Paradigm Shifts in Pediatric Airway Management

GEORGIA SOCIETY of ANESTHESIOLOGISTS

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Julie Williamson, DO
Associate Professor, Anesthesiology & Pediatrics
Emory University and Children's Healthcare of Atlanta

Children's Healthcare of Atlanta | EMORY UNIVERSITY

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No financial disclosures or COI

julie.williamson@emory.edu

@Jwill_PediACCM

A&A Case Reports. 2016;7:143–5

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Objectives

- Review pediatric airway management
- Prioritize oxygenation over intubation
- Compare delayed sequence intubation to RSI
- Explore limitations of apneic oxygenation/THRIVE in kids
- Set realistic expectations for pediatric FONA
- Introduce the Vortex model of airway management

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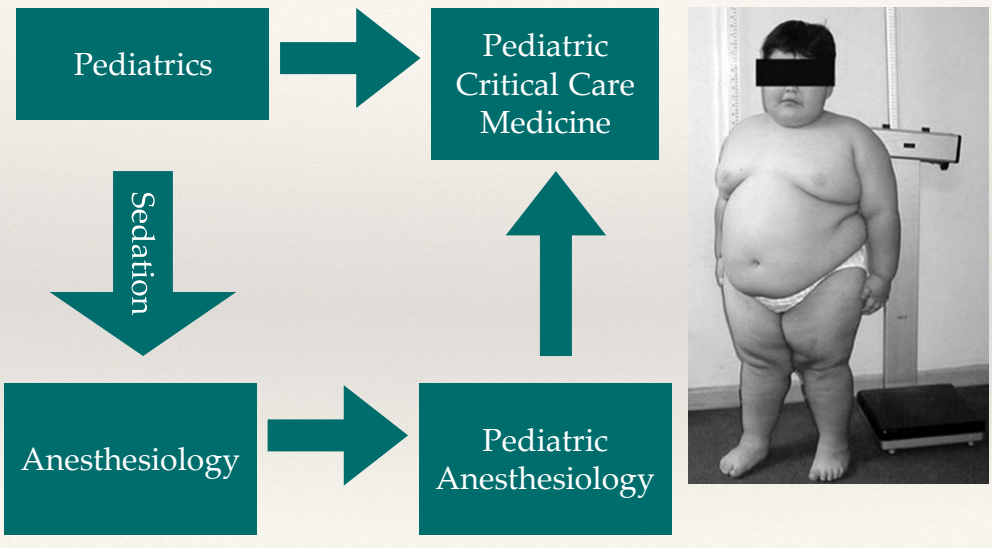
How did I get here?



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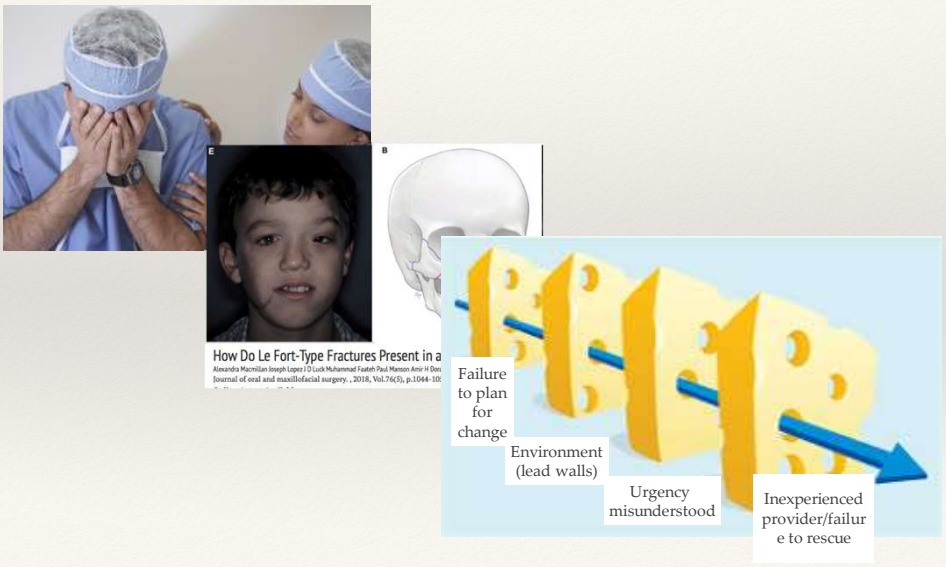
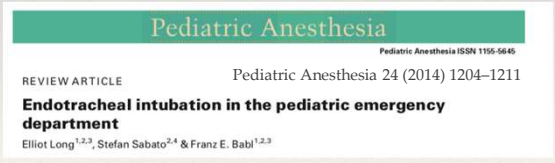
Why airways?



5

TI in the ED is tricky

Conclusion: Intubation of children in the ED is a low-frequency, high-risk procedure. The incidence of adverse events, particularly desaturation and hypotension, is high. The incidence of difficult laryngoscopy is low. First pass success rate without desaturation or hypotension is low. Strategies to avoid desaturation and hypotension in the peri-intubation setting should be prioritized.



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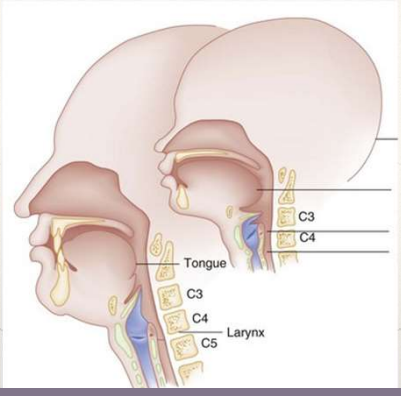
Airway Review

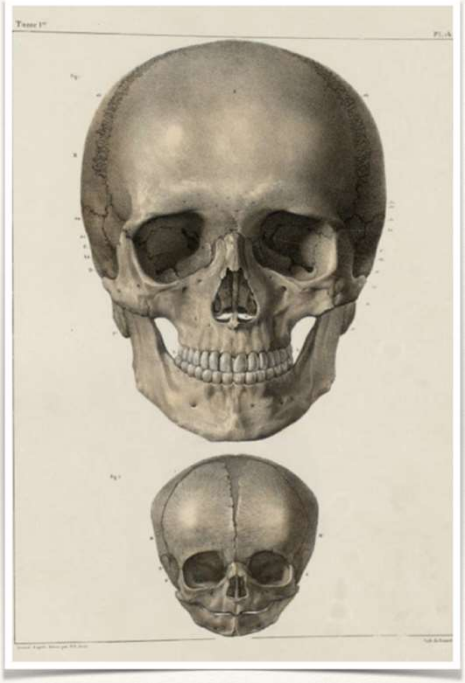
- Anatomy
- Physiology
- Equipment
- Expert Recommendations (QI/PS)

7

Anatomy



Occiput
Tongue
Nares
Epiglottis
Larynx
Narrowest point of entry:
VC vs. cricoid ring



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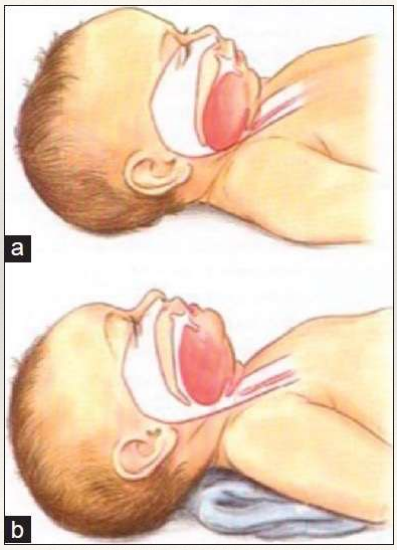
Positioning

Pediatric Anesthesia
Digital Handbook



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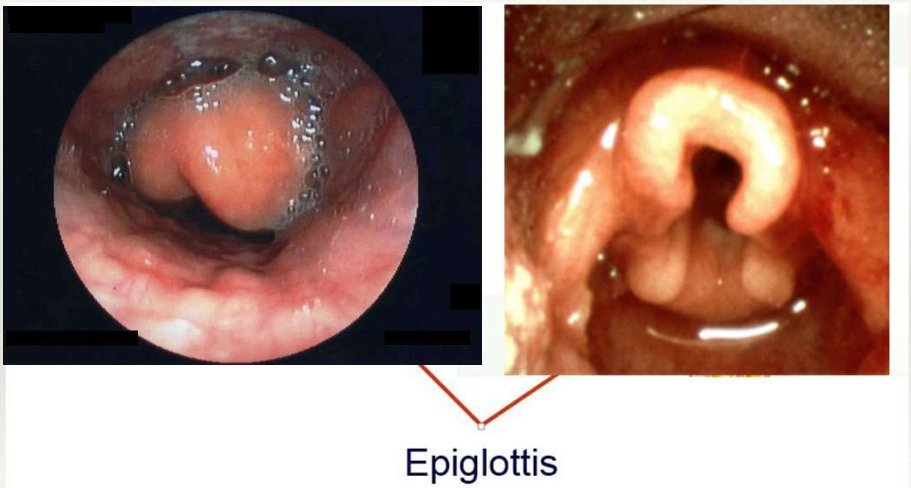
Epiglottis



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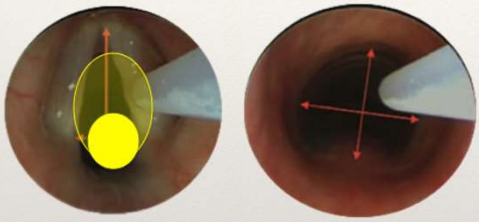
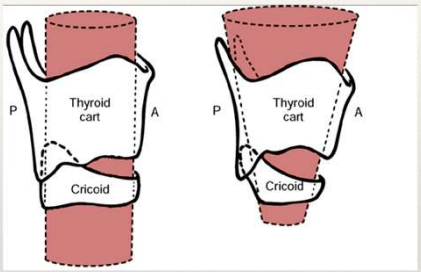
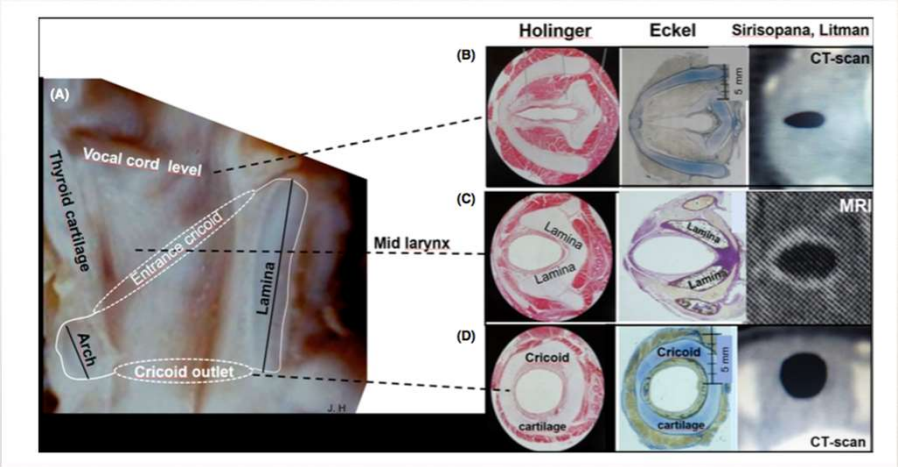
Larynx





Dalal *Anesth Analg* 2009

11



The anatomy of the pediatric airway: Has our knowledge changed in 120 years? A review of historic and recent investigations of the anatomy of the pediatric larynx

Josef Holzki[1] | Karen A. Brown[2] | Robert G. Carroll[3†] | Charles J. Coté[4]

Pediatric Anesthesia 2018

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Trachea and ETTs

High PIP
Low SpO2
Low ETCO2

- Small trachea —>
  - Right mainstream intubation,
  - ETT dislodges easily
- Depth at gums = 3 x ETT size
- ETT size = age/4 + 4
- **Downsize 1/2 size for cuffed ETT, edema, vomit, blood…**

Cuffed ETT Sizes:

Neonate: 3.0
1 yo: 4.0
5 yo: 5.0

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Physiology

- Compliant thoracic cage, increased volume of abdominal contents & over-insufflation of stomach with crying or BMV → **less FRC**
- **Increased metabolic demand**: 2-3 times that of the adult

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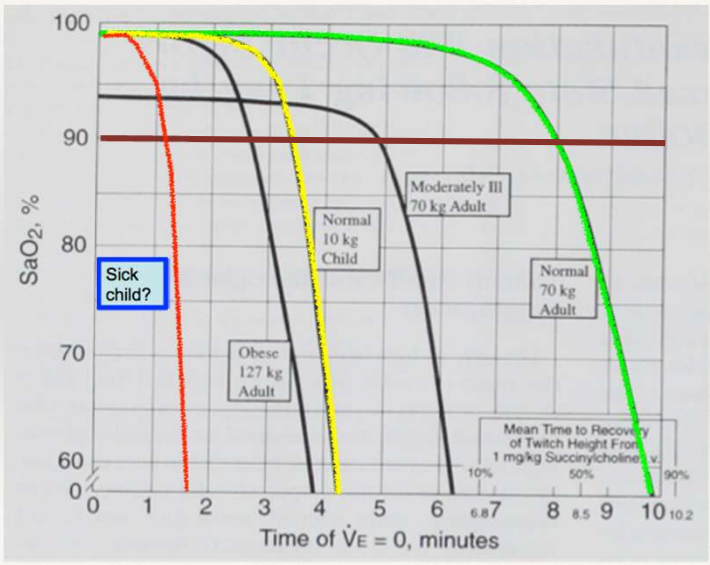
Physiology

Benumof
Anesthesiology 1997



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Lessons Learned: NAP4

https://www.rcoa.ac.uk/document-store/nap4-full-report

Poor assessment —> poor outcomes

No plan for failure

Obstructed airways require teams in optimal environment (OR)

Cannula cricothyrotomy rescue = 60% failure in adults, 100% failure in children

Surgical airways successful but often started too late

Qualitative capnography is mandatory

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Prehospital Intubation

Does NOT improve neurologic outcome or mortality
Pediatric - all cause
Adult - trauma

- **Effect of out-of- hospital pediatric endotracheal intubation on survival and neurological outcome: a controlled clinical trial. Gausche *JAMA* 2000**
- **Prehospital endotracheal intubation for severe head injury in children: a reappraisal. Cooper *Semin Pediatr Surg* 2001**
- **Intubation of pediatric trauma patients in the field: predictor of negative outcome despite risk stratification. DiRusso *J Trauma* 2005**
- **Time on the scene and interventions are associated with improved survival in pediatric out-of-hospital cardiac arrest. Tijssen *Resuscitation* 2015**
- **Pediatric Airway Management and Prehospital Patient Safety. Hansen *Pediatr Emer Care* 2016**
- **A systematic review and meta-analysis comparing mortality in pre-hospital tracheal intubation to emergency department intubation in trauma patients. Fevang *Crit Care* 2017**

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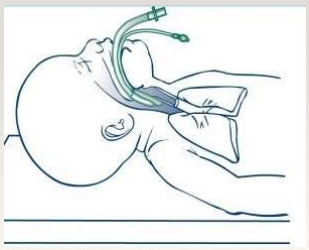
Prioritize oxygenation over intubation

Bag mask ventilation
Oral Airway
Nasal airway
Supraglottic airways



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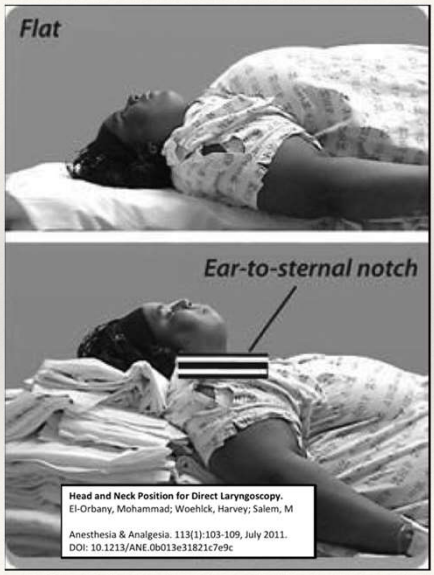
Positioning to avoid obstruction

Pediatric Anesthesia Digital Handbook



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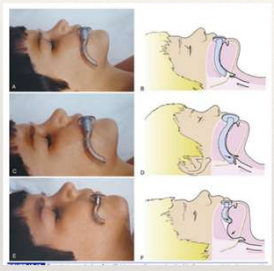
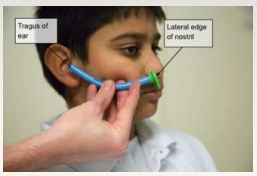
BMV: Relieve obstruction

Anatomic





Physiologic

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Contributors to Difficult MV

Wired jaw
Facial trauma
Limited C Spine mobility
Halo
Poor mask seal
Laryngospasm
Upper/lower airway tumor
Blood/secretions/pus
Upper/lower airway collapse

- **Cervical SCI in <1% of pediatric trauma**
- **Trisomy 21, achondroplasia, MPS**
- **Hyperangulated VL *may* cause less motion during TI than DL**
- **In extremis weigh risk of respiratory arrest against SCI exacerbation**

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Avoid multiple attempts at DL

610 MORT
COMPLICATIONS OF EMERGENCY INTUBATION
ANESTH ANALG
2004;99:607–13

Table 5. Complications by Intubation Attempts

Complication	2 or fewer attempts (90%)	>2 attempts (10%)*	Relative risk for >2 attempts	95% CI for risk ratio
Hypoxemia	10.5%	70%	9X	4.20 – 15.92
Severe hypoxemia	1.9%	28%	14X	7.36 – 24.34
Esophageal intubation	4.8%	51.4%	6X	3.71 – 8.72
Regurgitation	1.9%	22%	7X	2.82 – 10.14
Aspiration	0.8%	13%	4X	1.89 – 7.18
Bradycardia	1.6%	18.5%	4X	1.71 – 6.74
Cardiac arrest	0.7%	11%	7X	2.39 – 9.87

* All categories $P < 0.001$ when comparing 2 or fewer attempts to >2 attempts.

CI → CICO

No more than three attempts

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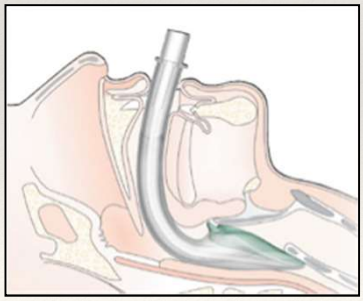
Supraglottic Airways

No protection from aspiration

Designed to leak at 20 cm H2O

Can be a conduit for FOI



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2nd Generation SGAs


LMA Proseal


airQ


iLMA


FastTrach

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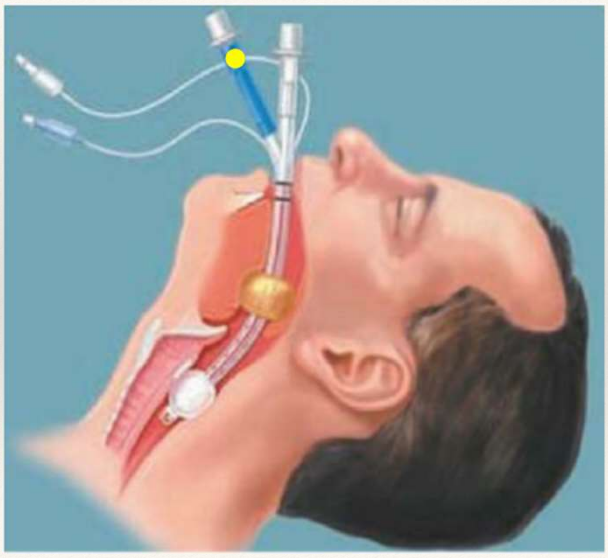
Combitube



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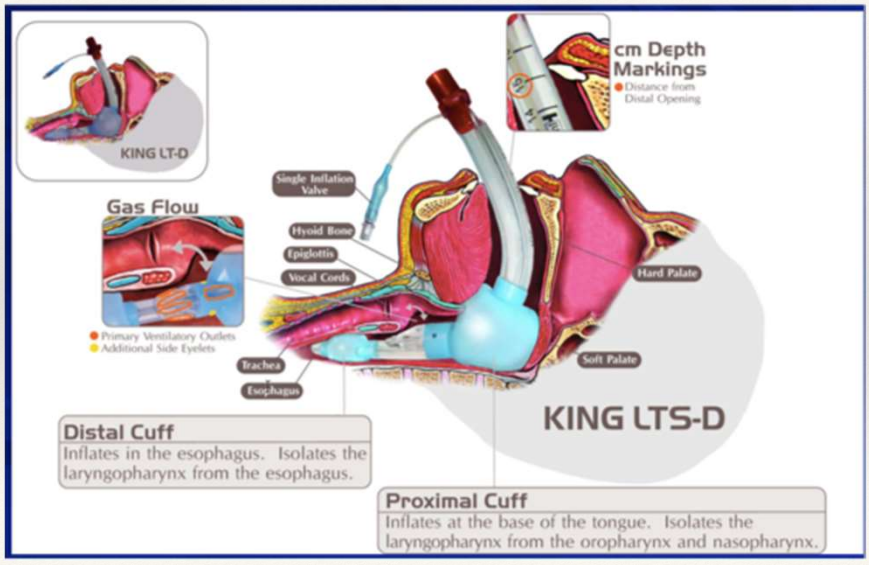
King LTS-D



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Predictors of Difficult SGA Placement

Restricted mouth opening

Obstruction/**O**besity

Disrupted / **D**istorted anatomy

Stiff lungs

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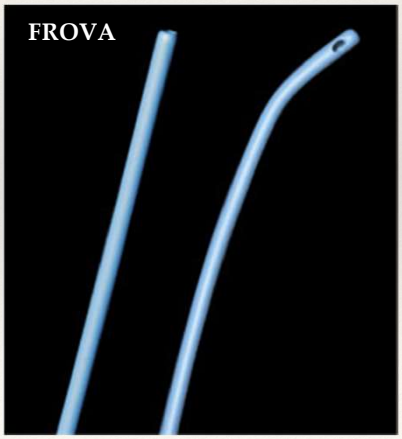
Simple Intubating Aids

Gum elastic bougie



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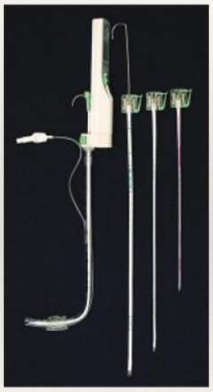
Simple Intubating Aids



Nishikawa Anesth Analg 2006

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Difficult Tracheal Intubation

Difficult TI: 1% overall

Low BMI <10%ile

Neonates 3.2%
Infancy 5%

MP 3 or 4

ASA 3 or 4

Type of surgery (**cardiac, oromaxillofacial**)

ORIGINAL ARTICLE 2012

Incidence and predictors of difficult laryngoscopy in 11.219 pediatric anesthesia procedures

Sebastian Heinrich*, Torsten Birkholz*, Harald Ihmsen, Andrea Irouschek, Andreas Ackermann & Joachim Schmidt

Pediatric Critical Care

2013 CCM

A National Emergency Airway Registry for Children: Landscape of Tracheal Intubation in 15 PICUs*

Akira Nishisaki, MD, MSCE[1,2]; David A. Turner, MD[3]; Calvin A. Brown III, MD[4]; Ron M. Walls, MD[5]; Vinay M. Nadkarni, MD, MS[1,2]; for the National Emergency Airway Registry for Children (NEAR4KIDS) and Pediatric Acute Lung Injury and Sepsis Investigators (PALISI) Network

H/O difficult airway
Airway obstruction

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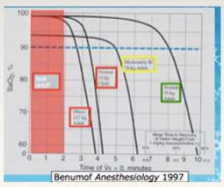
Rapid Sequence Intubation

- Avoids BVM to decrease aspiration risk
- Requires skill + speed
- Failure requires rescue BVM

Preoxygenate → Sedation + NMB → Intubate trachea



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Delayed Sequence Intubation

Goal = oxygenation + hemodynamic stability

Risk = Aspiration

Sedation → Pre-oxygenate → Sedation + NMB → Oxygenate → Tracheal intubation

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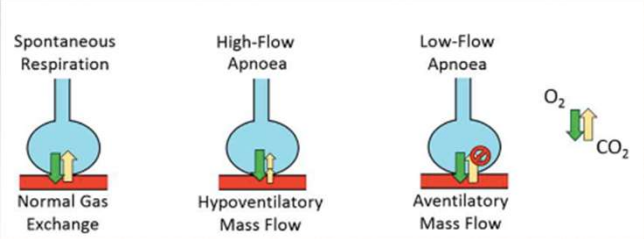
Apneic Oxygenation

- Airway must be **patent, alveoli open**
- Oxygen moves into the lungs secondary to mass flow
  Oxygen absorbed into alveoli via negative pressure gradient
- If CO2 not eliminated —> acidosis, arrhythmia



Anaesthesia 2017, 72, 1379–1387

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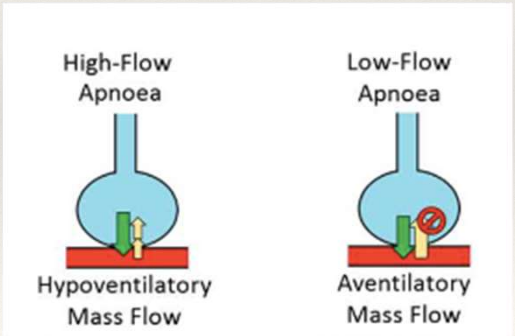
THRIVE

Transnasal
Humidified
Rapid
Insufflation
Ventilatory
Exchange

Figure 5. THRIVE: High-flow nasal cannula placed in position. Apneic oxygenation and apneic ventilation allow apnea times between 10 and 60 minutes.



ANESTHESIOLOGY NEWS AIRWAY MANAGEMENT 2016

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Kids THRIVE

Transnasal
Humidified
Rapid
Insufflation
Ventilatory
Exchange

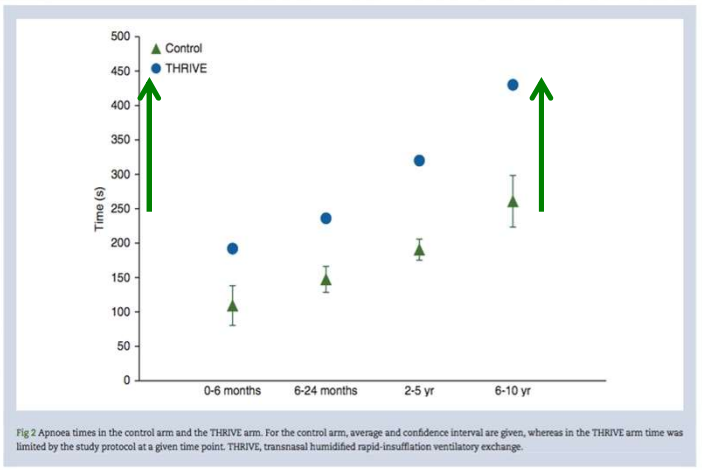

Fig 2 Apnoea times in the control arm and the THRIVE arm. For the control arm, average and confidence interval are given, whereas in the THRIVE arm time was limited by the study protocol at a given time point. THRIVE, transnasal humidified rapid-insufflation ventilatory exchange.

British Journal of Anaesthesia, 118 (2): 232–8 (2017)

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THRIVE Studies

SUPPORTIVE	NOT SUPPORTIVE
Ramachandran SK J Clin Anes 2010;22(3)	Vourc'h M Intensive Care Med 2015; 41
Wimalesena Y. Ann Emerg Med 2015;65(4)	Semler MW Am J Respir Erit Care Med 2016;193(3)
Oliveira JESL. Ann Emerg Med 2017;70(4)	Caputo N. Acad Emerg Med 2017; 24
Pavlov I Am J Emerg Med 2017; 35(8)	**Riva T Brit J Anes 2018; 120 (3)***
Sakles JC Intern Emerg Med 2016; 11(7)	
Sakles JC Acd Emerg Med 2016;23(6)	
Russotto V J Crit Care 2017;41	
Humphreys S. Brit J Anes 2017; 188(2)	
Vukovic A. Amer J Emerg Med 2018 (ePub ahead of print)	

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Videolaryngoscopy: A primary approach

Steering
GlideScope
Storz CMAC
McGrath

Channeled
AirTraq
Pentax Airway Scope

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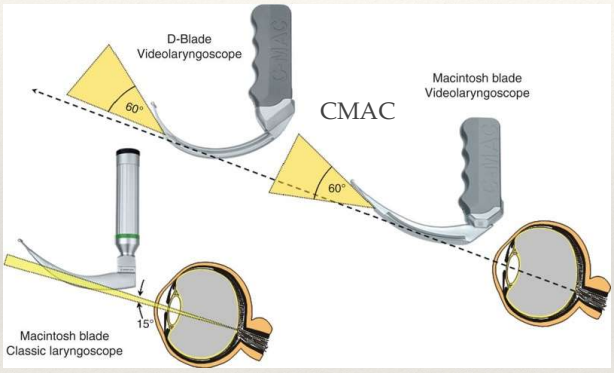
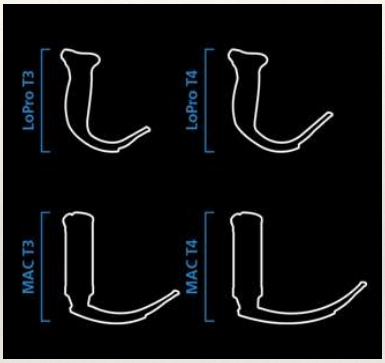
Hyperangulated Blades





BJA British Journal of Anaesthesia

GlideScope Titanium

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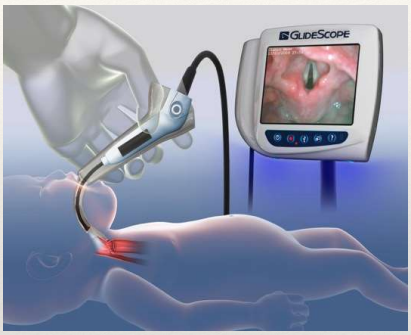
VL in Children: Caution Advised



Does not increase TI success in children <1 year or 10kg
May complicate an easy airway

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Fiberoptic Intubation

Pediatric Anesthesia
Pediatric Anesthesia 2010 20: 454–464 doi:10.1111/j.1460-9592.2010.03284.x

Proposal for the management of the unexpected difficult pediatric airway

MARKUS WEISS MD* AND THOMAS ENGELHARDT MD, PHDT
*Department of Anaesthesia, University Children's Hospital, Zurich, Switzerland and
†Department of Anaesthesia, Royal Aberdeen Children's Hospital, Aberdeen, UK

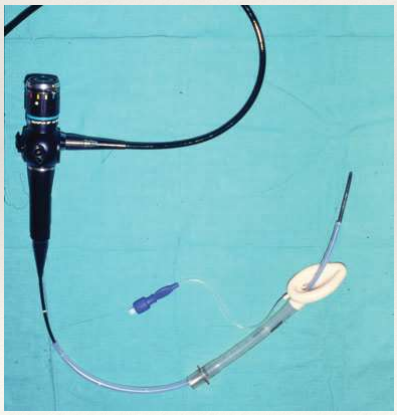

Table 2
Guide for fibreoptic intubation through the laryngeal mask airway (LMA). It is important to verify the distance between the grille of the LMA and the vocal cords for the make of tracheal tubes and LMAs used in each department

LMA	Bodyweight (kg)
1	<5
1.5	5–10
2	10–20
2.5	15–30
3	30–50
4	50–70
5	>70
LMA[a]	Tracheal tube size ID (mm)
1	3.0 uncuffed
1.5	3.5 uncuffed
2	4.5 uncuffed
2.5	5.0 uncuffed
3.0	6.0 cuffed
4	7.0 cuffed
5	7.5 cuffed
Fiberoptik OD (mm)	Tracheal tube size ID (mm)
2.0	>2.5
2.5	>3.0
2.8	>3.5
3.5	>4.0
4.1	>5.0
5.0	>5.5
Airway exchanger	
Cook 7F	≥ID 2.5 mm
Cook 8F	≥ID 3.0 mm
Cook 11F	≥ID 4.0 mm
Cook 14F	≥ID 5.5 mm[b]
Cook 19F	≥ID 7.0 mm

[a]Pilot balloon of cuffed tubes does not pass LMAs smaller than size 3.
[b]Manufacturer recommends size Cook 14 F for tubes ID 5.0 and higher.

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Storz "F.I.V.E."

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Contraindications to FOI

Absolute	Relative
Life threatening airway obstruction	Secretions/blood in airway
	Restricted pharyngeal space
	Friable UAW tumor
	Pointing abscess UAW

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No matter how you manage the airway…

Confirm with capnography

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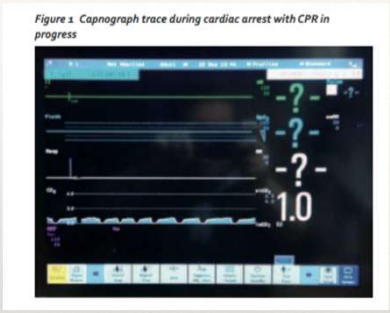
Capnography



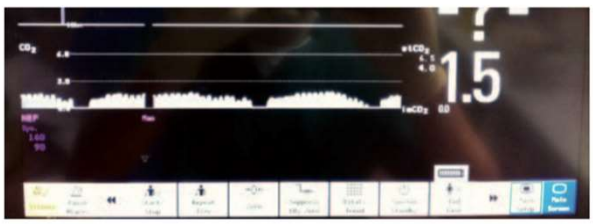


Figure 1 Exhaled carbon dioxide can be seen in low-cardiac output states, although the trace may be abnormal.

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All difficult airway algorithms presume:

Clinician is competent in advanced airway management

Team is trained *before* implementation

Promote situational awareness

Do not replace skill or experience

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But they are not all easy to use…

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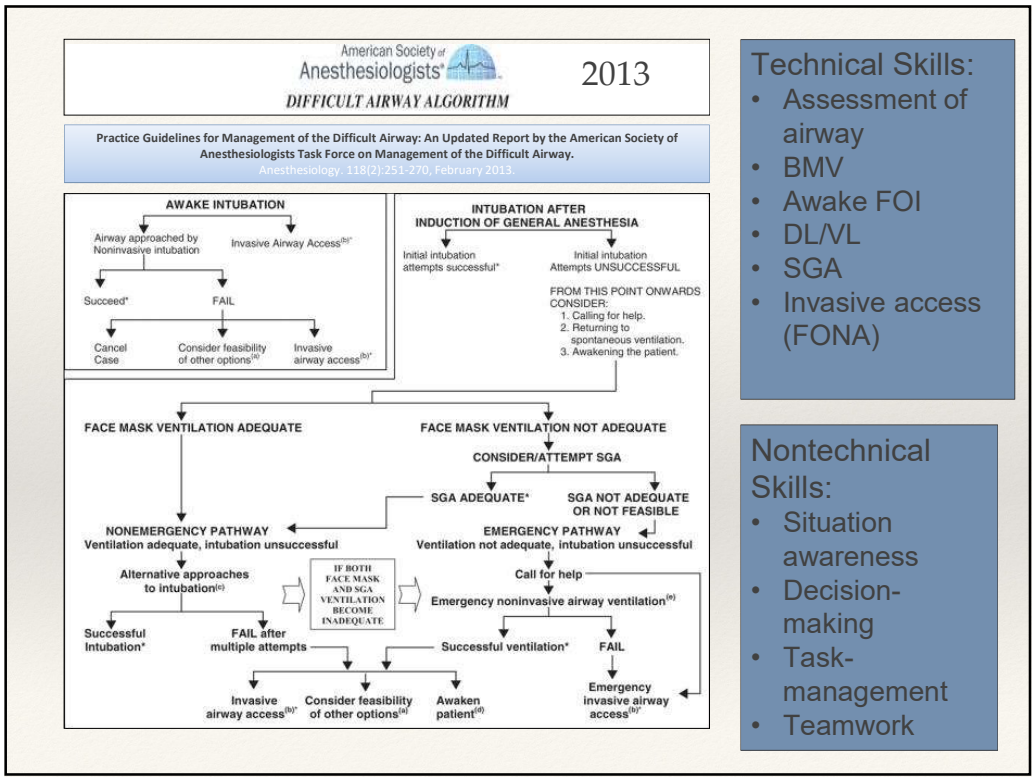

Technical Skills:
- Assessment of airway
- BMV
- Awake FOI
- DL/VL
- SGA
- Invasive access (FONA)

Nontechnical Skills:
- Situation awareness
- Decision-making
- Task-management
- Teamwork

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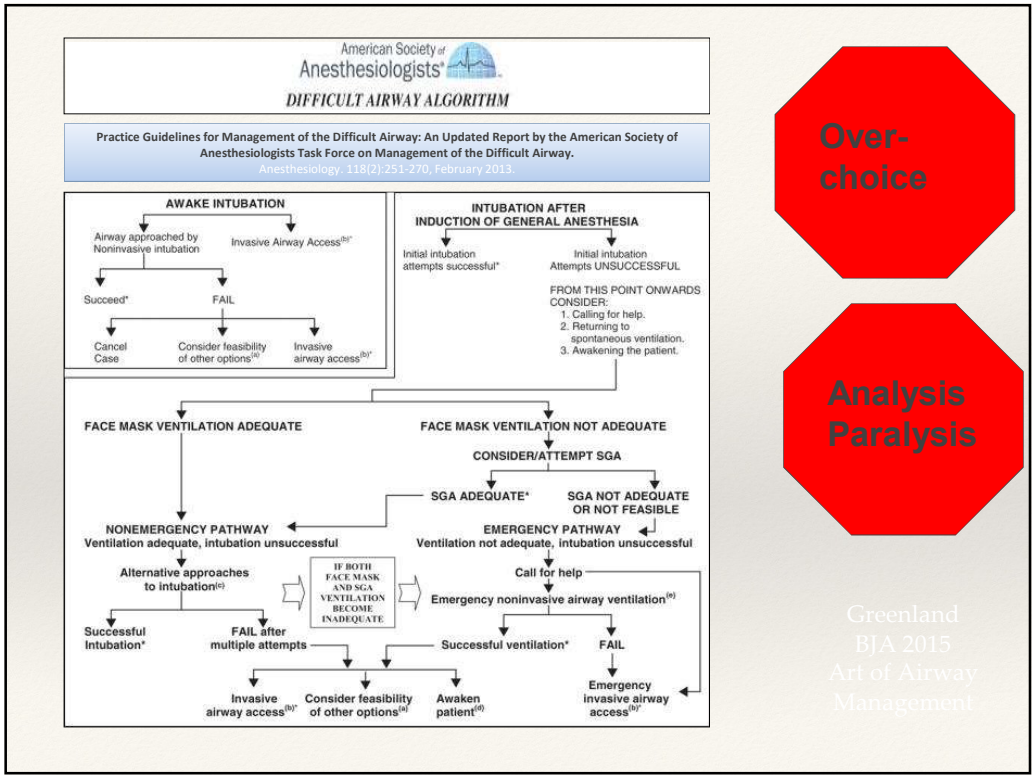

Over-choice

Analysis Paralysis

Greenland BJA 2015 Art of Airway Management

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SPECIAL ISSUE

The Vortex: a universal 'high-acuity implementation tool' for emergency airway management

N. Chrimes*

Department of Anaesthesia, Monash Medical Centre, 246 Clayton Road, Clayton, VIC 3168, Australia

British Journal of Anaesthesia, 117 (S1): i20–i27 (2016)

Fig 6 Lateral aspect of Vortex in three dimensions, demonstrating funnel concept.

http://vortexapproach.org

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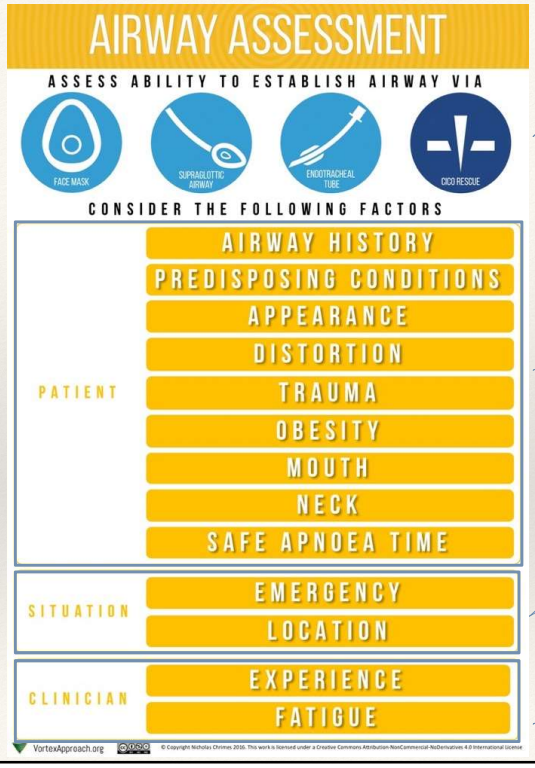

Technical Skills

Difficulty

Situation Awareness

Operator

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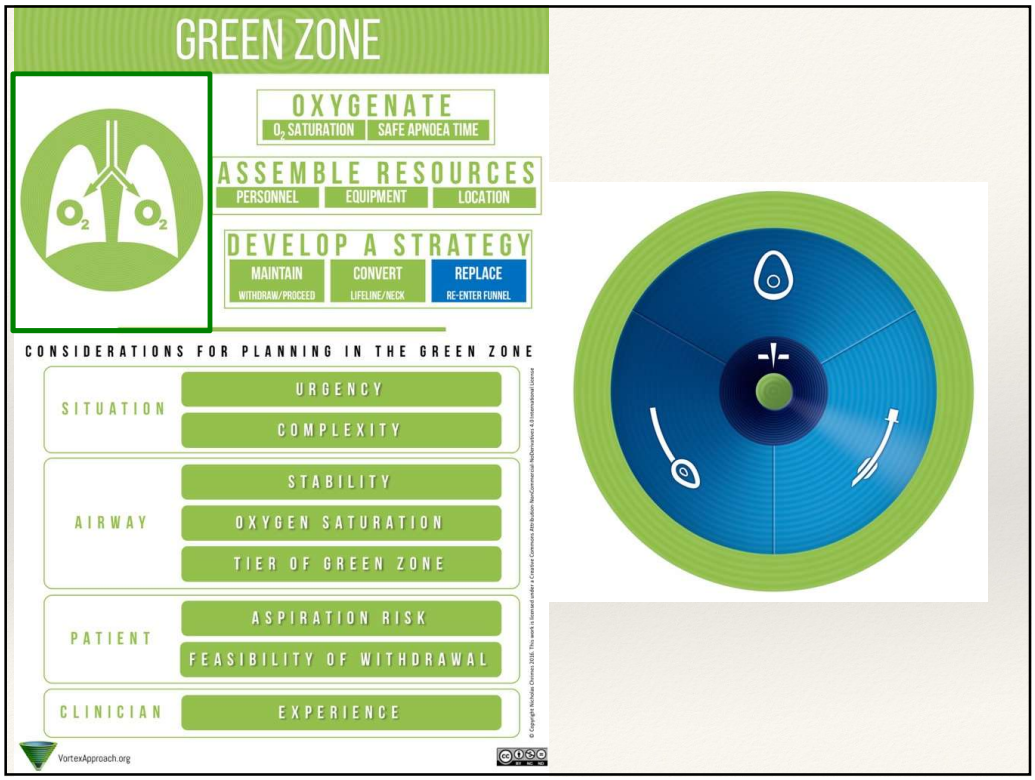
GREEN ZONE
OXYGENATE
O_2 SATURATION
SAFE APNOEA TIME
ASSEMBLE RESOURCES
PERSONNEL
EQUIPMENT
LOCATION
DEVELOP A STRATEGY
MAINTAIN
WITHDRAW/PROCEED
CONVERT
LIFELINE/NECK
REPLACE
RE-ENTER FUNNEL
CONSIDERATIONS FOR PLANNING IN THE GREEN ZONE
SITUATION
URGENCY
COMPLEXITY
AIRWAY
STABILITY
OXYGEN SATURATION
TIER OF GREEN ZONE
PATIENT
ASPIRATION RISK
FEASIBILITY OF WITHDRAWAL
CLINICIAN
EXPERIENCE
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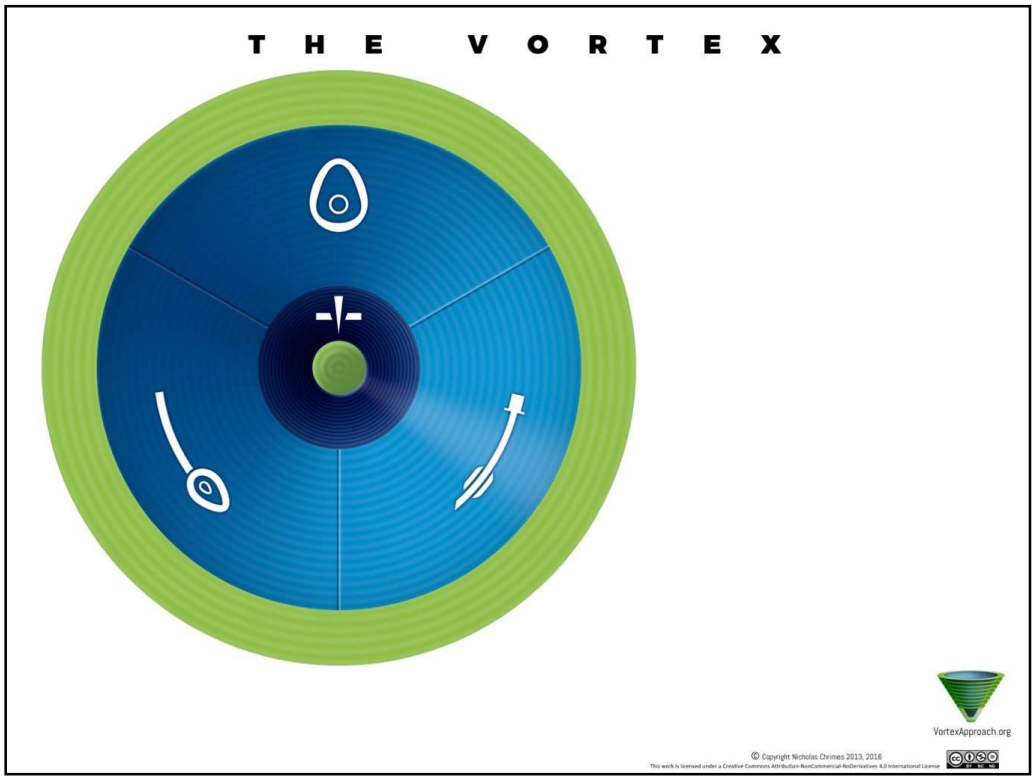
THE VORTEX
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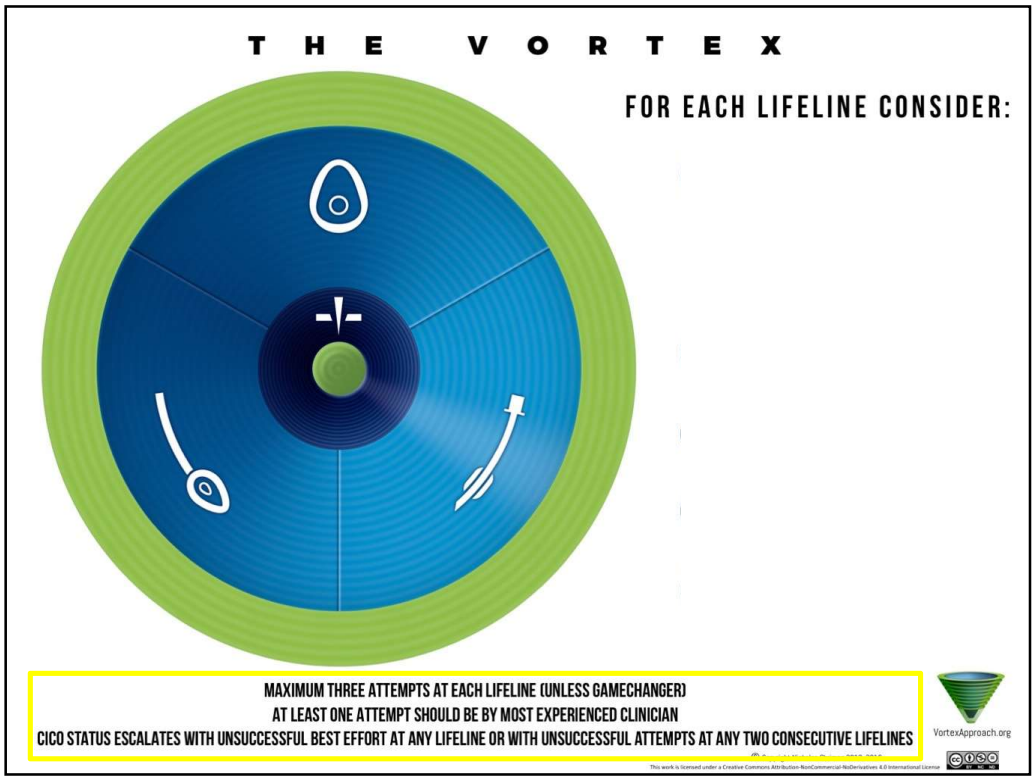
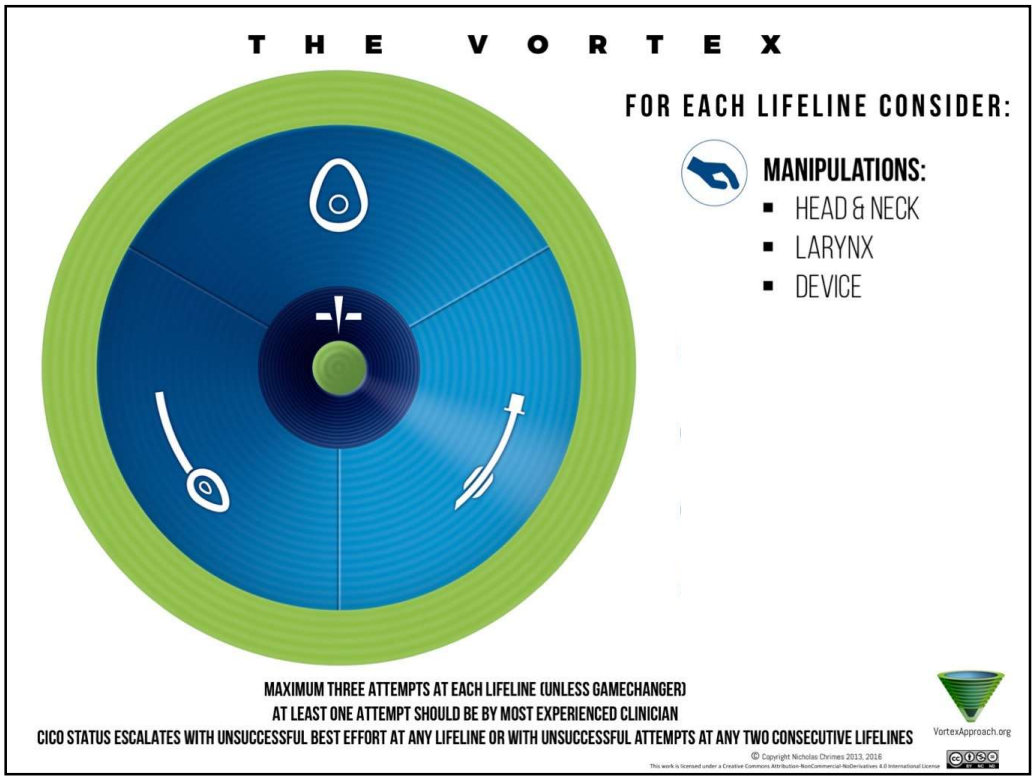
52


THE VORTEX
FOR EACH LIFELINE CONSIDER:
MAXIMUM THREE ATTEMPTS AT EACH LIFELINE (UNLESS GAMECHANGER)
AT LEAST ONE ATTEMPT SHOULD BE BY MOST EXPERIENCED CLINICIAN
CICO STATUS ESCALATES WITH UNSUCCESSFUL BEST EFFORT AT ANY LIFELINE OR WITH UNSUCCESSFUL ATTEMPTS AT ANY TWO CONSECUTIVE LIFELINES
VortexApproach.org

53


THE VORTEX
FOR EACH LIFELINE CONSIDER:
MANIPULATIONS:
HEAD & NECK
LARYNX
DEVICE
MAXIMUM THREE ATTEMPTS AT EACH LIFELINE (UNLESS GAMECHANGER)
AT LEAST ONE ATTEMPT SHOULD BE BY MOST EXPERIENCED CLINICIAN
CICO STATUS ESCALATES WITH UNSUCCESSFUL BEST EFFORT AT ANY LIFELINE OR WITH UNSUCCESSFUL ATTEMPTS AT ANY TWO CONSECUTIVE LIFELINES
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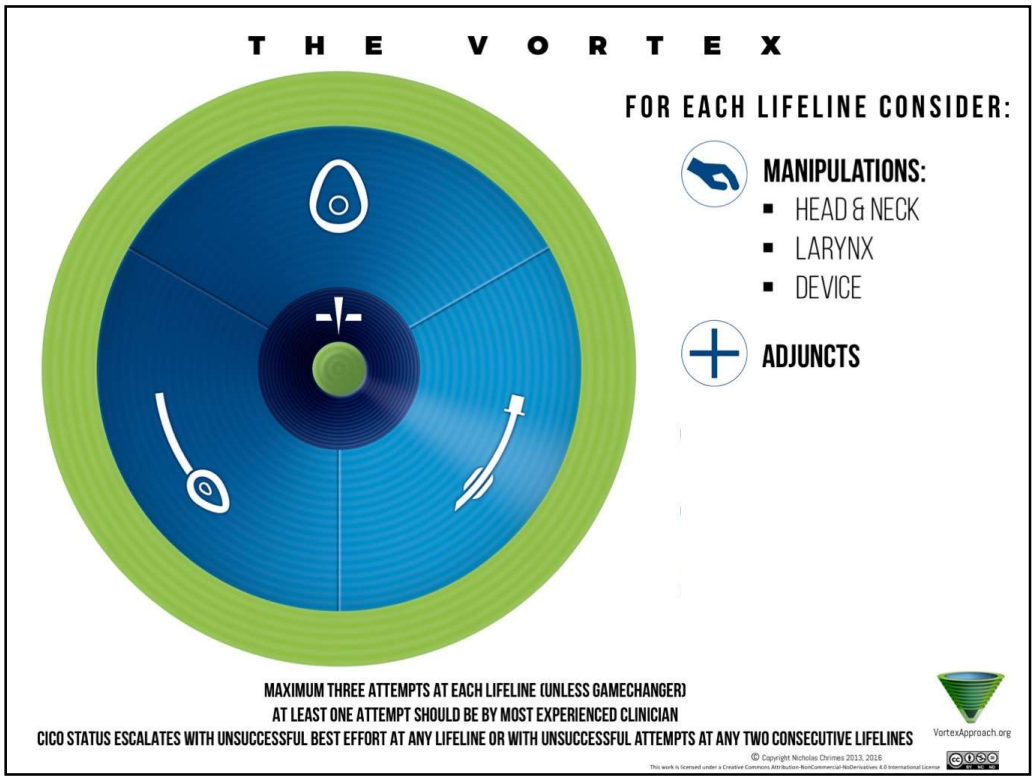
THE VORTEX
FOR EACH LIFELINE CONSIDER:
MANIPULATIONS:
HEAD & NECK
LARYNX
DEVICE
ADJUNCTS
MAXIMUM THREE ATTEMPTS AT EACH LIFELINE (UNLESS GAMECHANGER)
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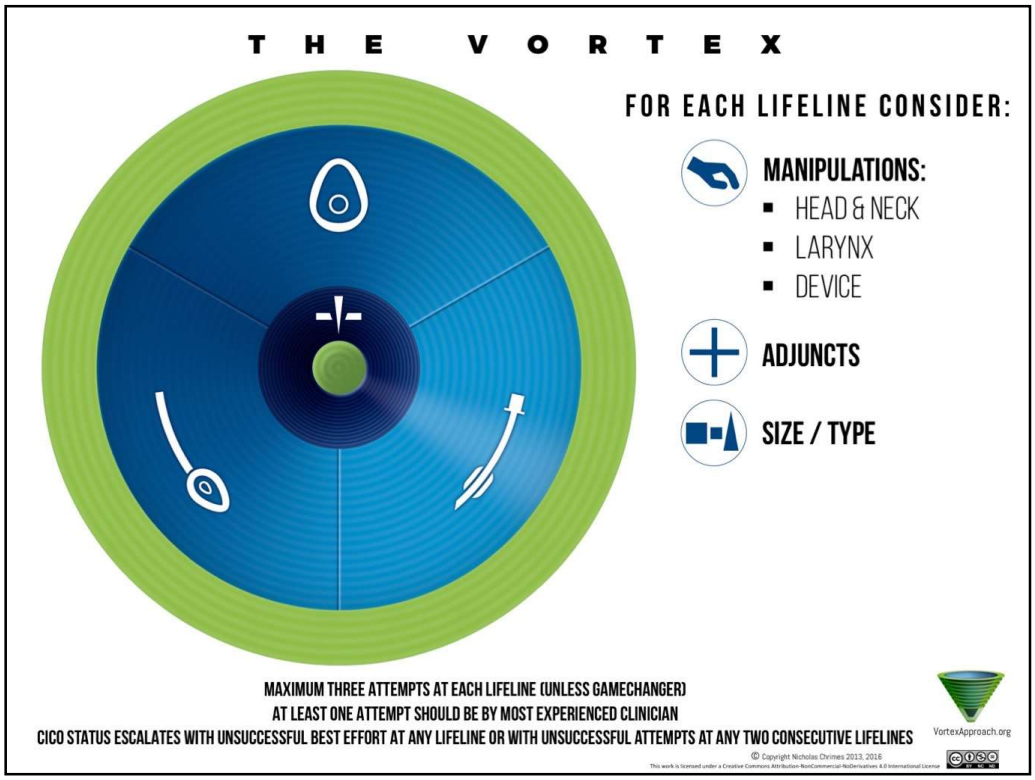
THE VORTEX
FOR EACH LIFELINE CONSIDER:
MANIPULATIONS:
HEAD & NECK
LARYNX
DEVICE
ADJUNCTS
SIZE / TYPE
MAXIMUM THREE ATTEMPTS AT EACH LIFELINE (UNLESS GAMECHANGER)
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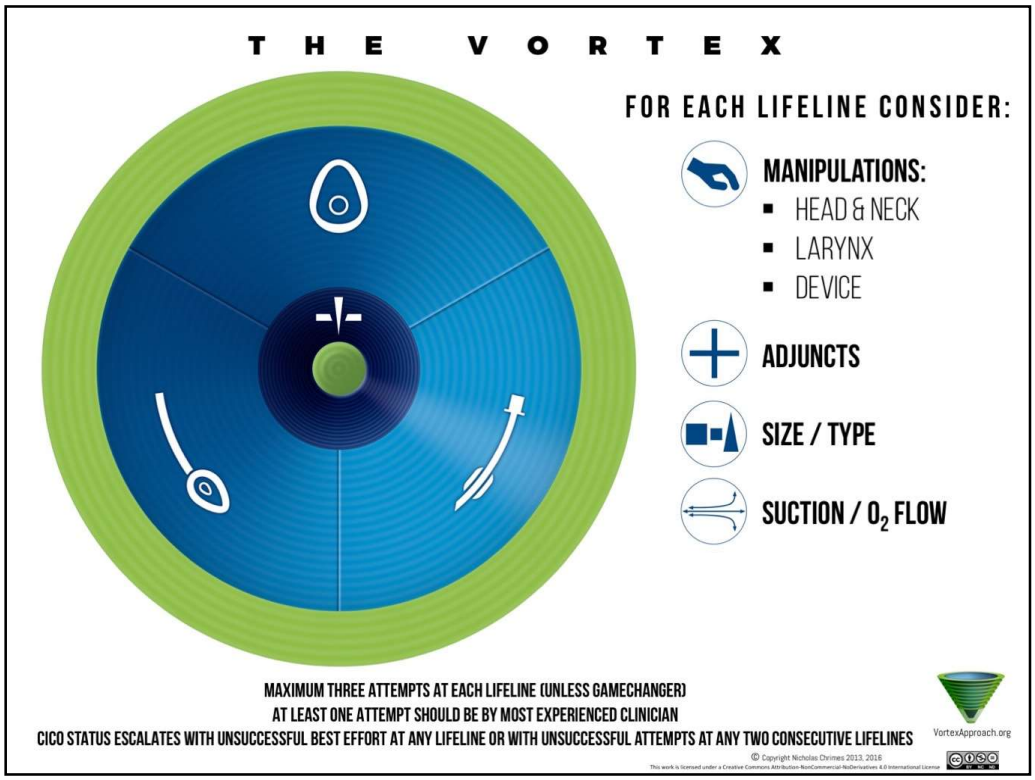
THE VORTEX
FOR EACH LIFELINE CONSIDER:
MANIPULATIONS:
HEAD & NECK
LARYNX
DEVICE
ADJUNCTS
SIZE / TYPE
SUCTION / O_2 FLOW
MAXIMUM THREE ATTEMPTS AT EACH LIFELINE (UNLESS GAMECHANGER)
AT LEAST ONE ATTEMPT SHOULD BE BY MOST EXPERIENCED CLINICIAN
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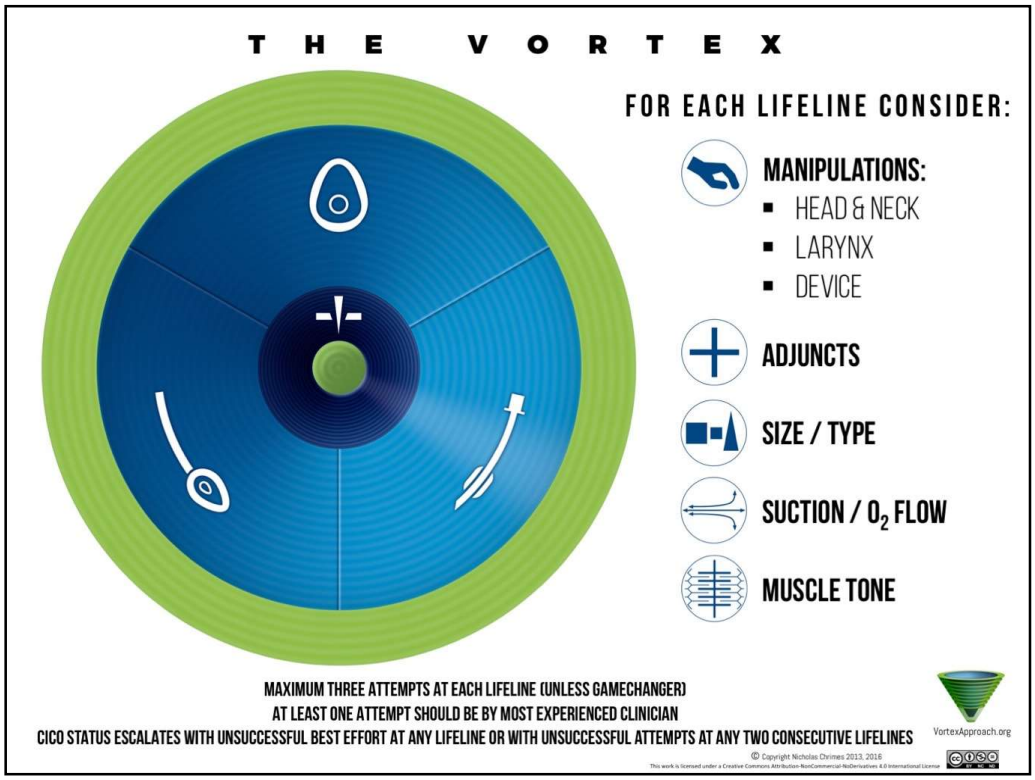
THE VORTEX
FOR EACH LIFELINE CONSIDER:
MANIPULATIONS:
HEAD & NECK
LARYNX
DEVICE
ADJUNCTS
SIZE / TYPE
SUCTION / O_2 FLOW
MUSCLE TONE
MAXIMUM THREE ATTEMPTS AT EACH LIFELINE (UNLESS GAMECHANGER)
AT LEAST ONE ATTEMPT SHOULD BE BY MOST EXPERIENCED CLINICIAN
CICO STATUS ESCALATES WITH UNSUCCESSFUL BEST EFFORT AT ANY LIFELINE OR WITH UNSUCCESSFUL ATTEMPTS AT ANY TWO CONSECUTIVE LIFELINES
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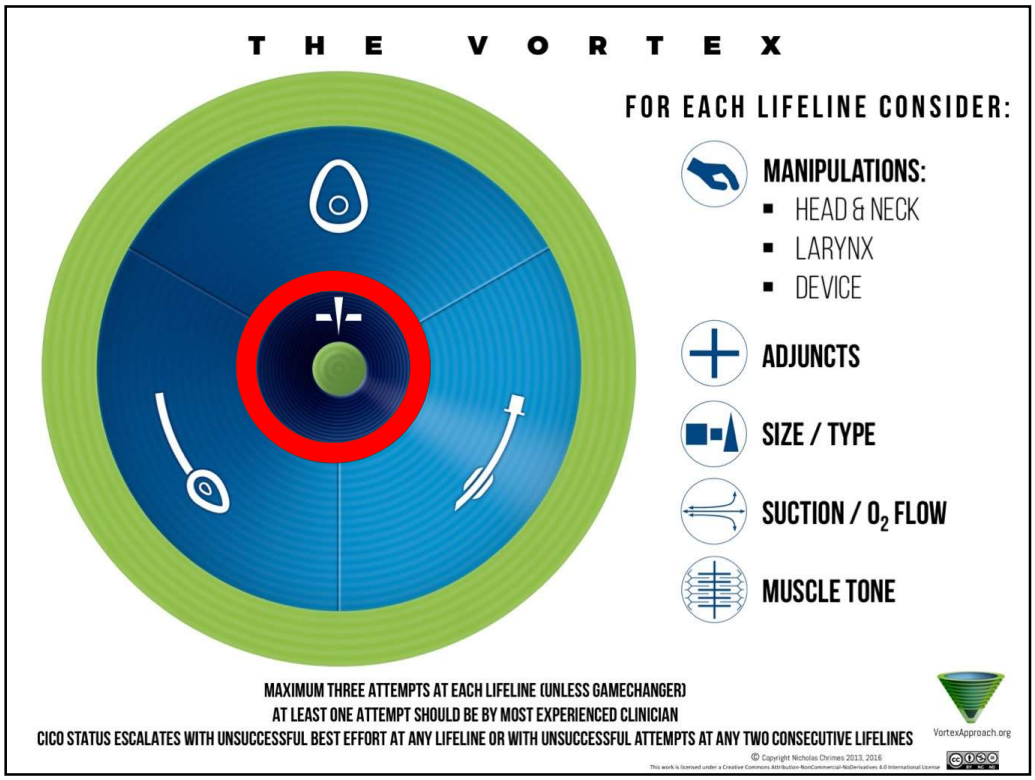
THE VORTEX
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CICO STATUS
READY
CALL FOR HELP
ALLOCATE PROCEDURALIST
KIT OUT AT BEDSIDE & CONFIRM CONTENTS
PRIME
SET
OPEN KIT & PREPARE EQUIPMENT
IDENTIFY ANATOMY
INFILTRATE ADRENALINE CONTAINING LA[1]
POISED
GO
OPTIMISE PATIENT POSITION
INITIATE CICO RESCUE
PERFORM
CICO STATUS ESCALATES WITH A UNSUCCESSFUL BEST EFFORT AT ANY LIFELINE OR WITH UNSUCCESSFUL ATTEMPTS AT ANY TWO CONSECUTIVE LIFELINES*
Consider additional escalation in CICO Status if:
Predicted difficult airway
SaO2 <90%
Rapidly deteriorating SaO_2
*ENSURE BEST EFFORTS AT ALL 3 LIFELINES BEFORE DECLARING GO STATUS
VortexApproach.org
1 Time Permitting. Must not delay GO status
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Adapted with permission from CriCon by S. Weingart, 2012
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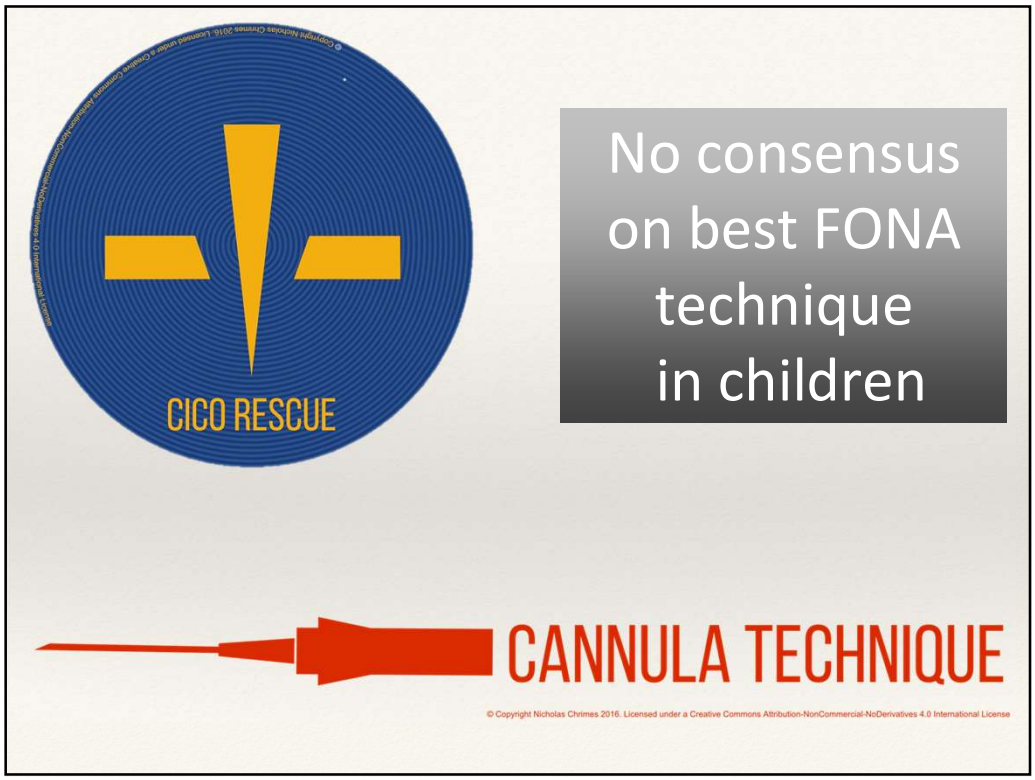
CICO RESCUE
No consensus on best FONA technique in children
CANNULA TECHNIQUE
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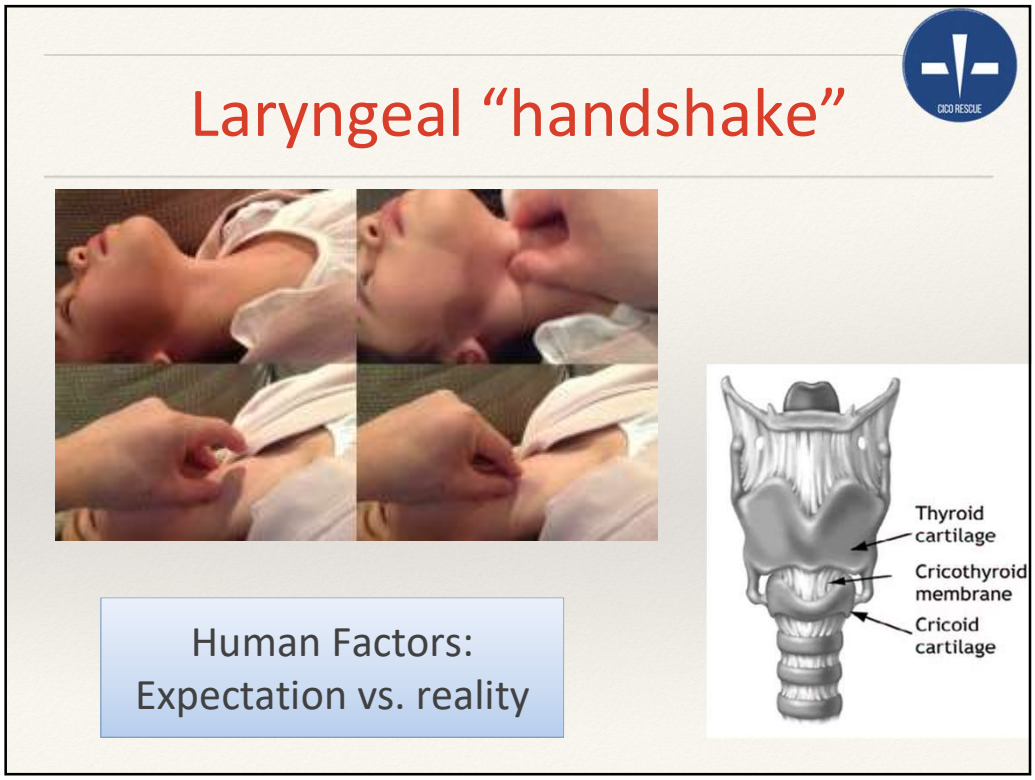
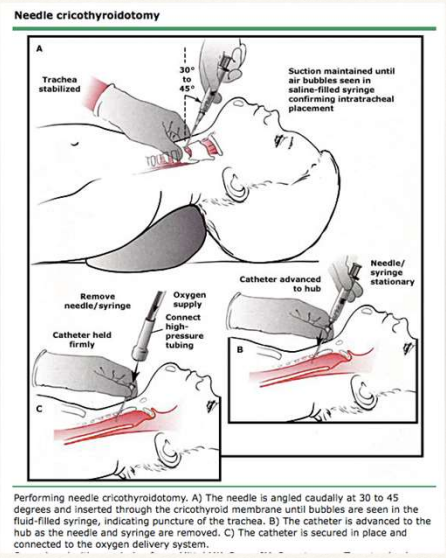

Laryngeal "handshake"
CICO RESCUE
Human Factors:
Expectation vs. reality
Thyroid cartilage
Cricothyroid membrane
Cricoid cartilage

62

Needle Cricothyrotomy



Performing needle cricothyroidotomy. A) The needle is angled caudally at 30 to 45 degrees and inserted through the cricothyroid membrane until bubbles are seen in the fluid-filled syringe, indicating puncture of the trachea. B) The catheter is advanced to the hub as the needle and syringe are removed. C) The catheter is secured in place and connected to the oxygen delivery system.

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Retrograde Intubation

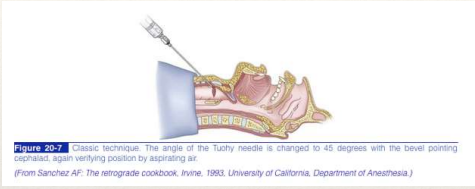
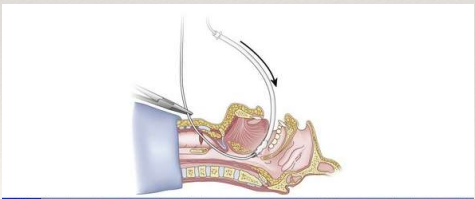


Figure 20-7 Classic technique. The angle of the Tuohy needle is changed to 45 degrees with the bevel pointing cephalad, again verifying position by aspirating air.

(From Sanchez AF: The retrograde cookbook, Irvine, 1993, University of California, Department of Anesthesia.)



20-11 Classic technique. Thread a well-lubricated endotracheal tube (ETT) over the epidural catheter. Main ate amount of tension on the epidural catheter *(arrow)* as you advance the ETT forward; you will feel a small cl T travels through the vocal cords.

Sanchez AF: The retrograde cookbook, Irvine, 1993, University of California, Department of Anesthesia.)

Maintain ***oxygenation*** during procedure

UAW obstruction is absolute contraindication

CICO rescue limited by ***time***

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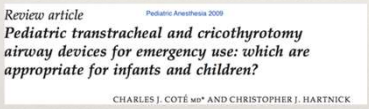
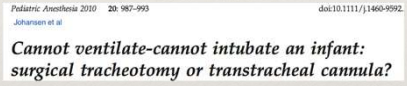
Low success rate as airway rescue

Ravussin 1987, 1994:
Elective jet ventilation


Review article
Pediatric transtracheal and cricothyrotomy airway devices for emergency use: which are appropriate for infants and children?
CHARLES J. CÔTÉ MD* AND CHRISTOPHER J. HARTNICK


ORIGINAL ARTICLE
2012
The 'Can't Intubate Can't Oxygenate' scenario in Pediatric Anesthesia: a comparison of different devices for needle cricothyroidotomy


Pediatric Anesthesia 2010 20: 987–993
Johansen et al
Cannot ventilate-cannot intubate an infant: surgical tracheotomy or transtracheal cannula?

- 60% failure rate for cannula cricothyrotomy in adults
- ***No success in children***

65

No consensus on best FONA technique in children

SCALPEL TECHNIQUE

66

Low success rate for rescue invasive access in children

Scalpel/finger/bougie technique?

Emergent ***cricothyrotomy*** may not be **anatomically appropriate** in small (prepubescent) children

Surgical tracheostomy = highest rate of success but greatest level of training required

67

Investment Saves Lives

- Berkhow et al**. Need for Emergency Surgical Airway Reduced by a Comprehensive Difficult Airway Program**. *Anesthesia & Analgesi*a Vol. 109, No. 6, December 2009
- Mark et al. **Difficult Airway Response Team: A Novel Quality Improvement Program for Managing Hospital-Wide Airway Emergencies.** *Anesthesia & Analgesia* July 2015 Volume 121 Number 1
- Atkins et al. **An Airway Rapid Response System: Implementation and Utilization in a Large Academic Trauma Center.** *The Joint Commission Journal on Quality and Patient Safety* 2017; 43:653–660
- Sterrett et al. **Critical Airway Team: A Retrospective Study of an Airway Response System in a Pediatric Hospital**. *Otolaryngology–Head and Neck Surgery* 2017, Vol. 157(6) 1060–1067
- Long et al. **Implementation of NAP4 emergency airway management recommendations in a quaternary-level pediatric hospital.** *Pediatric Anesthesia* 27 (2017) 451–460

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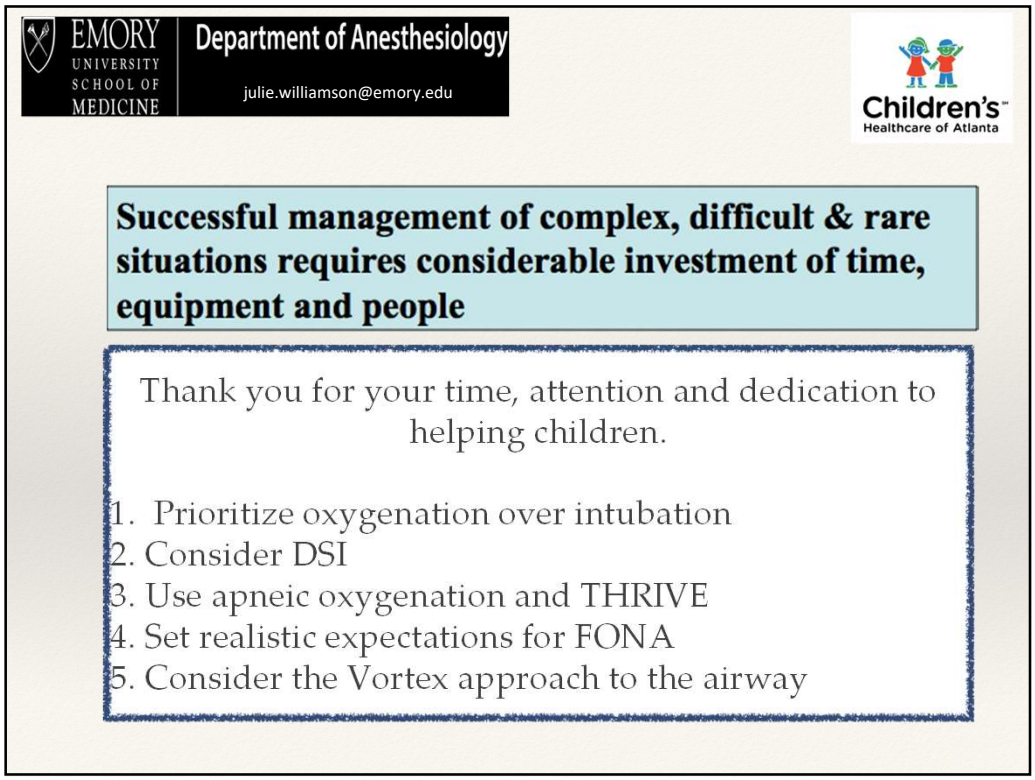
EMORY UNIVERSITY SCHOOL OF MEDICINE
Department of Anesthesiology
julie.williamson@emory.edu
Children's Healthcare of Atlanta
Successful management of complex, difficult & rare situations requires considerable investment of time, equipment and people
Thank you for your time, attention and dedication to helping children.
1. Prioritize oxygenation over intubation
2. Consider DSI
3. Use apneic oxygenation and THRIVE
4. Set realistic expectations for FONA
5. Consider the Vortex approach to the airway

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