco JA, Rooney JJ, Fankushen DS, et al. Massive hemoptysis. Arch Intern Med 1968;121:495-8.

Abdulmalak C, Cottenet J, Beltramo G, et al. Haemoptysis in adults: a 5-year study using the French nationwide hospital administrative database. Eur Respir J 2015;46:503-11

Hemoptysis

- The causes of hemoptysis are diverse and range from infectious to malignant to iatrogenic etiologies.
- Globally, tuberculosis is the most common cause due to its prevalence in developing nations, while malignancy is the underlying origin in most cases in developed countries.
- As medical treatments have advanced, the prevalence of various etiologies of hemoptysis has shifted.

Johnston H. Changing spectrum of hemoptysis. Underlying caus[illegible] undergoing diagnostic flexible fiberoptic bronchoscopy. Arch Intern Med 1[illegible]9-8

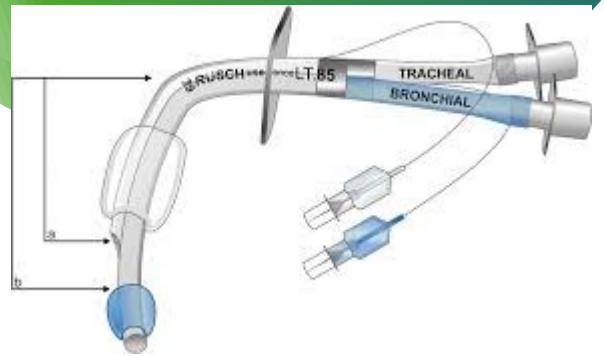
Hemoptysis and Respiratory Failure

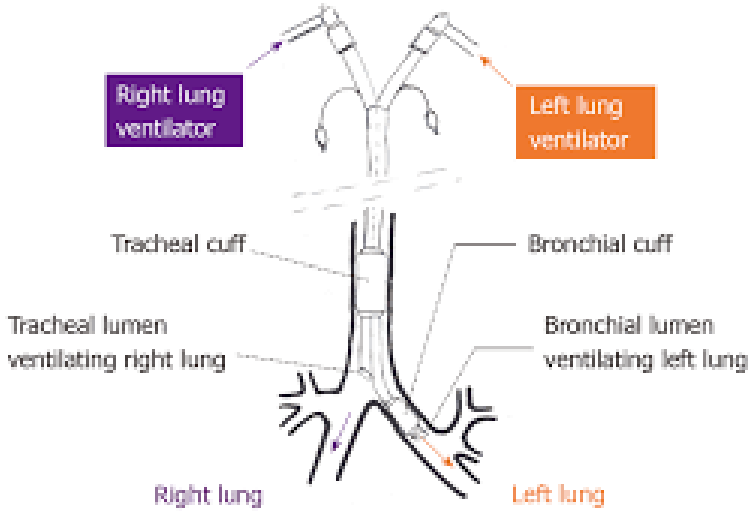
- If the patient is unable to maintain oxygenation or ventilation, has impaired mentation, or inability to expectorate, then endotracheal intubation should be considered, ideally in conjunction with early bronchoscopy.
- The patient should be intubated preferably with a large diameter endotracheal tube, 8.5 to 9 mm for men and 8.0 to 8.5 mm for women.
- This will facilitate passage of therapeutic bronchoscopes as well as endobronchial blockers. Placing the patient in the lateral decubitus position with the affected lung down can prevent aspiration of blood into the unaffected lung.

Hemoptysis and Respiratory Failure

- If the site of bleeding is able to be lateralized, then selective mainstem intubation of the unaffected lung can be attempted bronchoscopically after endotracheal intubation.
- In the case of selective intubation of the right lung, there is a risk of obstruction of the right upper lobe by the endotracheal tube, which can be problematic in patients with limited pulmonary reserve.
- Selective endobronchial intubation also prevents access to the affected lung for further bronchoscopic intervention.

Dual Lumen E



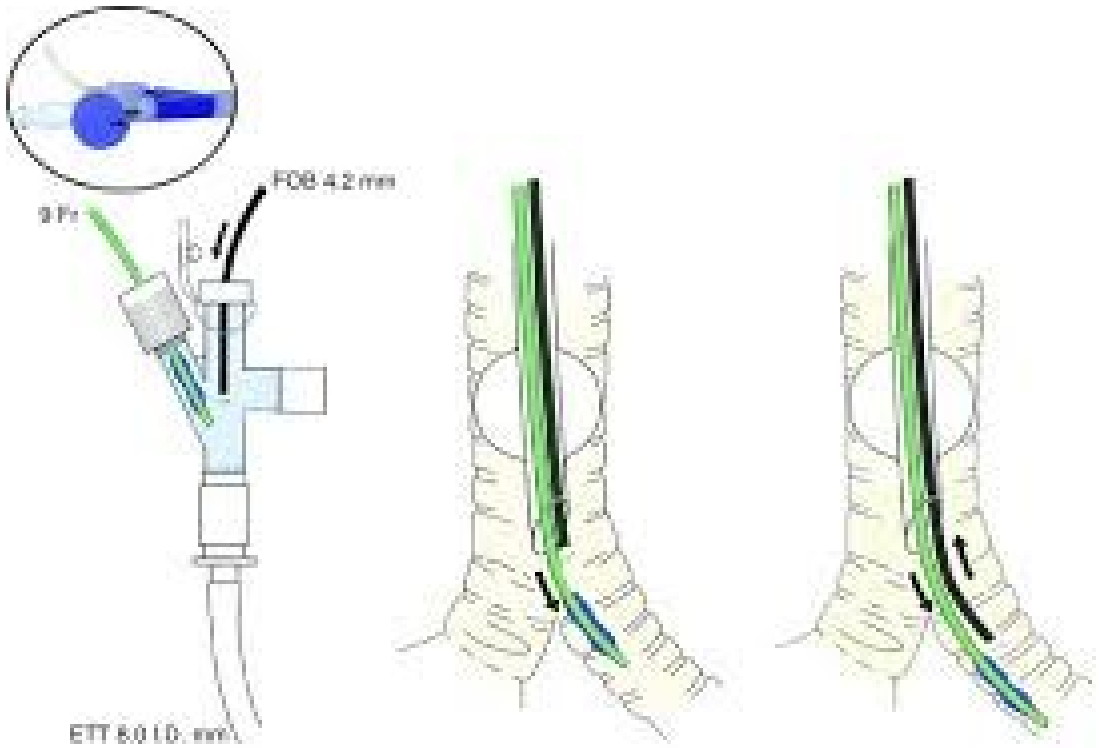


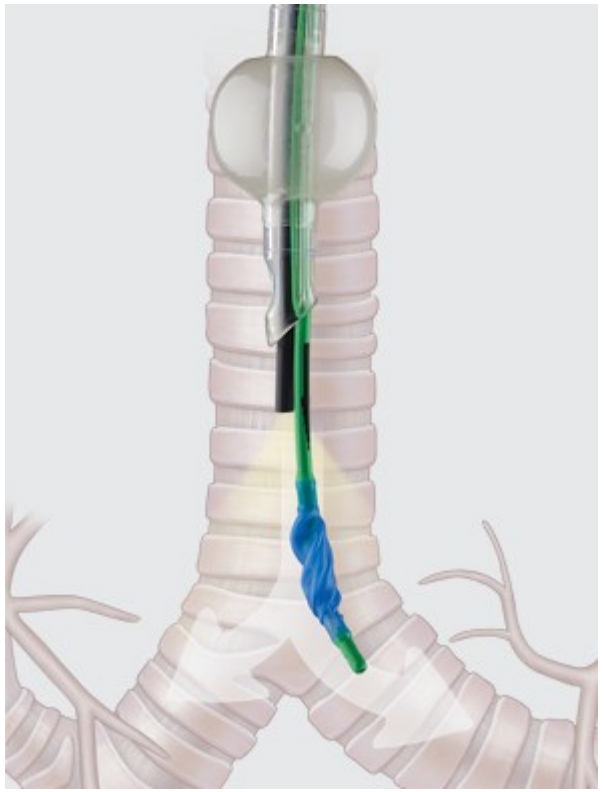
- Pulmonary isolation can also be accomplished by insertion of a double-lumen endotracheal tube (DETT), which provides ventilation to the unaffected lung and allows limited passage of instruments into the affected lung.
- The insertion of a DETT, however, can be technically difficult and requires an experienced operator for successful placement.
- Given the technical challenges of placi DETT and subsequent inability to p airway clearance or bronchosc therapeutics, intubation with lumen endotracheal tube is more ne recommended manageme ategy.

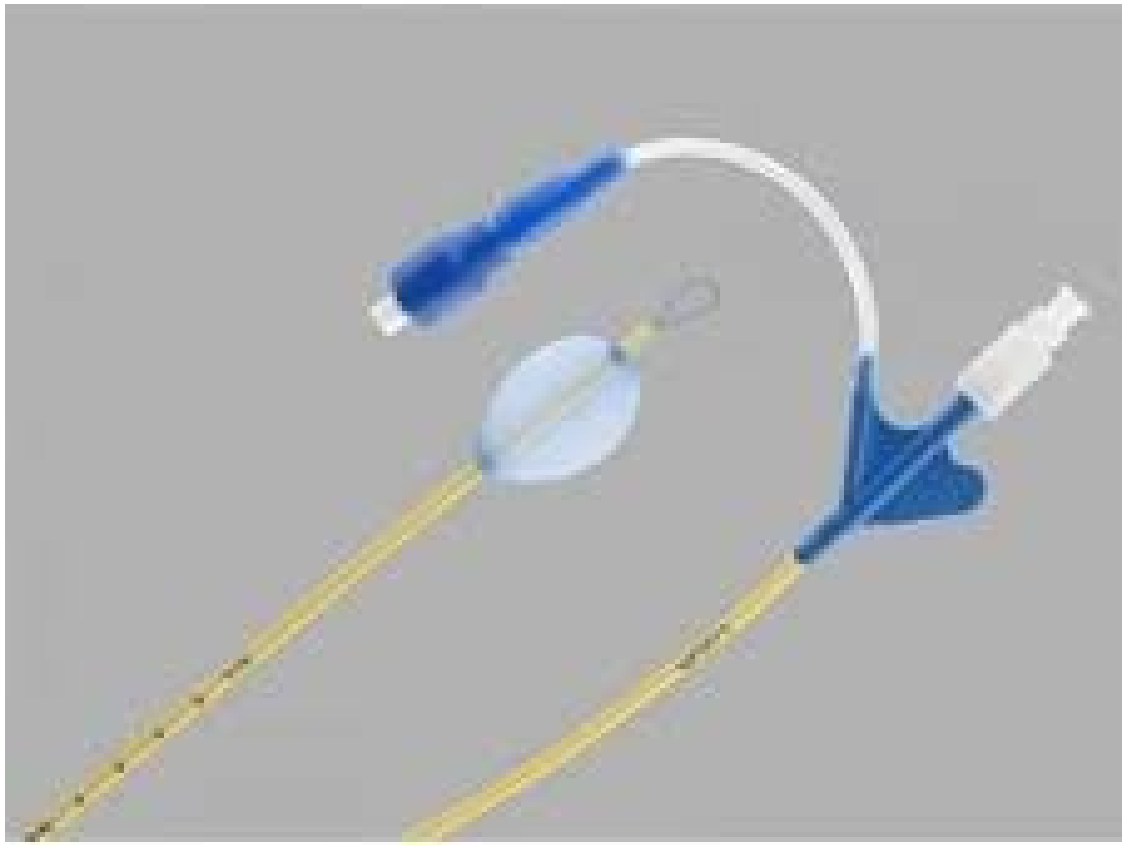
Balloon Occlusion Devices

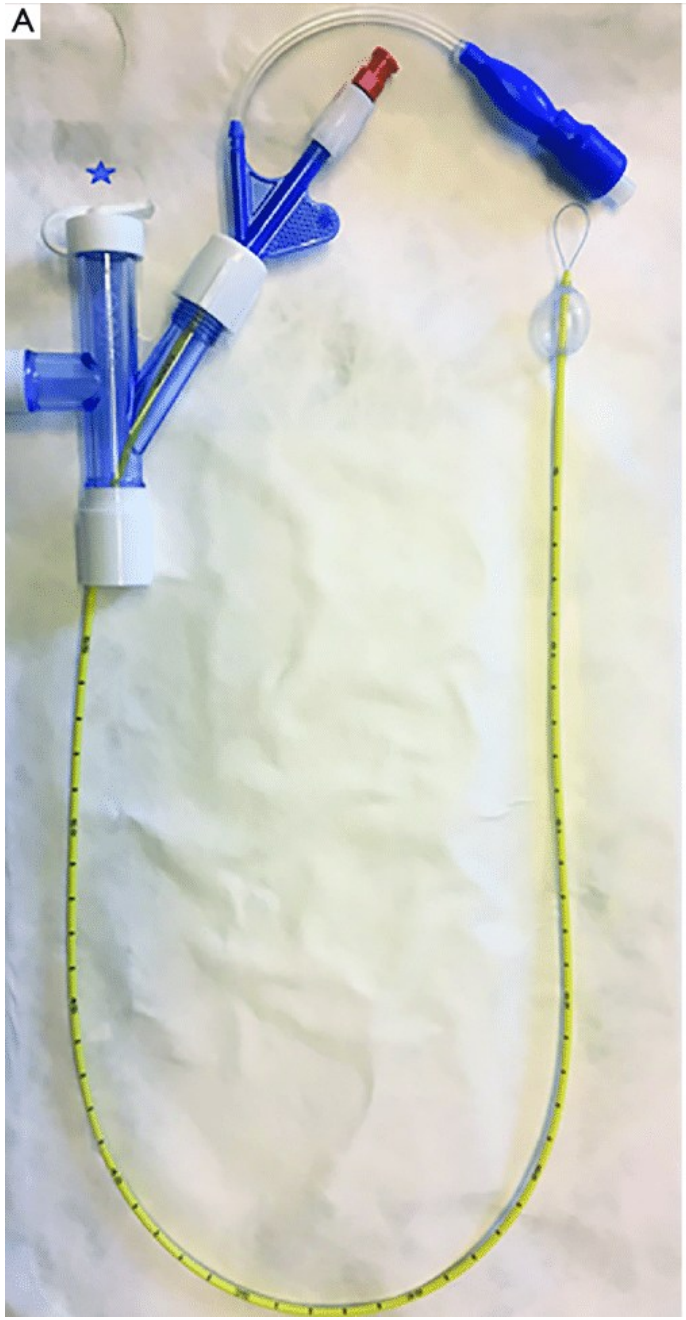
- Endobronchial blockers (EBB) may be used to selectively isolate the affected lung of the bleeding segment
- These devices can be bronchoscopically advanced through the ETT to occlude the affected lobe of the lung and are periodically deflated to evaluate for hemostasis and to prevent airway injury.

Balloon Occlusion Devices

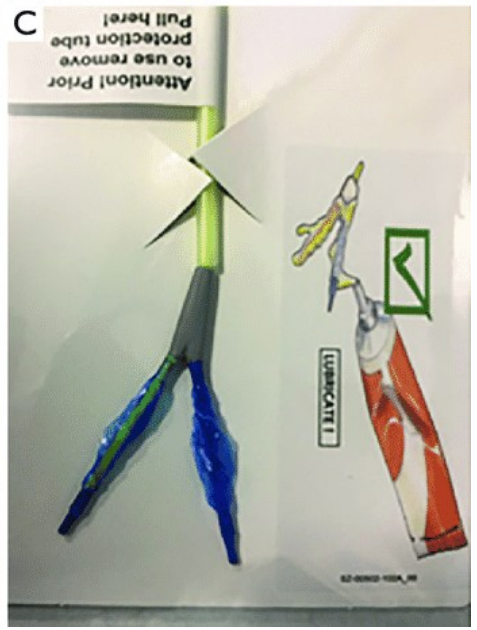


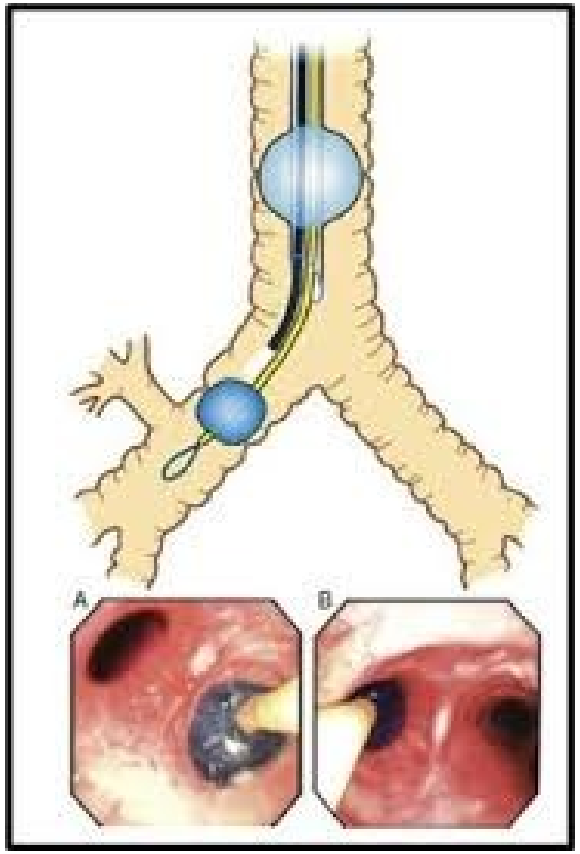





A


B


C
Attention! Prior
to use remove
protection tube
Pull here!
LUBRICATE !


A
B

Hemoptysis

- Cold saline irrigation is frequently used as a topical therapy to mitigate intra- and post-procedural endobronchial bleeding and can be used as a temporizing measure during management of life-threatening hemoptysis.
- Normal saline at 4 degrees Celsius in 50 mL aliquots.
- The average volume of saline used prior to cessation of bleeding is 500 mL.
- The sole adverse effect was transient sinus bradycardia. Twenty-five percent of patients underwent definitive surgical treatment.

Conlan AA, Hurwitz SS. Management of massive hemoptysis with the rigid bronchoscope and cold saline lavage. Thorax 1980;35:901-4.

Hemoptysis

- In addition to cold saline, topical hemostatic and vasoactive agents can be used as adjunct measures during life-threatening hemoptysis.
- Vasopressin desmopressin have been shown to achieve hemostasis with both the intravenous and endobronchial routes.
- Application of epinephrine diluted in normal saline can be used in conjunction with cold saline for endobronchial bleeding and can be used for life-threatening hemorrhage.
- In sources of bleeding that are visi endoscopically, use of APC o photocoagulation can be us eatment after bleeding has been c ed with topical therapies.

Tranexamic Acid - TXA

- TXA is a derivative of the amino acid lysine that inhibits the binding of plasminogen and its activators to fibrin, thus inhibiting fibrinolysis.
- TXA demonstrates reduced bleeding after administration during cardiac surgery, obstetric procedures, trauma, acute upper gastrointestinal bleeding, and hemoptysis.
- Pooled results from the studies showed significant reduction in bleeding tim receiving TXA as compared to pat eiving placebo.

Tranexamic Acid - TXA

- Bellam *et al.* conducted a single-blind, prospective RCT studying the effect of intravenous TXA in 66 patients with moderate to severe hemoptysis compared with control patients receiving normal saline.
- Use of TXA was associated with an improvement in the frequency and severity of hemoptysis as measured by visual analogue scale, but there was no significant difference between groups with regards to number of episodes per day and measured volume of hemoptysis.

Bellam BL, Dhibar DP, Suri V, et al. Efficacy of tranexamic acid in hemoptysis: A randomized, controlled pilot study. Pulm Pharmacol Ther 2016;40:80

Tranexamic Acid - TXA

- Endobronchial instillation of TXA has been shown to be efficacious in treating hemoptysis.
- In a randomized, double-blind RCT comparing endobronchial instillation of TXA compared to epinephrine, there was no significant difference in mean time to achieving bleeding control.
- Additionally, nebulized/inhaled TXA has been used for moderate hemoptysis but not in patients with life-threatening hemoptysis.

Fekri MS, Hashemi-Bajgani SM, Shafahi A, et al. C drenaline with Tranexamic Acid to Control Acute Endobronchi . A Randomized Controlled Trial. Iran J Med Sci 2017;42:129-3

Segrelles Calvo G, De Granda-Orive I, López D. Inhaled Tranexamic Acid as an Alternative for Hemoptysis Treat nest 2016;149:604

Bronchial Arterial Embolization

- Originally described by Rémy *et al.* in 1974, Bronchial Arterial Embolization (BAE) has become one of the first-line interventions for life-threatening hemoptysis.
- BAE has been shown to be effective in hemoptysis of both benign and malignant etiologies, including tuberculosis, bronchiectasis, aspergilloma, pneumonia, cystic fibrosis, primary lung cancer, and metastatic disease.
- The immediate success rate of BAE in treatment of hemoptysis ranges from 73% to 100%.

Sopko DR, Smith TP. Bronchial Artery Embolization for Hemoptysis. Semin Intervent Radiol 2011;28:48-62

Endobronchial Valves

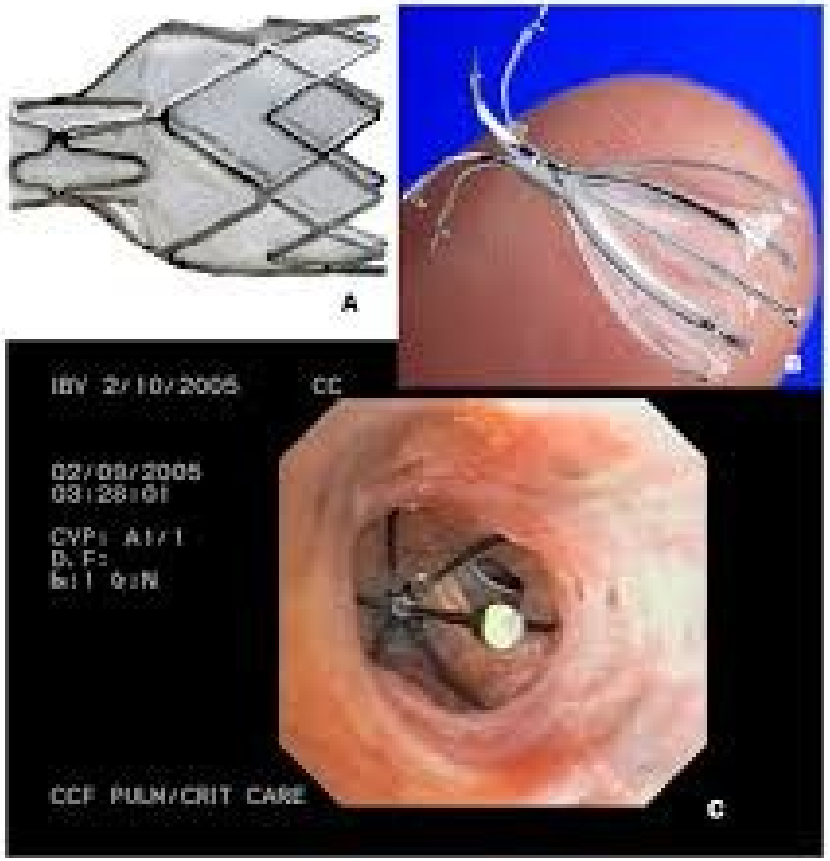
- There are some case reports of successful use of endobronchial valves for life threatening hemoptysis despite arterial embolization.
- This procedure could be an alternative in the management of recurrent hemoptysis in patients who are not candidates for surgery or as a preliminary step toward elective surgery.
- Clearly this would be unlikely to work in DAH.

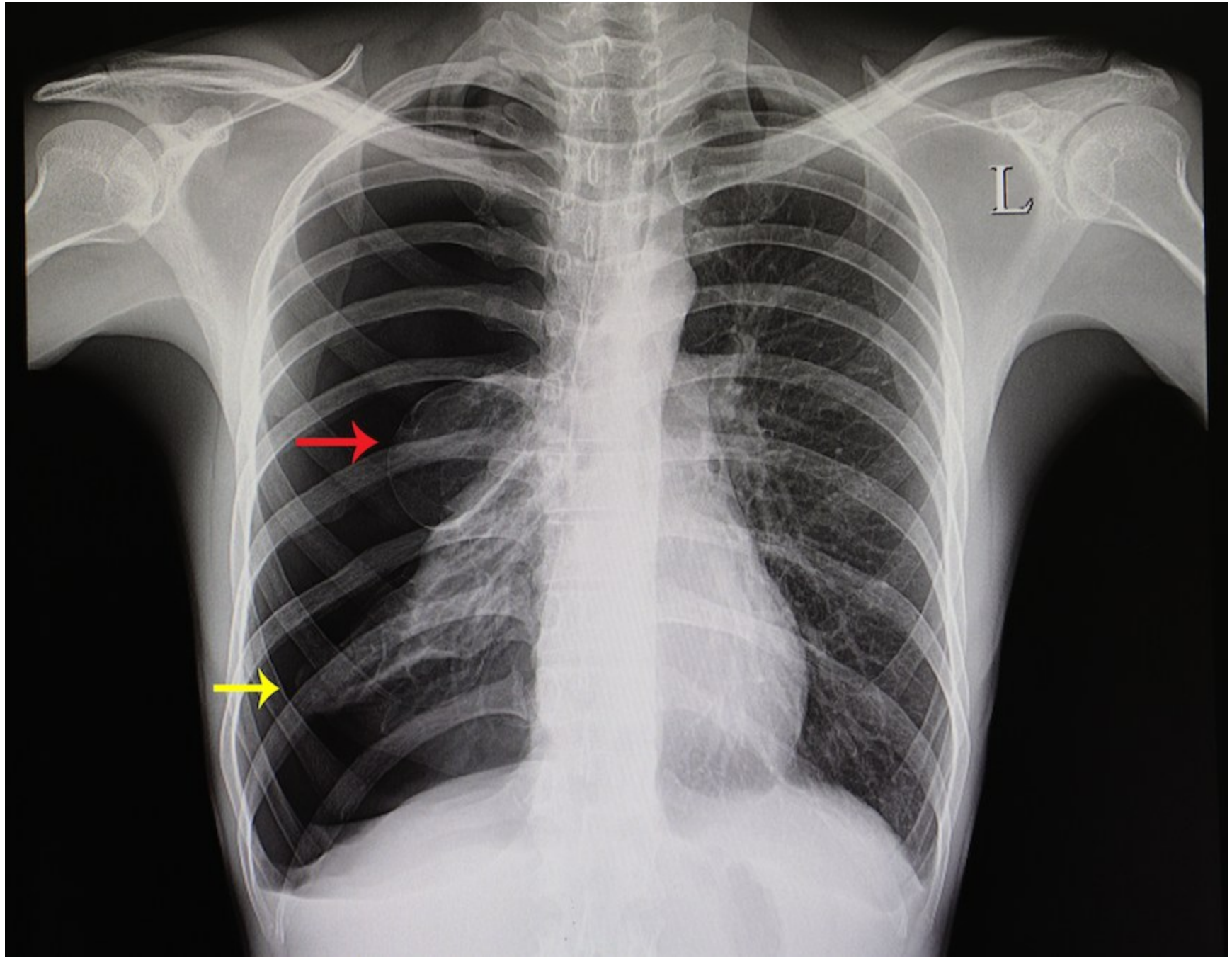
AJ Solis Open Resp Arch. 2024 Jun 22; (6) 100346

Surgery

- Surgical management of life-threatening hemoptysis can be appropriate for patients with localized lesions.
- Operative intervention may carry a high mortality, with reported rates of 10–38%, largely due to patients having an underlying compromised respiratory system prior to surgery.
- The indications and eligibility for surgical intervention are not standardized; however, surgical management may provide definitive treatment for patients that have had recurrent hemoptysis after prior BAE.
- Surgical procedures include lobectomy, bi-lobectomy, and pneumonectomy, with lobectomy being the most common
- Post-operative complications include recurrent hemoptysis, persistent air leak, bronchopleural fistulae, empyema, prolonged mechanical ventilation, and tracheostomy.

Endobronchial Valves

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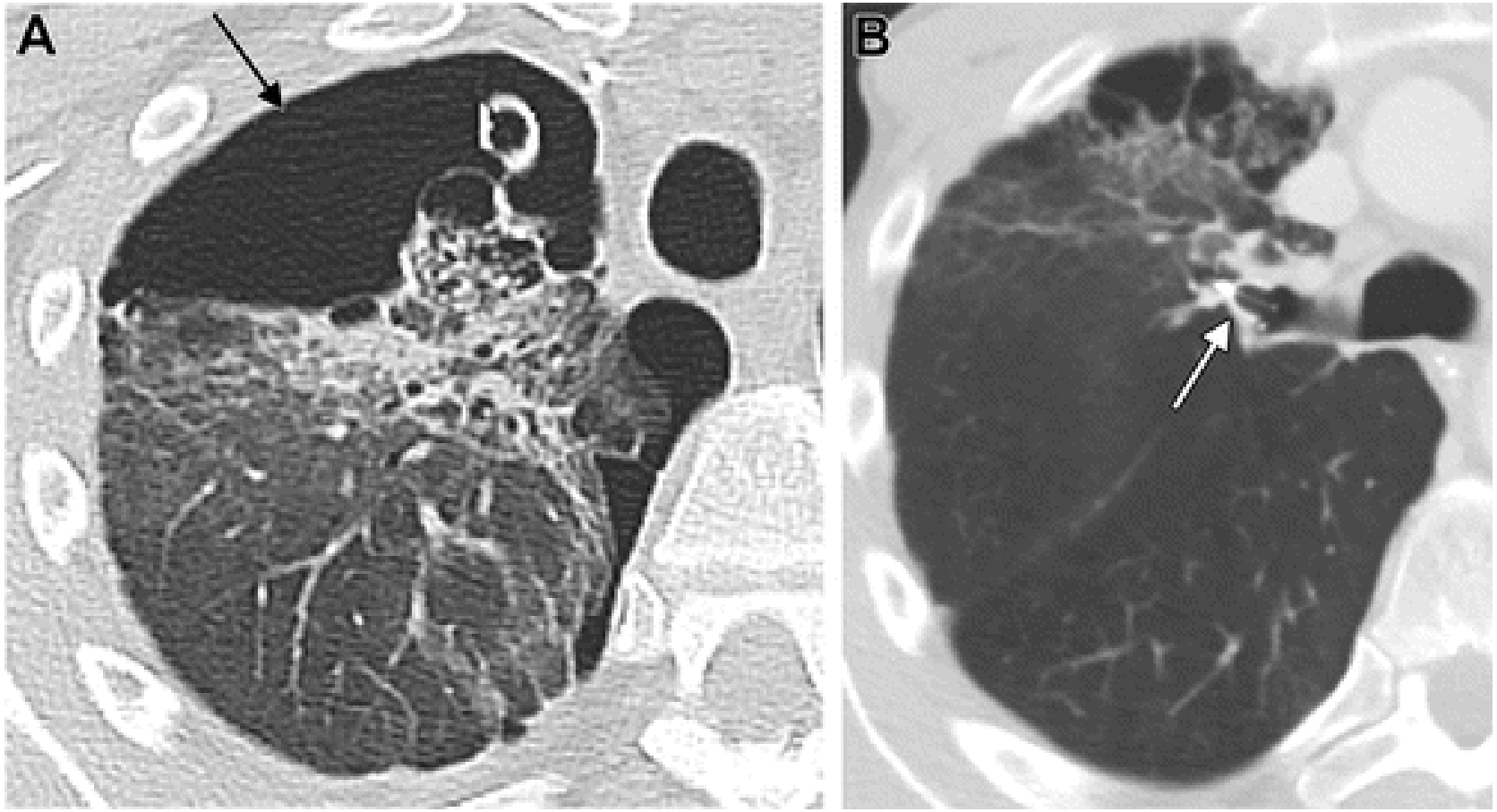
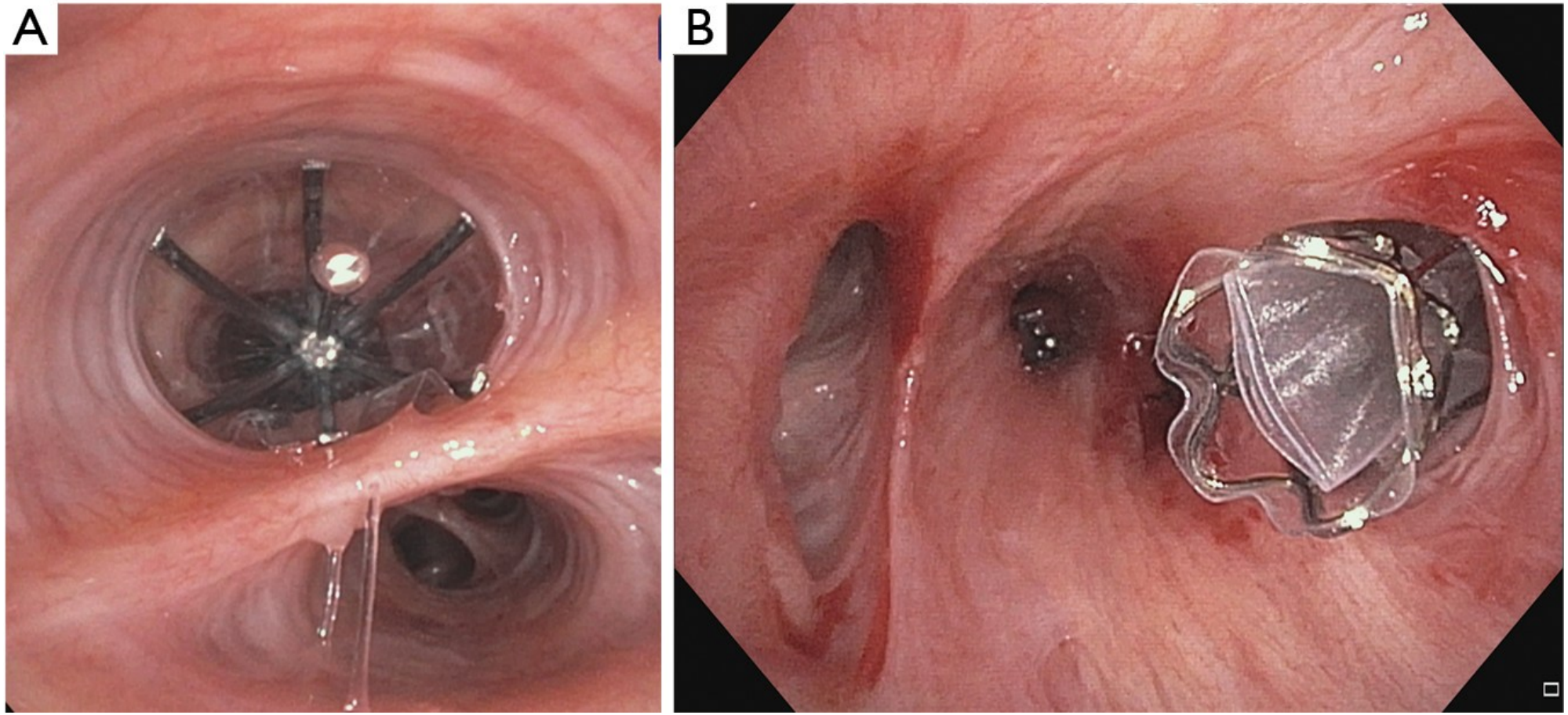
Endobronchial Valves

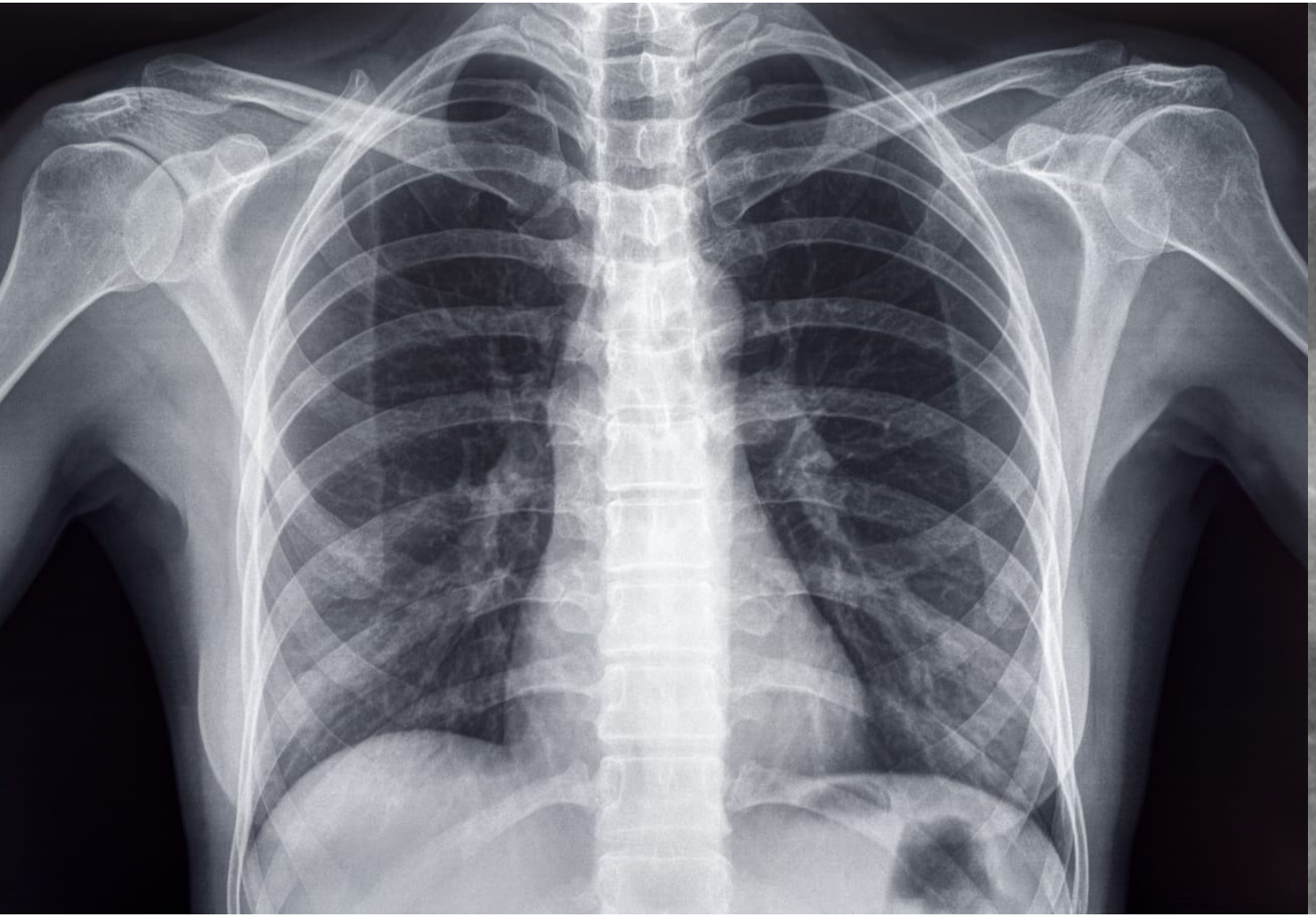


Endobronchial Valves for Persistent Air Leak

- One-way bronchial valves represent a novel minimally invasive option for Persistent Air Leak (PAL) treatment.
- Originally developed for patients with severe emphysema as an alternative to Surgical lung volume reduction (LVRS), their application for other uses has become apparent.
- In 2005, Snell *et al.* reported the first case of using these valves for a PAL.
- Although there are two endobronchial valves currently approved by the US FDA for BLVR, only the spiration valves have FDA approval for PAL post lobectomy, segmentectomy, or lung volume reduction.

EBV





Endobronchial Valves

- Both valves are one-way devices that allow air and other debris to move proximally into the central airways but block ventilation distally.
- In theory, this limits airflow through the fistula and permits apposition of the two edges of the pleural defect so that healing can occur.
- Because of this, valves are a temporizing intervention designed to be removed after approximately 6-8 weeks.
- The valve must be sized then lo the deployment catheter, wh introduced through the wo annel of a bronchoscope with at l 2.8-mm working channel.

EBV for Persistent Air Leak

- Before valve insertion occurs, identification of the culprit airway and valve sizing must be performed.
- Locating the culprit airway or airways is often the most challenging and time-consuming part of the procedure.
- There is also the potential for collateral ventilation leading to multilobar contribution to the leak.
- These causes are even more likely to be present in an ICU setting.

Kurman JS, Hogarth DK. Minimally invasive persistent air leak management. AME Med J 2018;3:80

Mahajan AK, Khandhar SJ. Bronchoscopic valves for prolonged air leak: current status and technique. J Thorac Dis 2017;9:S110-S115.

Finding the Leak

- The most common methodology employed to identify the involved airways is sequential balloon occlusion, whereby a balloon is used to occlude airways starting with the largest airway and proceeding distally to the segmental or subsegmental level.
- The patient must be carefully monitored for hemodynamic instability, especially during occlusion of more proximal airways.
- Other techniques for identifying the culprit airway include insufflation and insertion of a dye, such as methylene blue, through the chest tube and observing for emergence within the endobronchial tree.

EBV for Persistent Air Leak

- Both valves are composed of a Nitinol (combination of nickel and titanium) framework and then either a polyurethane or silicone covering.
- Both valves are present in 4 sizes to accommodate airways of various diameters.
- While valves are generally well tolerated, complications are possible.
- These may include pneumonia, acute worsening of hypoxia, valve malposition, and expectoration.

Persistent Air leak

- Data supporting bronchial valves is more robust than for the anecdotal approaches.
- In 2009, Travaline *et al.* demonstrated a 93% success rate and a 15% complication rate in 40 patients treated with the silicone covered valve for PAL.
- Chest tubes were able to be removed after an average of 7.5 days.
- The first case series of the polyurethane covered valve for PAL was published in 2011 and had a 100% success rate after an average of 4.5 days following the procedure without any procedure-related complications.
- In the largest multicenter study of polyurethane covered valves to date, Gilbert *et al.* identified improvement in the air leak in 56% of patient. In the largest single-center case series to date (N=60 patients), 80% of patients were able to have their chest tubes removed.

Conclusions

- The indications for bronchoscopy in the ventilated patient are many.
- The procedure can facilitate the location and potentially treatment of a source of bleeding when faced with massive hemoptysis, and recognition and removal of an endobronchial obstruction such as mucus plugging, foreign body or tumor.
- Bronchoscopy can facilitate the correct placement of a percutaneous tracheostomy tube, can be used to intubate a patient with a difficult airway, a
allow the placement of an endobronc
the setting of massive hemoptysis
- Bronchoscopic placement of en chial valves can improve resolution of pers air leaks.

Ref

Gilbert CR, Casal RF, Lee HJ, et al. Use of One-Way Intrabronchial Valves in Air Leak Management After Tube Thoracostomy Drainage. Ann Thorac Surg 2016;101:1891-6.

Bermea RS, Miller J, Wilson WW, et al. One-Way Endobronchial Valves as Management for Persistent Air Leaks: A Preview of What's to Come? Am J Respir Crit Care Med 2019;200:1318-20.

Kurman JS, Hogarth DK. Management of persistent air leaks: a shifting paradigm. Shanghai Chest 2018;2:26

Ghiani A, Hansen M, Tsitouras K, et al. Endobronchial One-Way Valve Therapy Facilitates Weaning from Extracorporeal Membrane Oxygenation in a Patient with ARDS and Persistent Air Leak. Case Rep Crit Care 2018;2018:9736217