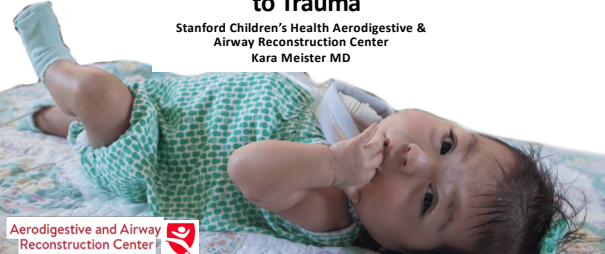




Pediatric Airway Reconstruction: Core Concepts and Applications to Trauma


Stanford Children's Health Aerodigestive &
Airway Reconstruction Center
Kara Meister MD



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No Financial Disclosures

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OBJECTIVES

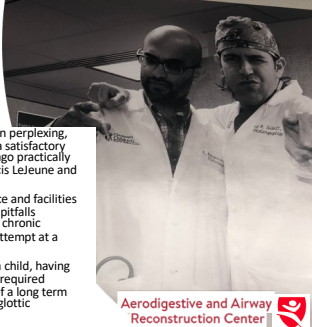
- Introduce a 3 core concepts of pediatric airway management and reconstruction
 - Introduce some of the peds Oto tools
- Describe the special population of traumatic aerodigestive injuries and caustic ingestions




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History of Pediatric Airway Reconstruction


- **INFECTON ERA** "This condition has always been perplexing, consistently resisting the best efforts to effect a satisfactory solution, and until a comparatively short time ago practically every case was an unfinished problem." —Francis Lelune and Neal Owens, 1934
- **AUTOMOBILE ERA** "Lack of patience, experience and facilities for a prolonged contest with the problems and pitfalls associated with the treatment of most cases of chronic laryngeal stenosis is a contraindication to any attempt at a cure." —Chevalier Jackson, 1942
- **INTUBATION ERA** "It is devastating to witness a child, having fully recovered from a critical illness which has required prolonged intubation, die from complications of a long term tracheotomy necessitated by an iatrogenic subglottic stenosis." —Robin Cotton, 1974




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Current State


- Endoscopic + Open techniques in tandem
- Multidisciplinary care
- Preop eval, post op planning
- Balance of the voice/swallow/breathe triad



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Core Concept #1

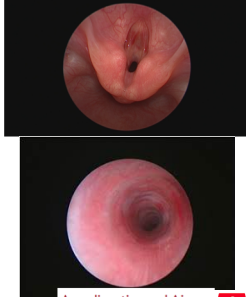
- Core Concept #1: Framework Concept
- Framework good – wiggle room for endoscopic mgmt. or open mgmt.
 - Mucosal/soft tissue components are significant
- Framework poor -- open mgmt. likely the best choice



Add Annotation

What makes poor framework?

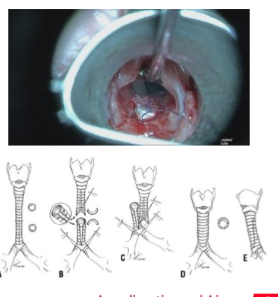
- Absence of cartilage
- Weak cartilage
- Congenital cartilage abnormality
 - Congenital subglottic stenosis
 - Complete tracheal rings
 - Laryngeal web with subglottic extension



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Core Concept #2

- Core Concept #2: Reconstructive Menu
- **Expand**
 - Balloon dilation
 - Augmentation grafting
- **Resect**
 - Tracheal resection
 - Cricotracheal resection
- **Slide**
 - Cervical trachea
 - Cervicothoracic trachea
 - Pharynx/nasopharynx: Z plasty
- **Replace**
 - Bypass



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Considerations in laryngotracheoplasty



- Graft
 - Rib
 - Thyroid ala
 - pericardium
 - periosteum
- Grafting
 - Ant
 - Post
 - a/p
 - none
- Single v Double stage
- Stent
- Age/weight
 - In children less than 24 months, the vocal folds are low, the cricoid is relatively soft, and edema can be a beast

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Core Concept #3: PreWork makes the DreamWork = Aerodigestive

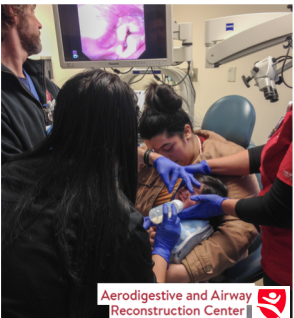


Core Concept #3: Holistic, multidisciplinary evaluation of the patient, family, and preop/postop environment

- Patient: entire aerodigestive tract, genetics, cardiac
 - Aerodigestive & Airway Reconstruction Center visit
- Family: and other children at home
- Preop environment: facility, daycare, exposure to illnesses
- Post op: robust, competent ICU (especially for single stage procedures) with excellent and meticulous communication


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Structure and Functions of Pediatric Aerodigestive Programs A Consensus Statement



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Aerodigestive preoperative eval



- Swallow, voice
 - Awake (no anesthesia)
- In OR: Lightest anesthesia to deepest
 - Pulm → OHNS → GI
- **ATELECTASIS MANGEMENT!**
 - IV time, equipment set up time, putting in cuffed ETT for recruitment as soon as able from an evaluation standpoint

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Demonstrating the Benefits of a Multidisciplinary Aerodigestive Program

Amanda G. Ruiz, BA; Jay M. Bhatt, MD; Emily M. DeBoer, MD; Joel Friedlander, DO; Norah Janosy, MD; Melissa Brooks Peterson, MD; Todd Wine, MD; Robin Deterding, MD; Jeremy D. Prager, MD, MBA


Procedure	N	Mean ± SD, min	Range, min
Aero triple scope	32	54 ± 15	32-95
ENT MLB	41	28 ± 14	13-84
GI EGD	846	23 ± 9	0-62
Pulmonary flexible bronchoscopy	32	39 ± 19	14-88

	Aero Charge per Visit Reduction, %	Aero Direct Cost per Visit Reduction, %
Anesthesia related	42.0	39.0
Lab related	24.0	40.0
Medication/surgical supplies related	43.0	31.0
Pharmacy related	51.0	52.0
Surgery related	34.0	32.0
Treatment/recovery room related	59.0	50.0
Grand total	39.0	42.0

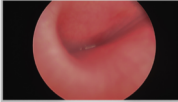
EGD = upper endoscopy; ENT = otolaryngology; GI = gastroenterology; MLB = microlaryngoscopic bronchoscopy; SD = standard deviation.

Ruiz et al.: Benefits of Aerodigestive Programs

Peds Oto Airway Eval




- Spontaneous ventilation
- Eval of the airway and the pathology
- Length of problem, proximity to trach
- Additional lesions: suprastomal collapse, tracheomalacia, pharyngeal pathology, laryngeal cleft, iatrogenic TEF
- *Dynamic exam of vocal folds unreliable with anesthesia on board*



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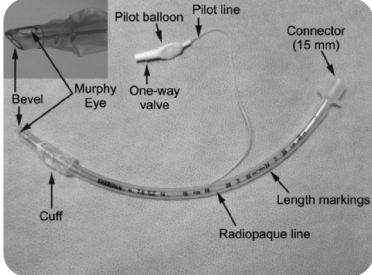

PEDIATRIC AIRWAY TOOLS

- ETT
- Rigid instruments
- Flexible instruments



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Endotracheal Tube

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Microcuff ETT

- 3.0 and larger
- No Murphy eye
- Cuff is more distal and material is thin – 18 microns thick



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Determine size of pediatric airway

See Our Manual Larynx!

PROPOSED GRADING SYSTEM FOR SUBGLOTTIC STENOSIS BASED ON ENDOTRACHEAL TUBE SIZES

CHARLES M. MYER III, MD
DAVID M. O'CONNOR CHENKUNAT, CHAO ROBERT T. COFFIN, MD

The classification of airway stenosis has been a problem for many years. As a result, both intraoperative and histopathologic comparisons of airway sizes remain difficult. It follows that comparisons of therapeutic measures are even more difficult. A proposed classification is simple, reproducible, and based on a readily available reference standard. Endotracheal tubes, which are made to high standards of precision and accuracy, can be used to determine the size of an obstructed airway at its smallest point. Endotracheal tubes will pass through the lumen, if an endotracheal tube of a certain size (20 to 25 cm ETT), can be used to the expected age-appropriate endotracheal tube size. By using the outside diameter of the endotracheal tubes, the size percentage of airway obstruction can be determined. We present a comparison of tube size to the proposed grading scale: grade I 50% obstruction, grade II from 31% to 70%, and grade III above 70% with any detectable lumen. An airway with no lumen is as to grade IV.

KEY WORDS — airway obstruction, endotracheal tube, plethys, laryngeal stenosis, subglottic stenosis.

Classification	From	To
Grade I	No Obstruction	50% Obstruction
Grade II	51% Obstruction	70% Obstruction
Grade III	71% Obstruction	99% Obstruction
Grade IV	No Detectable Lumen	

Fig 1. Proposed stenosis classification system.

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Determine size of pediatric airway: consistency

- Airway Mobile Card
- There is a sweet spot for the right amount of air that should pass between the larynx/trachea and the PVC of the ETT
- The "right" ETT is the largest tube that has a leak at less than 20cm of subglottic water pressure
- This is based on really old school data (like before cuffed pediatric ETTs where a thing). Also, the amount of space being taken up by a cuff is variable, so it is tradition to "size" the airway with an uncuffed ETT.
- We sometimes settle on a cuffed ETT size that is the same as the patient sized. Some of this is judgement in how long you expect the patient to be intubated, coating the ETT with steroid slurry (tobradex ointment), etc.



"Bronchoscopy" by any other name

Diagnostic: To view abnormalities of the airway

- To obtain tissue specimens of the inside the lungs by biopsy, bronchoalveolar lavage, or ~~endobronchial~~ brushing.
- To evaluate a person who has an airway symptom such as chronic cough

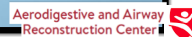
Therapeutic: To do something to the airway

- To remove secretions, blood, or foreign objects lodged in the airway
- Laser resection of tumors or benign tracheal and bronchial strictures
- Stent insertion or insertion of bronchial blocker or specialized endotracheal tubes (eg double lumen)
- For percutaneous tracheostomy (not in kids)
- Adjunct to intubation of patients with difficult airways



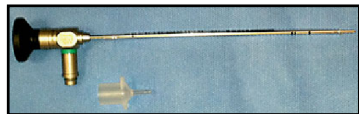
"Bronchoscope" by any other name

- Rigid bronchoscopy with ventilating bronchoscope
- <https://www.karlstorznetwork1.com/videos/karl-storz-pediatric-rigid-bronchoscopy-in-service>
- bleeding or hemorrhage, foreign body extraction, deeper biopsy specimen when fiberoptic specimen is inadequate, dilation of tracheal or bronchial strictures, relief of airway obstruction, insertion of stents or blockers



"Bronchoscope" by any other name

- Bronchoscopic telescope
- Great for intubation when the larynx is pretty normal, but the trachea may not be
- Complete tracheal rings
- s/p TEF



"Bronchoscope" by any other name

- Flexible bronchoscope
- Pulmonary bronchoscope
- OR 2, OR 10 are setup with mounts
- Visualize the secondary bronchi
- PEEP titration
- BAL easier?
- 3.5 is smallest ETT that a working channel scope will fit
- 4.0 gets much better optics
- EXPENSIVE AND DELICATE





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Choosing a technique

- You must look, but you must also see
- Missed diagnoses are potentially as harmful as wrong diagnoses
- Careful, thoughtful, and with an open mind
 - Tempered with a “same thing everytime” approach to be systematic
- **Choose whatever technique you need to accomplish the reason for the procedure**

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Summary of Core Concepts #1-3

- #1: Framework Concept – **How are you going to get there?**
- #2: Reconstructive Menu – **What are you going to do?**
 - Expand
 - Resect
 - Slide
 - Replace/Bypass
- #3: Aerodigestive Approach – **Who is going to be on the patient’s team?**
 - Holistic, multidisciplinary evaluation of the patient, family, and preop/postop environment

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Traumatic and Caustic Aerodigestive Injuries

- Preop preparation is minimal
- Factors that cannot be controlled: COVID-19, prehospital management, unknown patient baseline
- How might one apply core concepts of airway management, and how does trauma change the algorithm?

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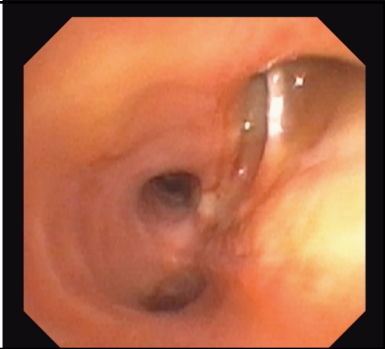
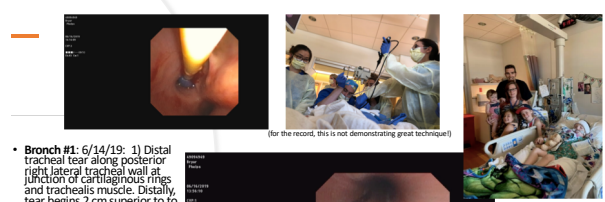
Case 1: BP

- 4 year old little boy, accidentally runover in driveway
- Trauma to OSH
- Extreme subcutaneous emphysema, cannulated onto ECMO

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How do you approach management of this injury?

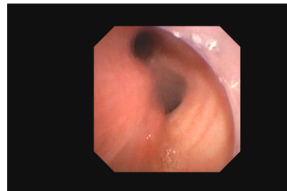

- What is the status of the framework?
- How do you choose from the reconstructive menu?
- Would this patient benefit from multidisciplinary aerodigestive management?

(for the record, this is not demonstrating great technique!)

- **Bronch #1:** 6/14/19: 1) Distal tracheal tear along posterior right lateral tracheal wall at junction of cartilaginous rings and trachealis muscle. Distally, tear begins 2 cm superior to the carina and extends for approximately 2.5 cm in the vertical direction
- **Bronch #9:** 6/29/19: 2 tiny focal areas of concern in the mid to distal aspect of the tear, but overall much improved

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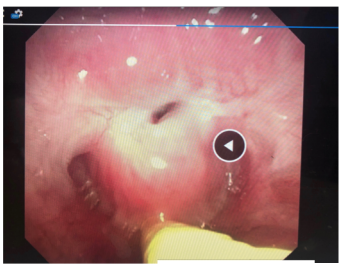



Learning Points

- As fast as children can heal, they can "unheal"
- Isolate the injury from barotrauma, suction trauma, secretions - BYPASS
- Kids can HEAL!

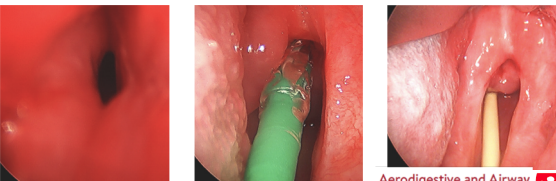
Case 2: CL

- 2 year old with progressive dyspnea, sleepiness, and lethargy a few weeks after traumatic intubation
- How do you approach management of this injury?
 - What is the status of the framework?
 - How do you choose from the reconstructive menu?
 - Would this patient benefit from multidisciplinary aerodigestive management?



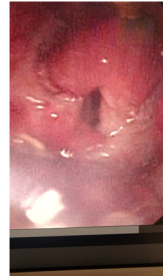

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Bypass, Expand, Slide



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Speech, GI, Pulmonology, PEDI Oto

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Learning Points

- Kids can REALLY heal
- Management may involve different options from the reconstructive menu along the patient's journey
- Aerodigestive management extends beyond the perioperative window



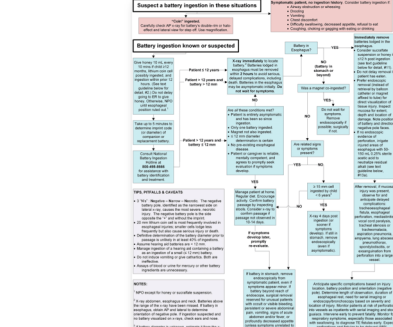
Post-extubation glottic and subglottic scarring

Case 3: IN

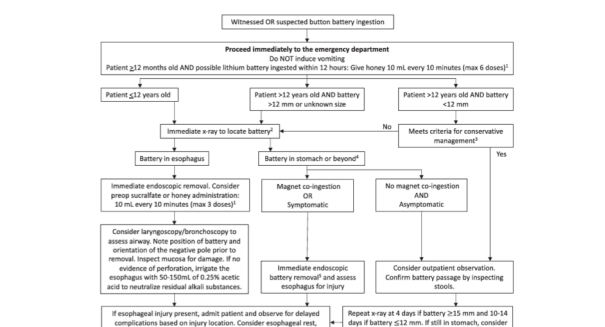
- 18 month old little boy
- Playing with twin brother and "a bag of batteries" and starts refusing milk
- Starts drooling a few hours later
- Mom calls the pediatrician, who calls the on-call pediatric otolaryngologist...




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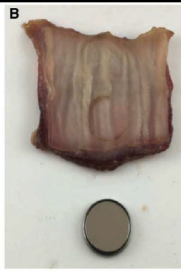


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Saline



Honey



Carafate®

Figure 5. Mucosal surface of cadaveric piglet esophagus exposed to a lithium button battery with serial irrigations of (A) saline, (B) honey, and (C) carafate. Reproduced with permission from John Wiley and Sons: Anfang RR, Jatana KR, Linn RL, Rhoades K, Fry J, Jacobs IN. pH-Neutralizing Esophageal Irrigations as a Novel Mitigation Strategy for Button Battery Injury. Laryngoscope. 2019;129:49-57. © 2018 The American Laryngological, Rhinological and Otological Society, Inc.

Honey: coat the battery to prevent local generation of hydroxide, thereby delaying alkaline burns

- Non artisanal
- Do not delay – don't go wait in line at the grocery store, just call 911
- Think...12.
 - Do not give if longer than 12 hours since ingestion (risk of perforation is high)
 - Do not give if child less than 12 months of age (risk of botulism)



“Negative, Narrow, Necrotic”

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Now what?

- How do you approach management of this injury?
 - What is the status of the framework?
- How do you choose from the reconstructive menu?
 - Would this patient benefit from multidisciplinary aerodigestive management?
- Intraop GI consult: 50 mL to 150 mL of 0.25% sterile acetic acid
- Airway management?
- Any role for imaging?
 - at least 3 mm of tissue between the area of esophageal injury and adjacent vessels

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Observe and prepare for delayed complications

- Immediate: airway edema, recurrent laryngeal nerve palsy (unilateral v bilateral), pneumothorax
- First week: TEF, esophageal perforation, mediastinitis and other infections (lung abscess, empyema), tracheal stenosis
- Up to 1 month: esophageal-vascular fistula
- Weeks to months: esophageal strictures and spondylodiscitis

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Learning Points: Multispecialty care is key

Evaluation & Management:

- Peds Oto, GI, PICU, CT Surgery, SLP/OT
- Serial endoscopy with Peds Oto, GI- timing depending on extent and location of injury
- Flexible laryngoscopy once awake and extubated, prior to PO
- Esophagram: at least 1-2 days after battery removal, earlier (1 day) for cases with mucosal injury only, and later for cases with deeper injury
- Diet may be advanced to soft as tolerated, but should be limited to soft foods for a full 28 days to avoid mechanical damage to a healing esophagus
- Management extends through the window of possible complications

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Evaluation of a patient with suspected ingestion of caustic substances

Annual Incidence of CDP Ingestion

Clinical and Endoscopy Findings in Children With Acute Caustic Ingestion: A Systematic Review and Meta-analysis
Singh, Anand, Anderson, Mitchell, et al. (2016)
Journal of Pediatric Gastroenterology & Nutrition
DOI: 10.1097/MPG.0000000000001176

FIGURE 1. Annual incidence of accidental CDP ingestion in children (showing average). CDP = concentrated detergent powder.

UpToDate

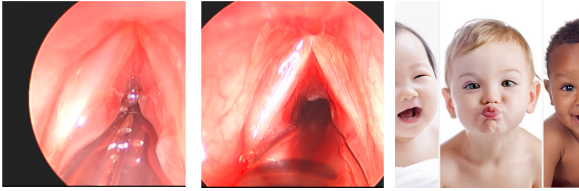
Caustic Ingestion

oral burns not always correlative


Timing of tissue damage and repair after caustic injury of the esophagus

Injury	Time
Acute injury	Day 0
Inflammation, vascular thrombosis	1 to 7 days
Granulation tissue	10 to 21 days
Fibrosis/stricture	3 weeks

UpToDate



- **How are you going to get there?** -Kids can heal
- **What are you going to do?** -Kids can REALLY heal
- **Who is going to be on the patient's team?** -Kids can evolve

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Aerodigestive and Airway Reconstruction Center Overview

Care Team

 David Sidell, MD, MChD, FACS Aerodigestive Center Director	 Kara Meister, MD Otolaryngology	 Karthik Balakrishnan, MD, MPH, FAAP, FACS Otolaryngology	 Tala Vetter, MD Otolaryngology	 Marlene Cavitt Aerodigestive Center Coordinator	 Janet Rankin, BS Clinical Nurse Coordinator
 David Cavitt, MD Chief, Division of Pediatric Pulmonary Medicine	 Hilary Kim, MD, FAAP Pediatric Pulmonary Medicine	 Emanuela, MD Pediatric Pulmonary Medicine	 Robbie, MD Pediatric Pulmonary Medicine	 Alison, MD Pediatric Pulmonary Medicine	 Margaret, PhD Asthma, COPD, Gastroenterology
 Rissa Gidycz, MD, CCC-SLP Speech-Language Pathologist	 April Edwards, MA, CCC-SLP Speech-Language Pathologist	 Bryan, MD Pediatric Surgery	 James Weil, MD Pediatric Surgery	 Talia, AuD Audiologist, BS, MA, CDP Neurotology Services	

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