Airway Surgery

Objectives

At the conclusion of this session, the participant will be able to:

1. Describe the surgical anatomy and methods of upper (tracheal) and lower (carinal) airway resection and reconstruction

2. Discuss anesthetic challenges, including preoperative assessment, airway management, endotracheal and endobronchial tube choice and intubation, modes of ventilation, emergence and post-anesthesia care management

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Case #1: Upper Airway (Tracheal) Surgery

Preop

A 59-year-old female presented with several months of progressive stridor and dyspnea. She had been first treated for adult onset asthma without effect. A chest CT showed severe tracheal narrowing.

The patient underwent a flexible and rigid bronchoscopy with general anesthesia. Bronchoscopy showed normal subglottic opening, normal vocal cords and a well healed tracheostomy site beyond the cricoid at the 2nd tracheal ring. Additionally, there was a 2 to 3 cm long, tight tracheal stenosis with an appearance of a mature scar at about 4 cm above the carina.
Past medical history was significant for an episode of sepsis from a perforated diverticulitis, which required prolonged ICU admission and intubation. Due to failure to wean from mechanical ventilation a tracheostomy was placed and eventually removed after recovery.

Her medical history also includes obesity (152 cm & 105 kg), insulin dependent diabetes mellitus, and a history of pulmonary embolism. Current medications are insulin, Combivent and Advair.

Tracheal resection and reconstruction was scheduled.

Questions

1. What are the most common causes of tracheal stenosis?
2. What can an anesthesiologist do to avoid tracheal injury?
3. What are the signs and symptoms of tracheal stenosis, and at what degree of stenosis do they usually appear?
4. What is the most important part of the physical examination in these patients? (Pattern of breathing, ability to breathe while supine)
5. Patient informs you that due to her ‘lung function’ on the advice of her primary physician she did not stop her PO prednisone before the surgery as was advised by the surgeon. How would you proceed? Would you proceed or would you inform the surgeon first?
6. How would you proceed? Would you proceed or would you inform the surgeon first?
7. Are pulmonary function tests reliable with tracheal stenosis? (bronch and dilate first and then test) What flow-volume curve do you accept with a fixed extrathoracic tracheal obstruction?
8. What are the preferred imaging studies? (CT with reconstruction, bronch)
9. What is your overall anesthetic goal? (Controlling the airway and an awake patient at the end)
10. Any other co-morbid considerations?

Case Continuation - Induction

The patient was met for the first time on the morning of surgery. She was sitting up in the bed with an audible stridor. She requires 1 L of oxygen via nasal cannula. Her breathing pattern did not change in the supine position. Her airway examination showed a normal neck circumference, large tongue, Mallampati III, normal mouth opening, and a TMD 5-6cm. The previous anesthetic record noted that the previous flexible bronchoscopy was done with an LMA, which was placed awake into the tropicalized airway. Subsequently under general anesthesia she underwent an uneventful rigid bronchoscopy and tracheal dilatation.

The patient was premedicated with 1mg midazolam IV and 20 mg famotidine IV and brought to the operating room. The patient was moved to the OR table which was prepared by creating a ramp by arranging blankets underneath the patient’s upper body. An inflatable rubber pillow was placed underneath the shoulder in anticipation of intraoperative neck extension. An arterial line and a second IV were placed. The patient
was induced with 180 mg propofol IV and a #4 disposable LMA was placed. The position of the tracheal stenosis was confirmed; its length was re-measured with flexible bronchoscopy. The patient was given a neuromuscular blocker and intubated with a regular, cuffed 6.0 endotracheal tube.

Questions

1. What is the role of LMA in the assessment of tracheal stenosis?
2. The patient is very anxious and requests more sedatives? Would you comply?
3. What information can you get from a previous successful rigid bronchoscopy?
4. The patient becomes very short of breath when you ask her to lay supine. Would this change your approach to induction? Would inhalation induction be a valid alternative?
5. What is your tube selection, what airway devices and equipment would you get ready for the surgery?
6. Is an arterial line always indicated for tracheal resection?
7. What is the significance of neck extension and flexion during the surgery?
8. Is there a role for extra long endotracheal tubes in proximal airway surgery?

Case Continuation – Open Airway

After dissecting the neck and exposing the trachea distal from the stenosis the trachea was opened. The surgeon initiated on-field ventilation by placing a sterile endotracheal tube into the distal trachea. The oral endotracheal tube was pulled back to above the level of the stenosis to expose the lesion. Anesthesia was maintained with an infusion of remifentanil and propofol and muscle relaxation.

The dissection required the frequent removal of the on-field endotracheal tube, with intermittent handbag ventilation and constant attention to the field and monitors. Before the complete closure of the trachea, the distal airway was inspected and secretions and blood were suctioned. At the completion of the anastomosis the neck was flexed (by deflating the rubber pillow) and the oral endotracheal tube was passed beyond the resection site under fiberoptic visualization.

Questions

1. What are the pros and cons for inhalational versus intravenous anesthesia? (discontinuous ventilation, polluting the OR with gas)
2. Would you use long acting opioids during the case?
3. Is there a concern with high FiO2?
4. When the surgeon asks you to pull back your oral endotracheal tube, how do you avoid accidental extubation? At the end of the case the surgeon asks you to insert a larger endotracheal tube. How would you accomplish this?
5. The on-filed endotracheal tube is interfering with the surgical exposure. What alternative do you have?
6. What are the pitfalls of jet ventilation?

Case Continuation – Emergence & Extubation

After skin closure as a constant reminder for the patient to keep the neck in flexion, a chin to chest suture was placed. The patient was repositioned to a semi-sitting position and ondansetron 4 mg IV was given. Neuromuscular blockade was completely reversed, that patient was transitioned to spontaneous ventilation.

Fentanyl was titrated in small doses to achieve a respiratory rate of 14 to 16 breaths per minute. An albuterol, and racemic epinephrine nebulizer was prepared. The pharynx was gently suctioned. When the patient awoke the endotracheal tube was removed under fiberoptic visualization; supplemental oxygen was given via facemask. Soon after extubation the patient became very anxious, and kept repeating “can’t breath, can’t breath”.

Questions:

1. How would you evaluate the patient at this stage?
2. If you needed to reintubate, are there any issues with direct laryngoscopy? Would you alert the surgeon?
3. How would you exclude recurrent laryngeal nerve damage post-extubation?
4. Other than verbal reassurance would you give midazolam for anxiolysis?
5. Is there a role of dexmedetomidine infusion before, during or post-extubation?
6. Under what circumstances would you opt to use racemic epinephrine rather than albuterol?
7. What would be your plan for re-intubation? Would you alert the surgeon?
8. Would you do it at the PACU or would you move the patient back to the OR?

Case Continuation – Emergence

Auscultation revealed unobstructed tracheal airflow with expiratory wheezes over both lung fields. She was positioned sitting more upright and a dose of albuterol nebulizer was given. The patient was verbally re-assured that his oxygen level was normal and his trachea was open. She was repeatedly reminded on the importance of slow, deep breathing and keeping her neck flexed. An arterial blood gas sample sent after extubation came back normal.

Case Continuation – Postop/ICU

The patient was admitted to the ICU for postoperative care. Oxygen was provided by a humidified facemask. The pattern and effort of breathing was
constantly evaluated, oxygenation and CO$_2$ retention were followed by regular arterial blood gas sampling. Pain was controlled with small doses morphine. About 3 hours after arriving to the ICU the patient became progressively short of breath. Arterial blood gas revealed decreasing PaO$_2$ with decreasing breath sounds on the left side, and the absence of stridor. It was decided to perform an awake fiberoptic bronchoscopy. The airway was nebulized and topicalized with 4% lidocaine. Dexmedetomidine infusion 0.07 mcg/kg/hr IV was started. Fiberoptic bronchoscopy revealed a widely patent trachea with an intact suture line and a large obstructing mucus plug in the left main bronchus. As soon as the mucus plug was suctioned the oxygenation improved immediately. On POD#7 the patient was taken back to the OR for re-examination of the airway. The patient was positioned again in a head slightly up sniffing position. After an induction dose of propofol IV, a disposable #4 LMA was placed. The airway was anesthetized by injecting 4% lidocaine into the trachea via the bronchoscope. The trachea was found to be again widely patient with a well healing and intact suture line. There was no mucus in the bronchus and distal airway was clear of secretions. The chin suture was cut, she was awakened and the LMA was removed. She was discharged home on POD#8.

**Question**

1. What is the most common surgical complication after tracheal resection?

**Case #2: Lower (Carinal) Airway Surgery**

**Preop**

64 year old previously healthy man presented to the primary physician with coughing spells and significant shortness of breath during exercise. Chest x-ray appeared normal, while chest CT was suspicious for a carinal/left endobronchial mass, which was confirmed following flexible bronchoscopy. The mass was seen to involve the carina slightly extending towards the left main bronchus.

He was scheduled for a carinal resection and reconstruction.

**Questions**

1. Is the surgical approach different from proximal airway surgery?
2. Would you offer an epidural for pain control?
3. What is your choice for induction? IV with muscle paralysis or inhalation induction?
4. Would you use a custom made extra long ET tube or a standard double lumen tube to intubate?
5. You chose to go with an extra long single lumen tube, but now the surgeon requests lung isolation to facilitate surgical exposure. What are your options?
6. Soon after lung isolation you encounter hypoxia. What will you do to improve oxygenation?
7. Is there a role for jet ventilation? The saturation still not improving. Is there anything the surgeon can do to improve oxygenation?
8. After the completion of the reconstruction you are getting ready to wean the patient. Is there a difference in emergence compared to proximal airway surgery? What are the more common and less common complications you can encounter?

Case continuation

The patient had an uneventful recovery and was discharged to home on POD #7. 2 months later you are on call for the general OR when you recognize that this patient is on the schedule for an urgent Laparoscopic Cholecystectomy.

1. Is there any contraindication for a general anesthetic?
2. How would you intubate this patient?
3. Is there a role for endobronchial intubation after carinal resection?

Summary & Discussion

Anatomy of the trachea:

- The origin of the trachea is defined as the inferior aspect of the cricoid cartilage at the approximate level of the sixth or seventh cervical vertebra
- The distal margin of the main carina making the bifurcation into the left and right main bronchi is at the approximate level of the fifth thoracic vertebra
- Trachea is divided into:
  - Extrathoracic trachea, above the suprasternal notch, approximately 1/3 of its total length
  - Intrathoracic trachea, below the suprasternal notch approximately 2/3 of its total length
- The trachea maintains its structure with the rigid structural support of 18-24 C shaped cartilaginous anterior ring
- The posterior wall of the trachea is a membranous band that lacks cartilaginous support
- The membranous airway is the weakest point and most vulnerable to injury
Etiology:

Tracheal resection is most often performed for postintubation stenosis or tumor resection. Risk factors for postintubation stenosis include duration of intubation, ETT cuff overinflation, ETT repetitive movement, hypotension, infection and comorbid conditions (diabetes). Other indications for stenosis include congenital lesions, infectious/inflammatory pathology

Postintubation Tracheal Stenosis

- Iatrogenic lesion caused by cicatricial healing of an area of transmural injury to the airway
- Etiologically intubation of the airway resulting in local ischemia or necrosis and subsequent stenosis during the phase of healing by secondary intention
- Incidence up to 20%
- Caused by the cuff of the endotracheal tube or pressure from the rigid endotracheal or tracheostomy tube
- Blood supply of the trachea is segmental, blood vessels perforate the tracheal wall at each interannual space and arborize the submucosa
- Compression of the submucosa can thus cause regional ischemia of the cartilaginous ring
- Ventilated patients have frequently decreased systemic perfusion pressure which can be a contributing factor
- With the removal of the tube healing by secondary intention leads to cicatrization and local stricture, typically in 3-6 weeks
- New more compliant, D-shaped, high-volume, low pressure cuffs have been shown to greatly reduce the incidence of airway injury
- In addition it has become the standard of care to routinely monitor intracuff pressure and maintain it below 30 mmHg, or as low as needed to create an adequate seal for ventilation
- Persistently high intracuff pressures, usually the result of a size mismatch between the patient’s airway and the endotracheal tube, can still cause injury even with the modern cuff design
Preoperative considerations

- Pre-operative assessment includes a detailed history: smoking history, ability to clear secretions, exercise tolerance, and symptoms when supine.
- Cardiac screening with echocardiography, or stress test should be taken into consideration based on history and guided by ACC/AHA guidelines.
- Physical exam pays meticulous attention to the airway including neck mobility, stridor at rest and maximal exercise, size of mouth opening, and assessment of the ability to mask ventilate.
- Diagnostic studies are used for identifying and characterizing the tracheal lesion. They include Chest X-Ray, Linear tomography, fluoroscopy, computed tomography, barium study of the esophagus in some cases, aortic arch angiograms, pulmonary functions tests (PFTs) and spirometry, 3D renderings of the trachea, and bronchoscopy.
- Flow volume loops allow for the assessment of inspiratory and expiratory irregularities associated with tracheal pathology. They demonstrate variable or fixed obstruction to flow. Severe variable obstruction is managed most appropriately with spontaneous ventilation. The flow limitations seen may increase in severity when positive ventilation is substituted for spontaneous ventilation. This is since the negative intrapleural pressure associated with spontaneous inspiration can provide a stenting effect which is lost with loss of spontaneous breathing.
- Ratio of peak expiratory flow (PEF) to FEV1 > 10 is suggestive of airway obstruction.
- In fixed airway obstruction the PEF is reduced, producing a plateau on its waveform; the inspiratory flow has the same characteristic plateau.
- In variable obstruction the maximal cutoff to flow depends on the location of obstruction; intrathoracic variable lesions tend to have alterations in the expiratory flow curve with no effect on inspiration, while extrathoracic or cervical variable lesions affect the inspiratory limb with minimal effect on expiration.
- The degree of stenosis is estimated with a mouthpiece of variably decreasing diameter. The flow volume loop will change once the mouthpiece opening is smaller than the airway stenosis.
- Signs and symptoms of airway obstruction include the degree of obstruction, location of obstruction and degree of cardiopulmonary disease. Symptoms include dyspnea, wheezing, difficulty clearing secretions and obstruction with inability to clear mucus.
- “Adult onset asthma” – wheezing, stridor, cough, dyspnea on exertion, then at rest, with clear lung fields.
- Symptoms due to underlying carcinoma may predominate.
- Symptoms due to stenosis become manifest when airway reduced to 30% of normal; cross sectional diameter can reach 5 to 6 mm before symptoms present clinically.
• Onset of symptoms may be delayed in patients recovering from serious illness
• Treatment history will usually include MDIs, nebulizers, and particularly steroids
• Better to defer surgical resection when:
  • Mechanical ventilation still required (absolute contraindication)
  • Active inflammation present or infection (absolute contraindication)
  • Steroid dependent (absolute contraindication)
  • Prior treatment makes additional surgical resection excessively hazardous (relative contraindication)
  • Severe pulmonary disease (absolute contraindication)
• Up to half (5-6 cm.) of trachea (~11 cm.) may be resected when releasing maneuvers used
• Initial management usually involves dilation via rigid bronchoscopy

Patient preparation

• Monitoring includes standard ASA monitors but reliable pulse oximetry is particularly important
• An intra-arterial catheter is useful for continuous blood pressure monitoring and for additional periodic monitoring of oxygenation and CO2 retention. Since the innominate artery lies anterior to the trachea, a left arm or femoral cannulation is desired to avoid conflicting readings from compression or ligation of the artery.
• Required Anesthesia equipment
  o Anesthesia machine capable of delivering 20 L/min O2
  o ETT : size 4mm uncuffed to 8 cuffed, flexible armored tubes (sterile and unsterile various sizes), extra-long ETTs (customized or standardized)
  o High frequent positive pressure ventilator – optional
  o Automated jet ventilator or type of manual jet ventilation capabilities (high frequency and low frequency) with catheters
  o Extra anesthesia circuits - sterile
  o Second anesthesia machine
  o Fluid warmer
  o Warming blanket
  o NG tube
• Central line access is typically not indicated unless mandated by the patient’s history. Neck and chest access may not be ideal sites for central line access.
• Reliable IV access is necessary with typically two peripheral IVs, one in each arm.
• A decision-making algorithm is helpful in determining anesthetic management with open communication between the surgeon and anesthesiologist.

Anesthesia Induction
• Premedication and induction take into consideration the extent of tracheal stenosis. Preoperative sedation should be managed carefully to avoid total airway obstruction. This might be best avoided until the patient is in the operating room with preparation made for induction.
• Non-particulate antacids and metoclopramide and histamine-2 blockers should be administered in patients with reflux.
• Consideration for not administering anti-sialalogogues is made as they may create thickening of secretions and form mucus plugs causing further obstruction.
• Proper positioning of the head and neck extension with shoulder elevation are critical for manipulation of the airway with rigid bronchoscopy. The eyes should be properly protected.
• If an awake examination or intubation is required, topical anesthesia minimizes the response to instrumentation. Structures anesthetized include the tongue, posterior pharynx, epiglottis, glottis, and infraglottic airway.
• The major nerves of the airway are branches of the trigeminal nerve and glossopharyngeal nerve, superior laryngeal nerve, and recurrent laryngeal nerve.
• Nebulized 4% lidocaine usually provides topical anesthesia for most of these structures. More intense block to the tongue, pharynx, and superior epiglottis occurs with intraoral glossopharyngeal nerve block and superior laryngeal nerve block. Topical anesthesia to the lower airway can be accomplished with transtracheal block, spray injection via fiberoptic bronchoscope or inhalation of nebulized local anesthetic.
• Medications for IV sedation include judicious use of benzodiazepines, dexmeditomidine, propofol and opioids such as remifentanil.
• In an awake intubation, induction of anesthesia is avoided until an airway (ETT) has passed the obstruction or if the obstruction is unlikely based on direct visualization.
• Less severe obstructions allow for an inhalational induction typically with sevoflurane with the patient spontaneously breathing. This is performed after aggressive denitrogenation with 100% oxygen for 5 minutes or more. If ventilation is compromised the patient is awakened.
• Placement of an LMA for flexible bronchoscopy can be performed or the anesthetic may be deepened to allow rigid bronchoscopy without paralysis. Blood pressure support may be with a vasopressor.
• An LMA can be placed to facilitate oxygenation and ventilation during bronchoscopic evaluation and treatment of proximal lesions.
• Regardless of the mode of induction, a physician or surgeon adept at rigid bronchoscopy must be available to control the airway.
• Once the obstruction is examined by rigid bronchoscopy and selective dilation is performed a more secure airway is established. If the obstruction is proximal to the carina, an ETT is placed with the tip above the lesion. In high lesions a small ETT is placed through the narrowing.
• In minimal airway compromise, IV induction after pre-oxygenation may be appropriate. Once the airway is controlled beyond the obstruction and positive pressure ventilation is adequate, neuromuscular blockers may be given.
• Cardiopulmonary bypass or extracorporeal membrane oxygenation have been used prophylactically or during airway catastrophes. Proper planning must be performed for potential cannulation strategies.

Surgical considerations for upper airway surgery

Ideal Anastomotic Conditions:

• Avoid excessive airway dissection, assuring excellent blood supply
• Atraumatic handling of tissues, precise suture placement
• Minimize anastomotic tension
• Separation of anastomosis from pulmonary vessels by pedicled wrap of vascularized tissue

Surgeon’s anesthetic view

• Avoid postoperative mechanical ventilation
• Extra-long, single lumen endotracheal tube
• Intubation of contralateral or distal airway across operative field
• Jet ventilation, independent lung ventilation
• Cardiopulmonary bypass rarely (if ever) needed
• Close cooperation between surgeon and anesthesiologist required!

Surgical Approach

• Laryngotracheal resection: Cervical
• Upper-Mid Tracheal resection: Cervical
• Distal Tracheal resection: Right thoracotomy
• Carinal resection: Right thoracotomy

Release maneuvers to decrease Anastomotic tension:

• Development of pre-tracheal plane
• Neck flexion
• Suprathyroid laryngeal release
• Hilar release

Emergence and Extubation

• Rapid extubation is the primary goal to avoid anastomotic failure from mechanical positive pressure ventilation
• Reverse neuromuscular blockade
  • Minimize coughing, gagging, and neck extension. Cervical flexion allows for maximum amount of approximation of the trachea. A guardian stitch is used to prevent head and neck extension. Additionally pillows placed behind the head support neck flexion
  • Anxiolysis upon emergence may be combated with dexmedetomidine, or low doses of propofol or remifentanil, and allows for a smooth transition and cooperative patient.
  • Criteria for extubation must be met with the patient following commands.
  • If controlled ventilation must be continued, repositioning of the ETT cuff distal to the anastomotic site is desirable. If extubation is delayed, spontaneous ventilation is desired.
  • Pain management can be performed with minimizing the use of opioid narcotics. Analgesics that do not depress respiration such as acetaminophen, ketamine, and ketorolac are considered good alternatives.
  • Oxygen via mask should be provided immediately after extubation.
  • Phonation is elicited to determine potential laryngeal nerve damage.
  • If reintubation is required, minimizing head extension is important to prevent tension on the anastomosis. The most ideal method of reintubation is with oral or nasal fiberoptic bronchoscopy. Typically an uncuffed ETT is reasonable to minimize contact with the anastomosis. Cuffed ETTs should be positioned with the cuff distal to the anastomosis.
  • During reintubation, examination of the anastomotic site is performed and vocal cord dysfunction can be identified.
  • In preparation of fiberoptic bronchoscopy gentle mask ventilation may be necessary.

Considerations for Lower Airway Surgery – for Carinal Resection and Reconstruction

Lesions (usually masses and tumors) near the carina add some new challenges to the process of the tracheal resection and reconstruction. The procedure is intrathoracic, usually approached from a right thoracotomy, and the lungs cannot be treated as a single entity. As in all thoracotomies, arterial monitoring is prudent and methods of postoperative analgesia, such as thoracic epidural catheters, are needed.

Considerations for induction and intubation:

1. They are similar to higher lesion, although surgical access in emergency is not an option (consider veno-venous bypass)
2. Tube can sit above the lesion and a bronchial blocker can be used to isolate the right lung to facilitate surgical exposure
3. Alternatively small tidal volumes can be used to help exposure, until the trachea is opened when the tube can be passed into the opposite bronchus
4. For more obstructing lesions selective distal endobronchial intubation is desired from the start. An endobronchial tube is chosen instead of a standard double lumen tube because the double lumen tube is too bulky to permit tracheal surgery. Long flexible tubes of small diameter but sufficient length (>31cm) to reach the bronchus are not currently widely available. It is possible to easily construct them by combining two tubes. Phycon silicone armored cuffed tube with its integral collar, and a length of standard PVC tubing placed in the collar with a friction fit. The lumen stays a constant diameter and the tube has the desirable properties of being more stiff in the upper portion and flexible and non-kinking in the lower portion. Note that the tip design in endobronchial tubes is important. There is not a long segment of bronchus for the cuff and distal potion to sit, so a shorter cuff to end design is preferable. Trimming the end of an endotracheal tube will make the cuff incompetent since the cuff air channel runs beyond the cuff. The endobronchial tube is positioned under fiberoptic guidance. The jury-rigged nature of these tubes, as well as the extensive surgical manipulation of the region causes frequent tube malposition. A fiberscope should be constantly at hand as the anesthesiologist will be required to make frequent corrections as the operation proceeds.

5. With endobronchial intubation, one lung will not be ventilated. As in all thoracotomies, the level of shunt and desaturation is variable and unpredictable. Standard maneuvers include suctioning, confirming position, increasing $F_{2}O_{2}$ and varying the ventilatory patterns. Unlike many thoracotomies, it is not as easy to administer ventilation to the deflated lung. While the airway is intact, deflating the endobronchial cuff, blocking the mouth and nose and delivering longer, larger tidal volumes can help. Alternatively, placing another endotracheal tube high in the trachea (yes, two endotracheal tubes of small diameter) can allow differential ventilation or at least constant positive airway pressure (CPAP). Another approach is to place an LMA after the endobronchial tube and, if it seals sufficiently, CPAP can be administered. Finally, a jet catheter can be placed in the trachea. The jet catheter has the advantage of not requiring a seal, but may not be effective if there is substantial distal obstruction. In extreme circumstances, blood flow to the pulmonary artery can be restricted, lessening shunt.

6. Once the airway is open, CPAP cannot be administered from above. A second tube or a jet catheter can be placed from the field into the deflated lung. The jet catheter has the advantage that it is small enough to allow surgery to continue and it does not require a separate ventilator.

7. There is little difference in the management of emergence from anesthesia in carinal surgery as opposed to tracheal surgery. Cord swelling is less likely, but obstruction from blood and secretions more common. Pain control will be a bigger factor; selection of methods that do not suppress respiratory drive is preferable.

8. Patients with previous carinal surgery that present for unrelated surgery should not, in general, present particular anesthetic problems. It would be prudent to avoid pushing an endotracheal tube too distal and risk injuring an anastomosis.
Most anesthesiologists at centers with experience with these patients would confirm good tube position and an undamaged distal airway with bronchoscopy after intubation. If lung isolation is required for the surgical procedure, the considerations are more involved. As much as possible it is wise to avoid instrumenting and especially inflating a cuff in a repaired region. The carinal anatomy will be abnormal, with possibly shorter bronchial lengths and different angles of departure for the bronchii. The use of an endobronchial tube may be necessary. In any case, all tube positioning should be done under fiberoptic guidance to avoid the risks of malpositioning.
Further Reading


Regional anesthesia \[\text{No}\] \[\text{Is general anesthesia necessary?}\] \[\text{Yes}\]

Difficult or impossible mask ventilation under GA due to severe stenosis or high collapsibility? (#1)

Yes: Don’t induce GA
Can you pass the ET tube through the stenosis? (#2) 
No \[\text{PCPS}\]
Yes \[\text{ET tube distal to the stenosis}\]

No: You may induce GA.

Facemask
Supraglottic airway
ET tube either proximal or distal to the stenosis

Always consider additional use of a tube exchange catheter and combination of the techniques as back-ups

Fig. 3. An algorithm for anesthetic management of patients with tracheal stenosis. #1: Airway imaging and pulmonary function test are helpful for this decision making. #2: Collapsibility or expandability of the trachea needs to be assessed for this decision making. GA _general anesthesia; ET_endotracheal tube; PCPS_percutaneous cardiopulmonary support. Anesthesiology 2010; 112:970 – 8