

Stanford Children's Health  
Aerodigestive Center

Stanford MEDICINE

# Pediatric Airway

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Presenters

Stanford MEDICINE

Kara Meister

Doug Sidell

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3-month male, inspiratory stridor

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**Infants and Children With Stridor:**

- Life threatening vs chronic process
- Thorough evaluation--always warranted
- Primary care providers: front lines

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**Patient Example**

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**DECISIONS!**

Do this patient need additional evaluation?

YES

BUT WHEN??

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### Pediatric Laryngeal Anatomy

Endoscopic view of the pediatric larynx showing the glottis and surrounding structures. The anatomical diagram shows the airway from the nasal cavity down to the larynx, highlighting the relative positions of the epiglottis and larynx compared to adults.

<http://thevoicenotes.com>

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### CHILDREN ARE NOT LITTLE ADULTS

Anatomy of the Pediatric Airway

- Pediatric larynx higher in neck (C3/4 vs C5/6)
- Epiglottis curved/omega shaped, in contact with soft palate
- Arytenoids are relatively large
- Funnel-shape larynx with subglottis narrowest portion of airway = ~5 mm at full term

The anatomical diagrams illustrate the differences in airway anatomy between children and adults, such as the higher position of the larynx and the omega-shaped epiglottis. The painting of the Virgin Mary and Christ Child is used to emphasize that children are not simply smaller versions of adults.

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### Diagnosing Stridor

**Stridor:**

- Variable pitch
- Originates in larynx/trachea
- ... a partial obstruction of the airway caused by abnormal apposition of 2 tissue surfaces in close proximity, with resultant turbulent airflow

**Stertor:**

- Lower in pitch, sonorous
- Nasal/nasopharyngeal origin

**Wheezes:**

- Occasionally misclassified as stridor

The photographs illustrate the clinical examination of a child with stridor, showing auscultation of the chest and neck.

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### THE 5 "A"'s OF STRIDOR

1. **Age**
2. **Acuity** (onset)
3. **Appearance** (toxic or non-toxic)
4. **Acoustics** (volume, pitch, phase)
5. **Associated signs & symptoms** (dysphonia, cough, drooling, posturing, dysphagia, signs of syndromes)

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### Diagnosing Stridor/Stertor:

1. Anatomy influences everything
2. Don't trust your laryngeal noises under anesthesia—be smart

The photograph shows a child in a clinical setting with medical equipment, illustrating the importance of careful diagnosis.

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### Diagnostic Algorithm: Step #1

```

    graph TD
      A[Unstable] --> B[ASAP Eval]
      A --> C[ER transfer]
      D[Stable] --> E[Clinic F/U]
      D --> F[Close Observation]
    
```

The flowchart provides a clear path for managing stridor based on the patient's stability. Unstable patients require immediate evaluation and transfer to the ER, while stable patients can be managed with follow-up and observation.

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### Algorithm Overview

Obviously-Stable vs Unstable

- Triage and manage appropriately

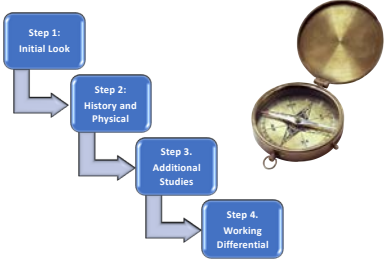
But what about... the "NOT UNSTABLE" patient?

- Gray area
- Should I be concerned?



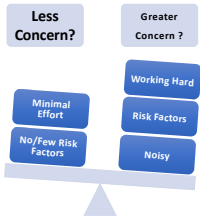

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### Algorithm Overview: Deciding Factors



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### Step #1-First Look

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HISTORY	EXAM
<p><b>Current situation</b></p> <ul style="list-style-type: none"> <li>• Acuity / progression</li> <li>• Severity, cyanotic spells</li> <li>• Exacerbating / relieving positions or activities</li> <li>• Feeding difficulties and growth</li> <li>• Possibility of foreign body aspiration</li> <li>• Similar episodes previously / history of croup</li> </ul> <p><b>Past</b></p> <ul style="list-style-type: none"> <li>• Birth history, especially prematurity</li> <li>• History of intubation or neck/chest surgery</li> <li>• Treatment for asthma and response</li> </ul>	<p><b>Vitals and growth curve</b></p> <p><b>Inspection:</b> patient positioning; anxiety/restlessness, cough; micrognathia, neck masses, stigmata of genetic syndromes, cutaneous hemangiomas</p> <p><b>Respiratory effort:</b> retractions, nasal flaring, tachypnea, diaphoresis</p> <p><b>Oxygen sats:</b> circumoral pallor, cyanosis, digital clubbing</p> <p><b>Stridor:</b> Volume, pitch, phase</p> <p><b>Auscultations:</b> where is stridor heard, additional lung sounds</p>

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### Risk Factors: Evidence of airway surgery

- Neck Incision
- Tracheostomy Scar
- Chest Incision (Rib Harvest)




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### Risk Factors: Craniofacial abnormalities\*

- Hemifacial Microsomia (1:3,500/boys/right side)
- Pierre Robin Sequence (1:8,000)
- Treacher Collins (1: 25,000-50,000)




Discolo C.Craniofacial Surgery. Pediatric Otolaryngology Head and Neck Surgery. Parikh (ed), 2014

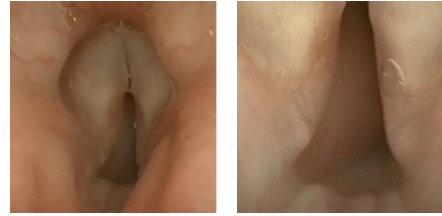
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Risk Factors: Cutaneous vascular anomalies



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Risk Factors: Cutaneous vascular anomalies



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Risk Factors: Younger/smaller patients

Poiseuille's (pwā-zə's) Law:

$$\text{Flow}(Q) = \frac{\Delta P \times r^4 \times \pi}{\eta L \times 8}$$



2mm of edema in the **infant** subglottis=**16x** reduction in airflow  
 2mm of edema in the **adult** subglottis=**3x** reduction in airflow

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**PATHOPHYSIOLOGY**

- Bernoulli principle: increased airflow velocity exerts negative pressure on the walls of the lumen → airway collapse

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Risk Factors: Younger/smaller patients

Poiseuille's (pwā-zə's) Law:

**DON'T MEMORIZE IT!**



2mm of edema in the **infant** subglottis=**16x** reduction in airflow  
 2mm of edema in the **adult** subglottis=**3x** reduction in airflow

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Risk Factors: Trisomy 21

- Down Syndrome

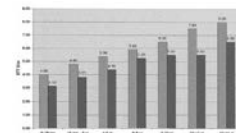


Fig. 1. Mean size of endotracheal tube for children with Down syndrome (black bars) versus control children (grey bars) according to age.

Shott SR. Down syndrome: analysis of airway size and a guide for appropriate intubation. Laryngoscope. 2009; 119(4):585-592.

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**Risk Factors: Stridor WITH DYSPHONIA**

- **Glottic Lesions**
  - RRP
  - Glottic web
- **Supraglottic Lesions**
  - Acute Infection (epiglottitis):
  - Infected lesions: Vallecular masses/cysts...
- **Subglottic lesions**
  - Bacterial tracheitis, subglottic stenosis, foreign body...
- **Tracheal lesions**
  - Severe airflow restriction (aphonia)

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**DEVELOPING A DIFFERENTIAL DIAGNOSIS**

**VINDICATE**

- V Vascular
- I Infection, inflammation
- N Neoplasia
- D Drugs (toxins), degenerative
- I Idiopathic, idiopathic
- C Congenital/developmental
- A Anatomic, allergy, anatomic
- T Trauma
- E Endocrine/metabolic, environmental/work exposure

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**Recurrent Respiratory Papillomatosis (RRP)**

Normal Larynx

Respiratory Papillomatosis

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**3-month male, inspiratory stridor**

**HPI:**  
Stridor began at 2-3wks. Becoming louder.

**PmHx:**

- Full term. No comp.
- No other medical problems

**Meds:** Zantac  
**All:** none

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**Feeds:**

- Gaining weight.
- Mom feeds him **all day long**
- Frequent pauses and gasps during feeds

**Sleep:**

- Marked stridor when supine
- Sleeps prone

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What would you do?

What are your options?

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**Conservative management:**

- **Reflux Medication:** evidence is poor; side effects are minimal
- **Sleep Study:** Infant data is lacking, and access is an issue
- **Physical Characteristics:**
  - Retractions vs stridor?
  - Feeds, weight gain

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Observe	Operate
<ul style="list-style-type: none"> <li>• Minimal retractions</li> <li>• Minimal feeding difficulty</li> <li>• Sleeping well</li> <li>• Trajectory: stable or improving</li> <li>• Few comorbidities</li> </ul>	<ul style="list-style-type: none"> <li>• Deep retractions</li> <li>• Poor weight gain/feeding trouble</li> <li>• Poor sleep/frequent waking</li> <li>• Very young with severe symptoms</li> <li>• Unfavorable progression</li> <li>• Multiple comorbidities</li> <li>• PSG findings dictate surgery</li> </ul>

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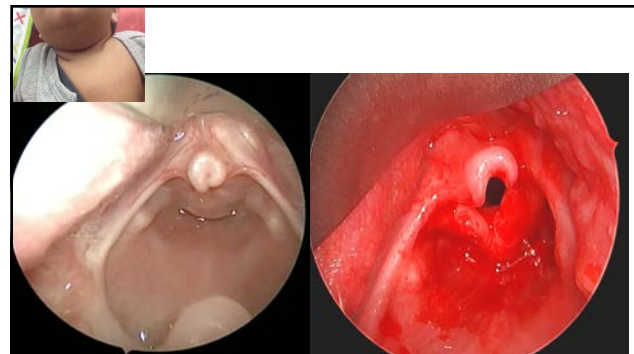
**Sleep Study**

“ Polysomnography (PSG) may provide better surgical sustenance in infants with severe laryngomalacia and OSA, as well as, serving as a monitoring tool of success. However, the surgical decision should not be reduced to polysomnographic results, and a good history and examination remain as the fundamental criteria”

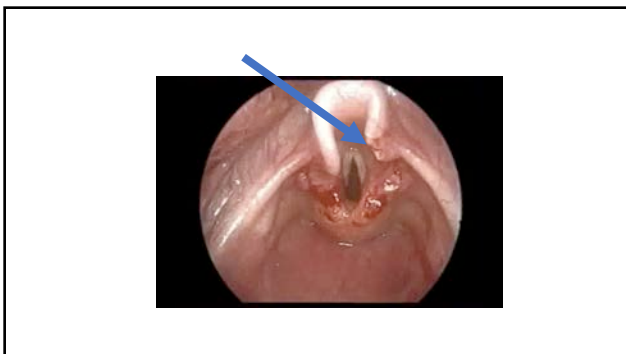
-Hiram Alvarez-Neri

Cortes MC, Villamor P, de la Torre González C, Álvarez-Neri H. Complete polysomnographic parameters in infants with severe laryngomalacia prior to and after supraglottoplasty. *Int J Pediatr Otorhinolaryngol.* 2019 Apr;119:131-135.

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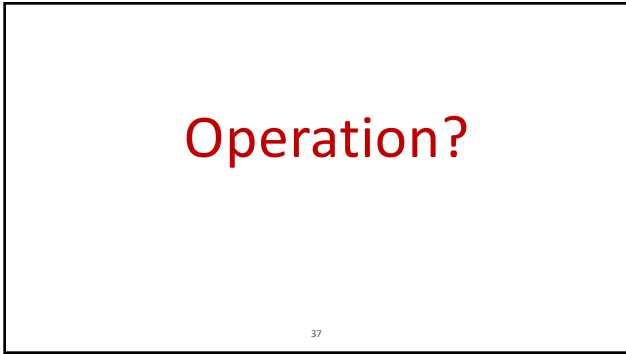


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**4mo M, Progressive stridor**

- Slow to gain weight
- Quiet when sleeping
- Intermittent retractions
- Some initial improvement on zantac
- Overall, getting noisier
- No difficulty with feeds
- Mom is a pediatrician

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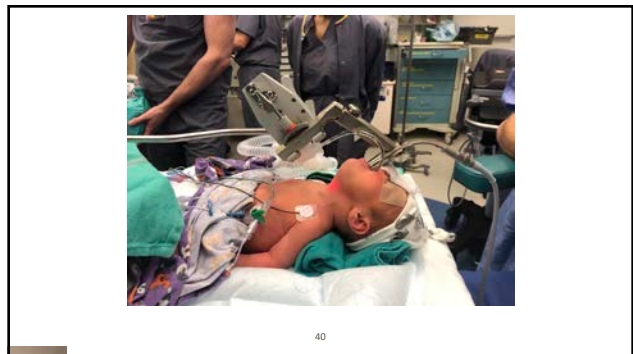
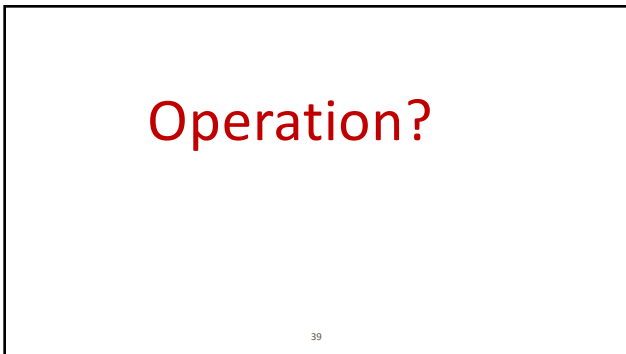
**3wk M**

- 1.8kg
- Stridor, retractions
- On ranitidine
- Difficulty feeding
- Failure to thrive
- Mom is Surgeon
- Dad is Surgeon
- Getting worse



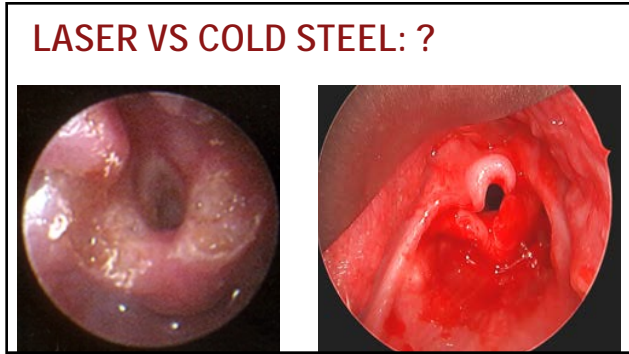
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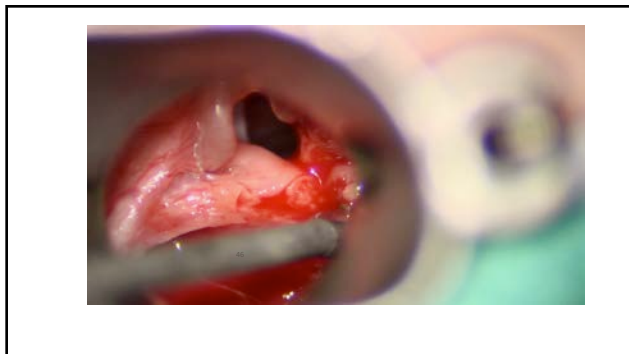
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**Laryngomalacia:** ?

**Surgical Success (46%-100%):**

**Persistent feeding or respiratory difficulties:**

- Premature or neurologically affected infants (Richter, Bower, 2014)
- 4.3x increased risk of aspiration if other co-morbidities (Preciado, 2012)
- 83% of comorbid cases VS 28% of isolated cases (Vaccani, 2013)

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**Why Endoscopy Can Be Helpful:**

3.5 mo FT Male

- Inspiratory stridor
- Weight loss, moderate retractions,
- difficulty with feeds

4 mo FT Male

- Inspiratory stridor
- Weight loss, mod-severe retractions,
- difficulty with feeds

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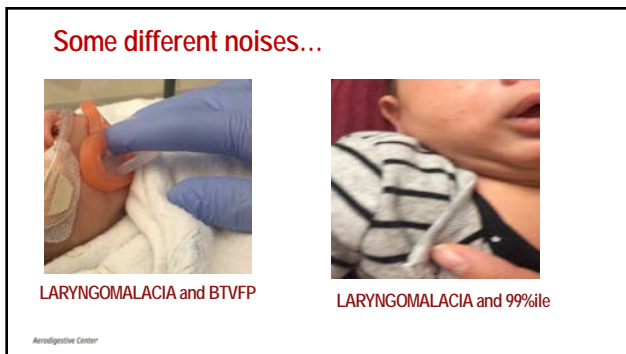




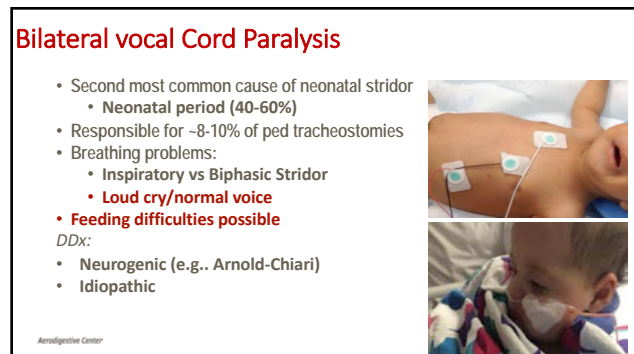
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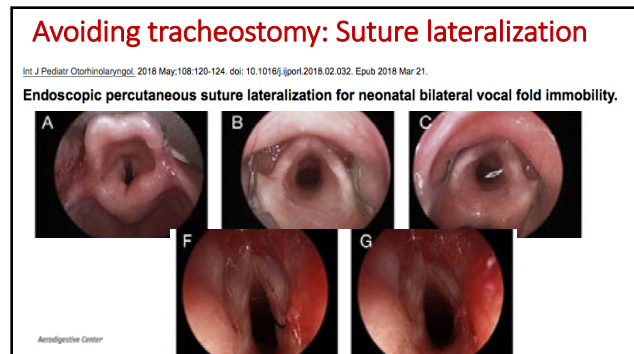
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1. How would you treat these patients?
2. Do all patients need an operation?
3. When do you operate on the larynx?
4. What can you do to avoid tracheostomy in the meantime?

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**Avoiding tracheostomy: Endoscopic Cricoid Split**


The Laryngologist  
© 2011 The American Laryngological, Rhinological and Otological Society, Inc.

**Endoscopic Anterior-Posterior Cricoid Split for Pediatric Bilateral Vocal Fold Paralysis**

Michael J. Butner, MD, Catherine K. Hart, MD, Alexandre de Alencar, MD, MPH,  
Sam J. Daniel, MD, PhD, FRCSC, MSc, Sangey R. Parikh, MD, Karthik Balakrishnan, MD, MPH,  
Derek Lam, MD, MPH, Kaitlan Johnson, MD, Douglas R. Sidel, MD

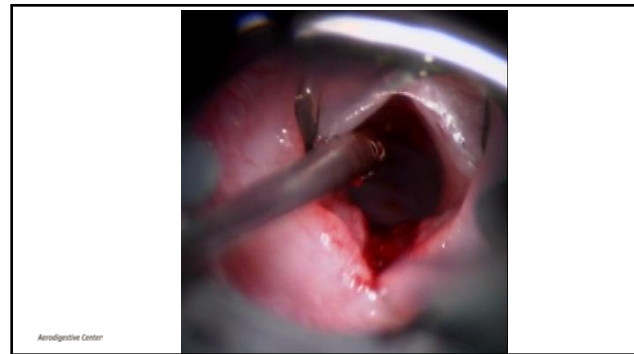
**19 APCS**

- 74% success rate (avoiding otherwise-necessary tracheostomy)



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**10 days of intubation  
Ett= Age appropriate + 0.5**



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**No Return of Vocal Fold Function**

- **When do you make this decision (what age)?**
- **What are your surgical options?**

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**No Return of Function:**

- Chronic Tracheostomy?
- Posterior costal cartilage graft?
- Cordotomy/Cordectomy/Partial arytenoidectomy?
- Open vs endoscopic fold lateralization?
- Other?

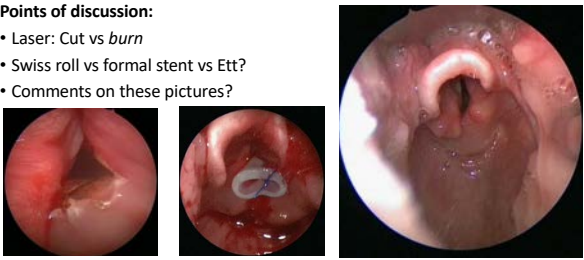
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### Cordotomy


**Points of discussion:**

- Laser: Cut vs burn
- Swiss roll vs formal stent vs Ett?
- Comments on these pictures?



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### Vocal Fold Lateralization?



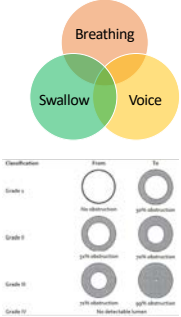
Open vs Endoscopic; With vs without arytenoidectomy

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### How to enlarge an airway

Making the pipe bigger (Poiseuille's Law):

- Expand
- Resect
- Slide
- Replace
- Some combination of the above



Classification	From	To
Grade I	No stenosis	grade I stenosis
Grade II	grade I stenosis	grade II stenosis
Grade III	grade II stenosis	grade III stenosis
Grade IV	grade III stenosis	grade IV stenosis

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### 5y M presents to clinic with retractions...

- He has a neck incision
- He has a chest incision
- He is in acute distress

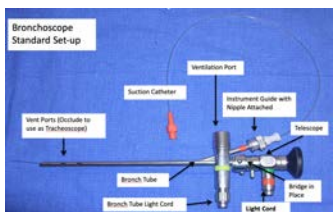

He required urgent bronchoscopy and tracheostomy...



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### WHAT NEXT?

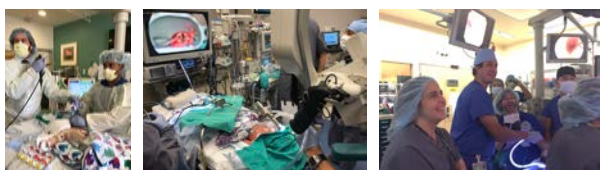
COMPREHENSIVE AIRWAY EVALUATION

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### THE PROPOSED ORDER OF THINGS:

FLEXIBLE bronchoscopy  
 RIGID Micro-laryngoscopy and bronchoscopy  
 EGD with biopsies (revision operations, aerodigestive cases)



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### The Evaluation:

	Rigid	Flexible
		
<b>Advantages</b>	Expand/suspend a malacic airway (-)	"Impossible" anatomy
	"Difficult" anatomy Can palpate/tactile feedback	-Mandibular/cervical ankylosis -Oropharyngeal mass
	Statics/anatomic detail Higher resolution optics	Dynamics Artificial airways (tracheotomy)
	Airway size "objectively"	Airway size very subjective
	Surgical intervention	Minimal anatomic distortion
	Better ventilation	Peripheral bronchi
Foreign body or large plug removal	Suctioning, BAL, DISE	

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### Multidisciplinary patient workup is key

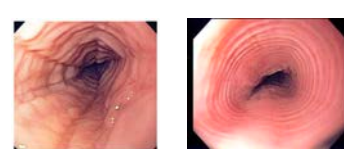


Balakrishnan, Sidell et al 2019

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### For example

- Eosinophilic esophagitis
  - Can have associated airway inflammation
  - If untreated, up to 80% failure rate for airway reconstruction
  - If treated, > 80% success rate

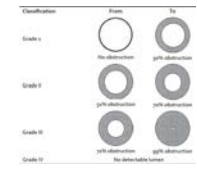


Images: Jeyalingam et al 2018; Nogrady 2015

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### Multidimensional evaluation of the stenosis

- Static vs dynamic
- Structures involved
  - Supraglottic, glottic, subglottic, tracheal, combination
- Severity of stenosis
- Length of stenosis
- Relationship to anterior and posterior glottis
- Relationship to trach stoma (if present)
- Vocal fold/CA joint mobility



→ will drive choice of reconstructive operation

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### Choosing an operation (fellowship in 5 min)

- If stenosis length >1/3 of trachea: slide > LTP
  - Check relationship to tracheostoma before resecting
- If stenosis <4-5mm from anterior commissure: LTP
- If stenosis is grade III/IV: CTR or TR > LTP
  - Extended CTR with graft if posterior glottis involved
  - See point about anterior glottis above
- If involves distal 1/3 to 2/5 of trachea
  - Consider thoracic approach on bypass (more later)
- If cartilage has poor structure/integrity
  - Consider resection (± slide if longer segment)
- If patient <4yo
  - LTP or slide > CTR or TR

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### Expand

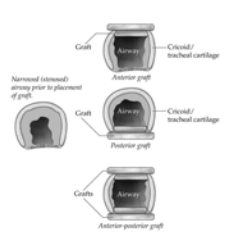
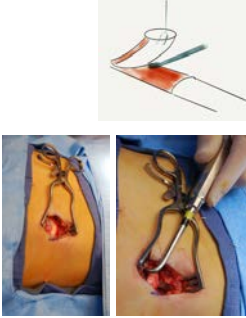


Figure 6. Cross-sectional view of grafts in position

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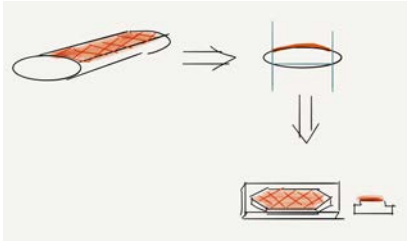
**Graft material**

- Usually R costal cartilage
  - Lots of material
  - Easy to sculpt
  - Beware flail chest
    - Can go to L chest if needed
- Can use auricular, septal, or thyroid ala
  - Thyroid ala best if <1yo or small anterior graft
  - Auricular and septal best as "cap" grafts
  - Cannot distract airway open



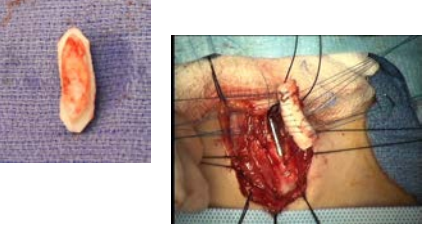
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**Anterior rib cartilage graft (ACCG): carving**



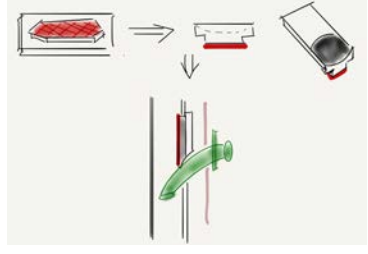
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**ACCG**



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**ACCG down to stoma: carving**




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**LTP with ATAG**

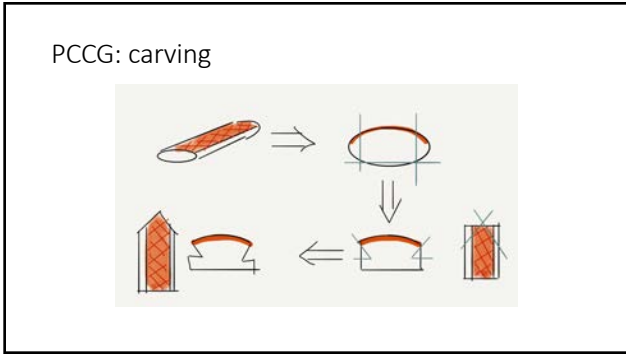


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**LTP with ATAG**



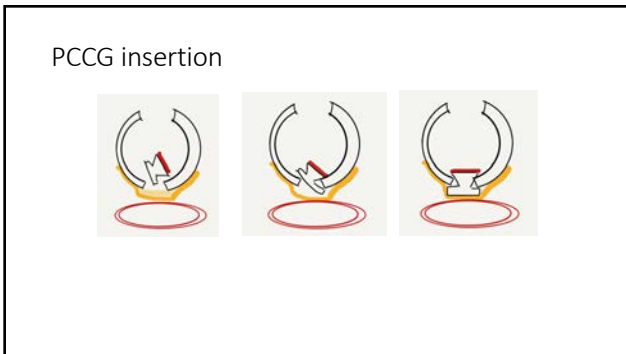
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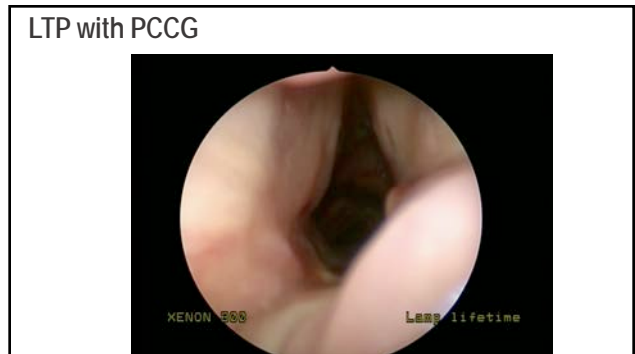
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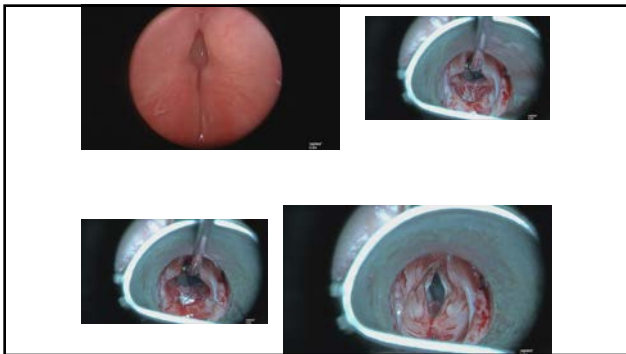
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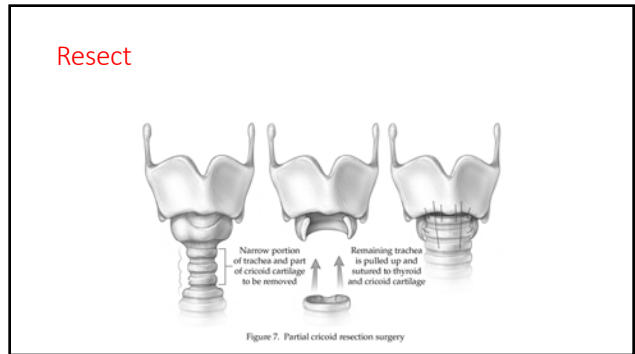
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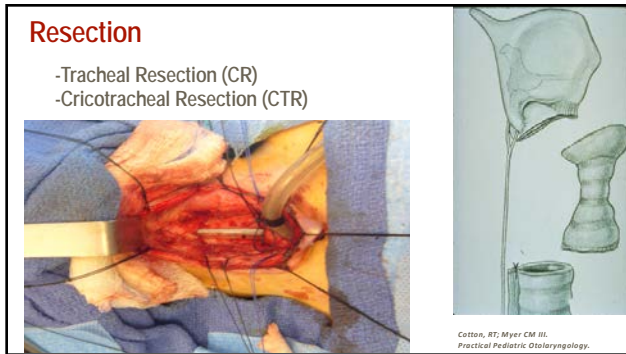
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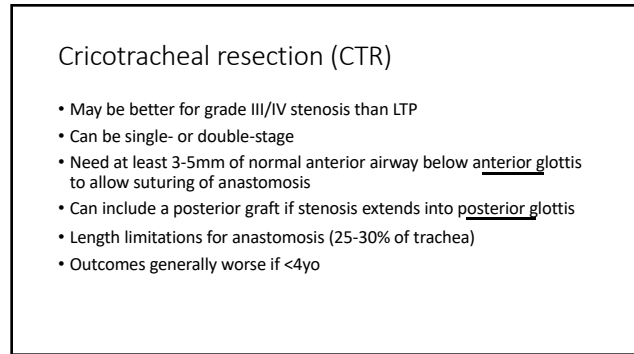
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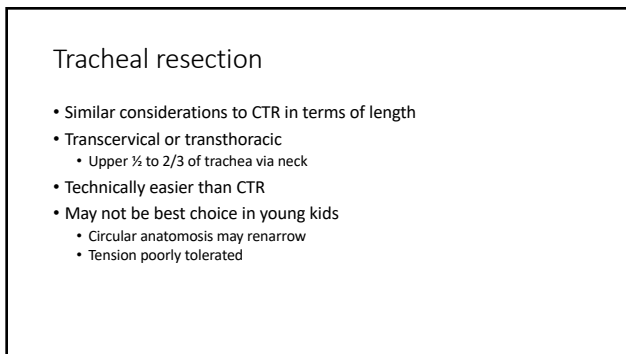
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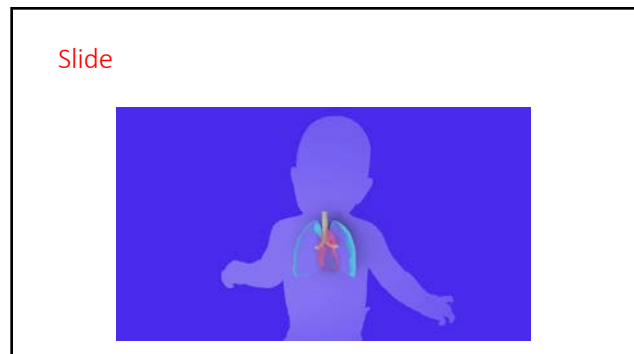
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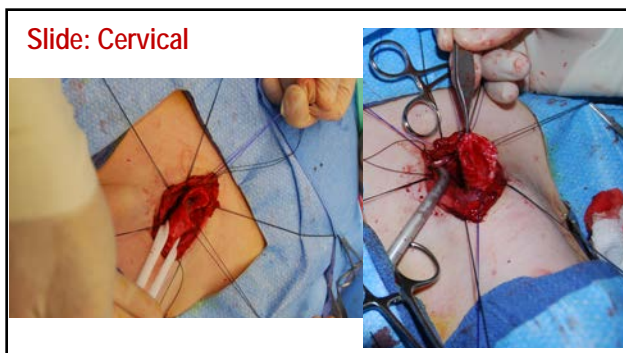
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### Slide tracheoplasty

- Can be used for any long-segment stenosis
  - I.e. too long to resect
- Uses native tracheal tissue
- Can also be used for complex short-segment stenoses
- Can be combined with resection
  - Allows removal of shorter segment
- Via neck or chest, with or without bypass
  - As with tracheal resection


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- If cartilage has poor structure/integrity
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- If patient <4yo
  - LTP or slide > CTR or TR

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### Open vs Endoscopic Laryngotracheal Reconstruction




Robin T. Cotton

“The question is not when should you go open, but when you should not go endoscopic”

1. Absence of cartilage/degraded framework
2. Severe stenosis
3. Endoscopic techniques unsuccessful
4. Poor exposure
5. The multi-revision patient






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### Single vs Double Stage

<p><b>Single Stage</b></p> <ul style="list-style-type: none"> <li>(+) No tracheostomy (removed)</li> <li>(+) Minimal granulation</li> <li>(+) No stomal collapse</li> <li>(-) No safety net – do you trust ICU?</li> <li>(-) Sedation requirements (&lt;3-4y)</li> <li>(-) Prolonged ICU/Hosp (\$\$)</li> <li>(-) Unable to stent for long periods</li> </ul> 	<p><b>Double Stage</b></p> <ul style="list-style-type: none"> <li>(+) Can stent for months</li> <li>(+) ICU not required</li> <li>(+) Safer</li> <li>(-) Stent required                             <ul style="list-style-type: none"> <li>• Swallowing issues</li> <li>• Granulation from stent</li> <li>• Stent may not be available</li> </ul> </li> <li>(-) Tracheostomy remains                             <ul style="list-style-type: none"> <li>• Suprastomal collapse</li> <li>• Granulation</li> </ul> </li> <li>(-) Need second stage...</li> </ul>
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### Stents: internal support for airway

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Otolaryngol Head Neck Surg. 2014 Jun;150(6):1056-61. doi: 10.1177/014599814528097. Epub 2014 Mar 26.

**Pediatric Exercise Stress Laryngoscopy following Laryngotracheoplasty: A Comparative Review.**

Siddi DRT<sup>1</sup>, Balakrishnan K<sup>1</sup>, Hart CR<sup>2</sup>, Wang J<sup>2</sup>, Knecht SR<sup>3</sup>, de Alarcon A<sup>4</sup>.

- 24% of LTP patients will have supraglottic collapse on ESL




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Who is appropriate for a multidisciplinary workup?

A FEW EXAMPLES/COMMON POPULATIONS:




1. Revision **Airway Reconstruction**
2. Chronic Aspiration (**TEF, LT Cleft**, other)
3. Extreme Premies with **SGS +/-** tracheostomy
4. Congenital Cardiac with multi-system disease
5. **Tracheoesophageal fistula** with and without atresia
6. **Congenital tracheal stenosis**

AERODIGESTIVE CENTER

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1wk F, 2.1 KG. Acute respiratory distress during cardiac echo







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**Complete Tracheal Rings**

Management:

- Minimize airway instrumentation
- Avoid intubation if possible (EPI, PPV with long E-times)
- Do not perform tracheostomy
- Diagnostic laryngoscopy and bronchoscopy—carefully
- Send the patient to a hospital capable of fixing and managing the child
- Fix the heart and vessels AT THE SAME TIME





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**Complete Tracheal Rings**

What NOT to do in the OR, or with an Ett





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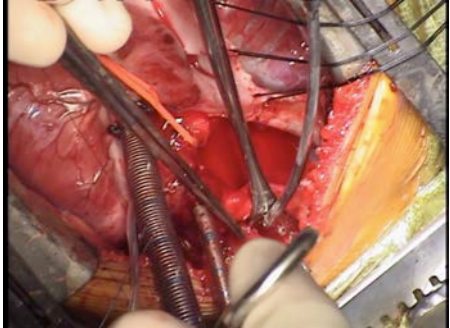


1.9mm camera.  
 SF suction cath (1.59mm)  
 Would not pass distal segment

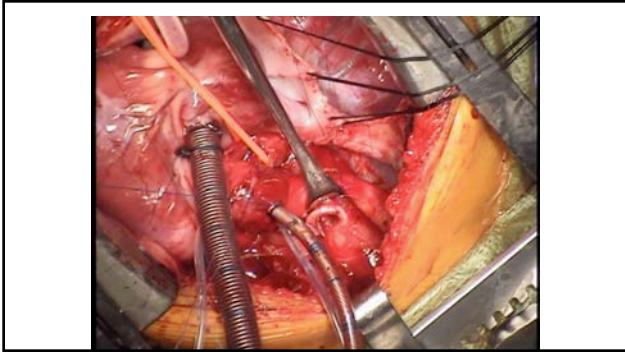
1 NL ring below cricoid; extends into LMSB

1.3 Kg

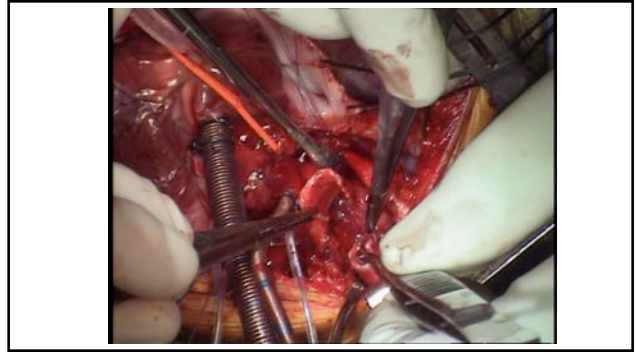
101



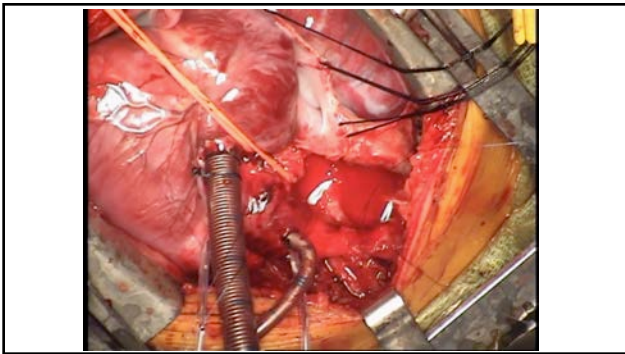
102



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105



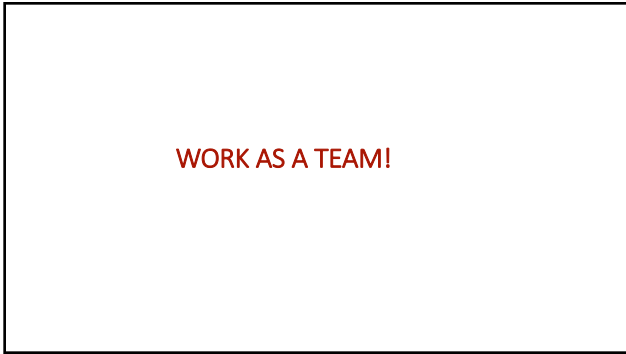
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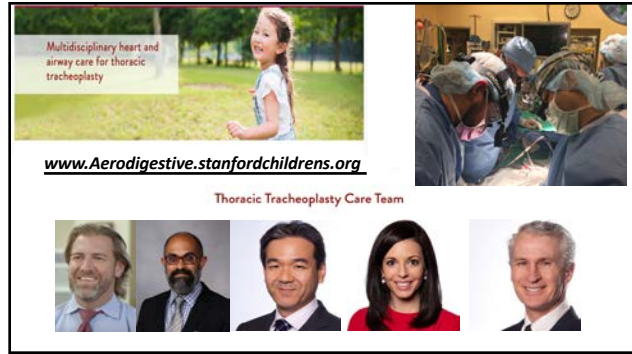
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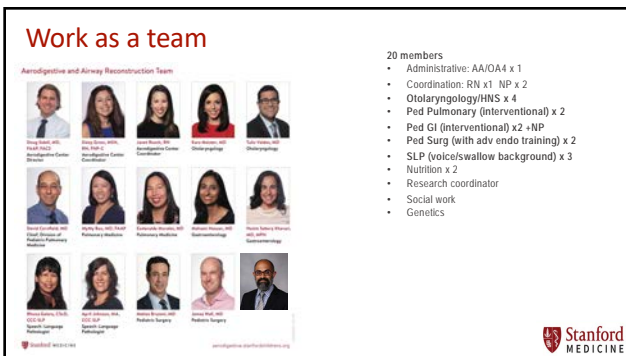
108



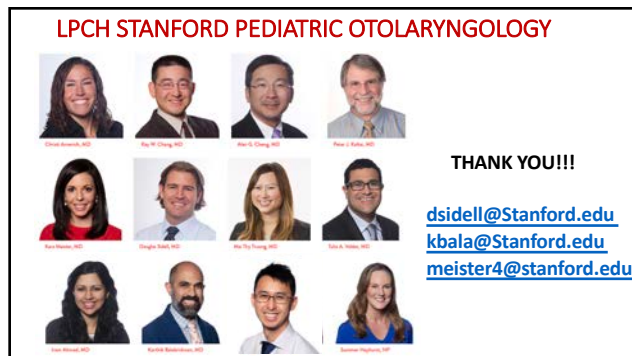
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