LARYNGOTRACHEAL RECONSTRUCTION (CRICOID SPLIT, SINGLE-STAGE, DOUBLE-STAGE)

Surgical Specialty:	Otolaryngology
Authors:	Erin Toaz, M.D., Michelle Tsao, M.D. Ann & Robert H. Lurie Children's Hospital of Chicago. Chicago, IL

Background:

- General Considerations
  - Subglottic stenosis (SGS) is a narrowing of the airway below the vocal cords and above the trachea.
  - SGS can be acquired or congenital.
    - Congenital SGS is thought to be due to malformation of the cricoid cartilage.[1]
    - Acquired SGS often is a consequence of endotracheal intubation.[2]
  - SGS severity is graded using the Myer-Cotton grading:[3]
    - Grade I: 0 to 50% stenosis
    - Grade II: 51% to 70% stenosis
    - Grade III: 71% to 99% stenosis
    - Grade IV: no lumen present
  - Infants with mild to moderate SGS may be asymptomatic or minimally symptomatic.
    - A typical history is one of recurrent croup or stridor with upper respiratory tract infections.
    - Conservative management with observation may be appropriate.
  - Infants with severe SGS are often symptomatic and may present with respiratory failure at birth.
    - Severe SGS may require tracheostomy and/or reconstructive surgery.
- Surgical Interventions
  - Cricoid split and laryngotracheal reconstruction (LTR) are two surgeries to treat SGS.
    - <u>Cricoid Split:</u>
      - The anterior cricoid split was originally described as an alternative for tracheotomy in neonates who failed ≥ 2 extubations due to glottic and/or subglottic edema.[4]
      - Can be performed open (historical) or endoscopically
        - Rarely performed in isolation as an open procedure
        - Can be combined with balloon dilation
        - May be done with a cartilage graft
        - Criteria for cricoid split: mobile vocal folds, minimal to no ventilatory support, minimal supplemental oxygen requirement, no cardiac disease, and weight greater than 1.5 kg.[5]

- Laryngotracheal Reconstruction (LTR):
  - May be indicated following trauma, acquired or congenital stenosis, or failure to maintain a safe airway following endotracheal extubation.[6]
    - Also indicated in moderate to severe SGS that is not responsive to endoscopic interventions.
  - Stenosis is augmented by the interposition of autologous tissue – typically uses the patient's own rib cartilage or thyroid ala cartilage.
    - It is placed anterior and/or posterior in the region of the stenosis.
  - More severe/circumferential SGS may require combined anterior and posterior cricoid split with cartilage graft placement
    - *Single-stage laryngotracheal reconstruction (ssLTR):*
      - Tracheostomy decannulation at the time of airway reconstruction (or avoidance of a tracheostomy altogether).
      - Reserved for patients undergoing a primary airway reconstruction with isolated SGS, can be easily reintubated, and have stable pulmonary function[7]
      - The airway remains stented using a nasotracheal tube for 7-14 days postoperatively.
    - *Double-stage laryngotracheal reconstruction (dsLTR):*
      - A tracheostomy tube is kept in place at the conclusion of the procedure with decannulation later.
      - Used for patients who have failed prior airway reconstruction attempts, have multi-level obstruction, have a history of difficult intubation, ongoing neurologic deficits, or significant pulmonary disease[7]
      - The airway remains stented using a suprastomal stent or, less commonly, a T-tube

Video animation: https://www.cincinnatichildrens.org/health/s/ssltr

- Patient Considerations
  - Presence of tracheostomy
  - Prior airway history including difficult laryngeal exposure, sizing of the airway, etc.
    - Gastroesophageal reflux (GER) must be optimized prior to airway reconstruction procedures.
  - Associated Comorbidities/Syndromes:
    - Complementary studies to uncover concomitant congenital cardiac, neuromuscular disease, or gastrointestinal disorders.
    - Sequelae of prematurity including chronic lung disease and pulmonary
    - hypertension.
    - Difficult airway syndromes or other craniofacial abnormalities that may affect the airway at other levels
  - Additional airway lesions may co-exist and need to be investigated during evaluation under anesthesia prior to intervention.

Anesthetic Planning:

- Pre-Anesthetic Evaluation
  - Thorough pre-anesthetic evaluation including identification and optimization of comorbid conditions.

    - Typically, patients will undergo a complete aerodigestive evaluation prior to surgery including microlaryngoscopy and bronchoscopy (MLB), flexible bronchoscopy with bronchoalveolar lavage (BAL), and upper endoscopy.
        - MLB:
            - Assess features of the stenosis including but not limited to:
                - Anatomic level, length, site (anterior, posterior, or circumferential), maturity, and the presence of granulations, fibrosis, or scarring.
                - The airway is sized formally and the stenosis is graded.[8]
            - Assess for untreated concomitant airway obstruction that may require intervention prior to reconstruction or multi-staging of procedures
        - Flexible bronchoscopy:
            - Optimization of pulmonary status including antibiotics as directed by BAL results.
        - Upper endoscopy:
            - Treatment of GER including acid suppression and/or referral for Nissen fundoplication.
            - Uncontrolled GER can lead to higher rates of failure following LTR.
        - Assess for acute upper or lower respiratory tract infections.
        - Administration of bronchodilators as indicated for history of chronic lung disease.
- Discussions to have with surgeon/family
    - Patients will require intensive care unit (ICU) admission post-operatively.
    - Code Status
    - ECMO Candidate
- Specific or Unique Room Set-up Requirements
    - Airway
        - There is often a shared open airway during the procedure (e.g., cricoid split, bronchoscopy immediately preceding the LTR).
        - A variety of endotracheal tubes (ETT) should be available.
        - If a tracheostomy is present, our surgeons prefer to replace it with a wire-reinforced ETT in the field.
            - Regular oral ETT or nasotracheal tubes are placed when intubated from above.
            - Discuss cuffed versus uncuffed with the surgeon.
    - Drugs/Infusions
        - There are many options for maintenance and institutional practice will vary.
        - May use TIVA or a combination of IV anesthetics and volatile agent:
            - Mitigates hypotension that can occur with using sevoflurane as a sole agent.
            - Reduces OR exposure to waste gases.
            - Guarantees anesthetic depth during open periods of the case where sevoflurane administration is unreliable.
        - Volatile anesthetics
            - Sevoflurane is the optimal volatile agent due to its low blood-gas solubility and ease of titration.
            - Desflurane also has low blood-gas solubility but is a greater airway irritant than sevoflurane and rapid increases can cause tachycardia.

- Dexmedetomidine bolus (0.5-1 mcg/kg over 10 minutes) or infusion (0.3-1.5 mcg/kg/hour)
    - Causes little to no respiratory depression.
    - Transient hypertension can be seen after a bolus.
    - The most common side effects are bradycardia and hypotension.
- Ketamine bolus (1 mg/kg) or infusion (5-10 mcg/kg/min)
    - Maintains hemodynamics and maintains respiratory drive.
    - May require co-administration of an anti-sialagogue such as glycopyrrolate to control secretions.
- Propofol bolus (0.5-1 mg/kg) or infusion (50-200 mcg/kg/min)
    - Boluses can quickly increase the depth of anesthesia as needed.
    - Supplements the anesthetic and reduces patient movement during periods of unreliable volatile agent delivery.
    - May be more challenging to maintain spontaneous ventilation than other intravenous infusions.
- Opioid bolus or infusion
    - Judicious dosing is needed to maintain spontaneous ventilation.
    - Opioid infusions may be started intraoperatively and continued post-operatively.
        - Fentanyl 0.5-1 mcg/kg bolus and 0.5-2 mcg/kg/hour infusion
        - Sufentanil 0.1-0.3 mcg/kg/hr infusion
        - Remifentanil 0.05 – 0.2 mcg/kg/min infusion
            - Easily titratable and rapid onset/offset.
            - Not typically continued post-operatively.
        - Other long-acting opioids such as morphine or hydromorphone may also be used.
- Muscle relaxants
    - Typically avoided during open airway parts of the case where ventilation may be challenging due to an open neck and frequent manipulation of the airway. Spontaneous ventilation better preserves oxygenation.
    - May be used for short periods during costal cartilage rib graft harvest or at the conclusion of the case for transport.
- Dexamethasone
    - Minimizes perioperative edema (per surgeon discretion).
- Topical local anesthetic
    - Applied to the vocal cords to blunt the effects of stimulation and minimize laryngospasm during endoscopic airway interventions.

- Monitors
    - Standard ASA monitors
    - Gas monitoring (end-tidal CO_2 and expired volatile agent concentration)
        - Will not be accurate during airway insufflation.
        - SpO2 and chest movement must be observed to monitor for adequate oxygenation/ventilation, signs of airway obstruction, apnea, or light anesthesia.
    - Extended dwell catheters (EDC) or peripherally inserted central catheters (PICC)
        - May be placed due to institutional preference given prolonged anticipated post-operative hospitalization and the need for intravenous access.

        - Arterial line
            - May be placed for close hemodynamic monitoring and blood sampling secondary to the long duration of surgery and the need for prolonged postoperative ventilation.
            - May be indicated due to patient comorbidities (e.g., congenital heart disease).
        - Foley catheter
    - Blood availability: Usually not required
    - ICU bed availability: Required post-operatively for prolonged intubation/ventilation to allow adequate graft healing prior to periodic endoscopic evaluations.

Intraoperative Considerations:

- General
    - Anesthetic goals include ***maintaining spontaneous ventilation, immobility, and hemodynamic stability.***
    - Rigid MLB performed at the start of the procedure to confirm the appropriateness to proceed (no evidence of infection, granulation tissues) and assess stenotic lesion and sizing for costal cartilage graft (CCG).
        - Topicalization of the larynx with atomized lidocaine
        - TIVA or insufflation of anesthetic gas via a ventilating side port, a small endotracheal tube in the patient's mouth with spontaneous ventilation (no tracheostomy present), or inhaled gas via tracheostomy.
    - *ssLTR*:
        - If the patient has a tracheostomy in situ
            - This will be removed and a cuffed ETT placed in the stoma by the surgical team and connected to a sterile anesthesia circuit (covered with an ultrasound probe cover) for the majority of the case.
        - If the patient does not have a tracheostomy
            - The patient will be orally intubated at the start of the case for the initial neck dissection and obtaining the CCG.
            - A sterile circuit is placed onto the field and ventilation is switched from the orotracheal tube above to a distal endotracheal tube placed in the neck after the airway is opened.
            - Institutional/surgeon preference regarding RAE tube versus wire-reinforced tubes.
            - Typically sutured to the neck by the surgeon.
        - Near completion, the patient is nasotracheally intubated by the surgeon under direct visualization and the distal ETT is removed.
    - *dsLTR:*
        - Ventilation during the case is achieved through the in-situ tracheostomy or temporary placement of a wire-reinforced endotracheal tube for ease of insertion and removal during airway reconstruction.
        - The airway is reconstructed around a suprastomal stent or T-tube.
        - The tracheostomy tube remains in place upon conclusion of the procedure.
            - *****Caution***: Patient cannot be intubated from above with the airway stent or T-tube in place.**
        - If the procedure is successful, the patient is decannulated during a separate hospital admission, usually several weeks or months later.
- Positioning
    - Supine with neck extended and the operating room table is turned 90 degrees.

- Maintenance:
  - Drugs as above.
  - Neuromuscular blocking agents are avoided during the airway reconstruction.
- Hemodynamic/Physiologic goals
  - Maintenance of spontaneous ventilation is preferred.
    - This minimizes the risk of hypoxemia during periods when the airway is open and positive pressure ventilation may be difficult or impossible.
      - Many patients have underlying chronic lung disease and will not tolerate prolonged periods of apnea.
    - Surgeons will need to remove and replace the ETT or tracheostomy during the procedure.
- Surgical Considerations
  - Field avoidance.
  - Close communication with surgeons is necessary as the airway is inserted and removed to gain surgical exposure.
  - FiO2 decreased to <30% during periods when electrocautery is utilized (neck dissection).
- Emergence/Disposition:
  - Patients are transported heavily sedated +/- muscle relaxation with nasotracheal tube (single stage) or tracheostomy with suprastomal stent/T-tube (double-stage) in situ to the ICU.
  - Require prolonged period of immobility to allow graft healing prior to first interval bronchoscopic assessment as specified by the surgeon (7-14 days on average).
    - May be less for double-stage LTR
- Post-operative Care:
  - May follow specific institutional clinical care guidelines for LTR.
  - These patients require sedation and analgesia with or without neuromuscular blockade to prevent excessive head and neck movement and possible injury to the reconstructed airway.
  - Communication with surgeon and ICU regarding ventilator settings, suctioning depth, airway rescue plan, and sedation needs.

Case-Specific Complications/Pitfalls

- Pneumothorax after cartilage rib graft harvesting or pneumomediastinum[9]
  - Can be seen on routine post-operative chest film.
  - May be conservatively managed with observation, serial films, and increased FiO_2. A large pneumothorax requires chest tube placement.
- Atelectasis from plugged bronchial secretions or migration of blood clots from the operative site to the lower airways.[9]
  - Can be seen on routine post-operative chest film.
  - Suctioning of mucous/blood/secretions at the end of the case, employing gentle recruitment maneuvers, and increased positive end-expiratory pressure can treat this.
- Mainstem bronchus intubation if the ETT is too deeply placed
  - Can occur intraoperatively with frequent insertion and removal of ETT in the neck by the surgeons.
  - The nasotracheal tube position is confirmed at the conclusion of the case with flexible bronchoscopy.
- Mucous plugging[9]
  - Typically seen several days post-operatively and can lead to hypoxemia.

    - Humidification, saline instillation, suctioning, and other pulmonary toilette are very important to prevent clogging of the ETT with dried secretions.
    - Discuss with the surgical team regarding suctioning depth and catheter size to avoid trauma to healing grafts
- Unplanned extubation
    - An airway escalation plan should be discussed in the event of an unplanned extubation.
        - This should include guidance for best temporizing measures (e.g., non-invasive positive ventilation, use of Heliox, etc.) until a definitive airway can be achieved.
        - Reintubation is ideally done by ENT under direct visualization to avoid disruption of the graft.
        - Consider having a printed document at the head of the patient's bed detailing specific recommendations for the individual patient.
- Graft dislodgement or dehiscence.
    - This may result in acute respiratory failure and can be life-threatening.
    - The airway escalation plan should also be deployed in this case.
    - Graft failure may require tracheostomy reinsertion.

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Reviewed by:

Reviewer #1: Goretti Chiang, DO, Children's Hospital of Philadelphia

Reviewer #2: Senthil Packiasabapathy, MD, Indiana University School of Medicine

Reviewer #3: Gail Shibata MD, University of California- San Francisco

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