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Baylor College of Medicine

Laryngeal Ultrasound: What can we see?

Julina Ongkasuwan, MD, FAAP, FACS

Adult and Pediatric Laryngology


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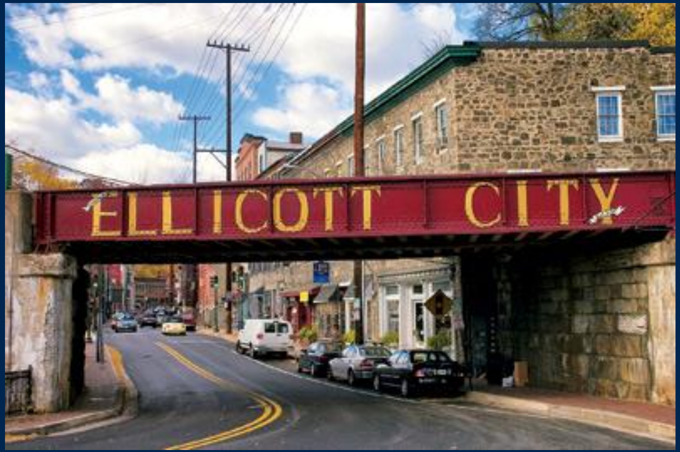
HOSPITAL CENTER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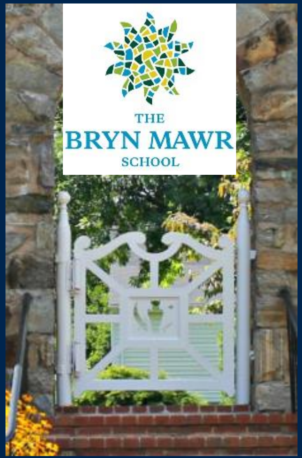
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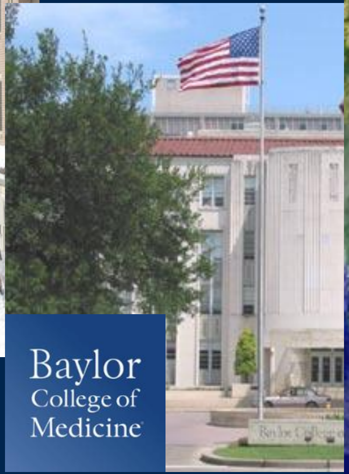
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Outline

Historical Perspective

Principles of Ultrasound

Vocal Fold Mobility in Infants

Laryngeal Lesions

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Historical Perspective

- 1880 Pizoelectric effect
- WWI to WWII SONAR (**SO**und **N**avigation **A**nd **R**anging)
- 1935 RADAR (**RA**dio **D**etection **A**nd **R**anging)
- 1930's Medical therapy and ablation
- 1940 Diagnostic tool 1.2MHz
- 1949 A-mode ultrasound
- 1953 B-mode ultrasound
- 1953 Echocardiogram
- 1960's OB applications
- 1970 The American Society of Ultrasound Technical Specialists aka Society of Diagnostic Medical Sonography

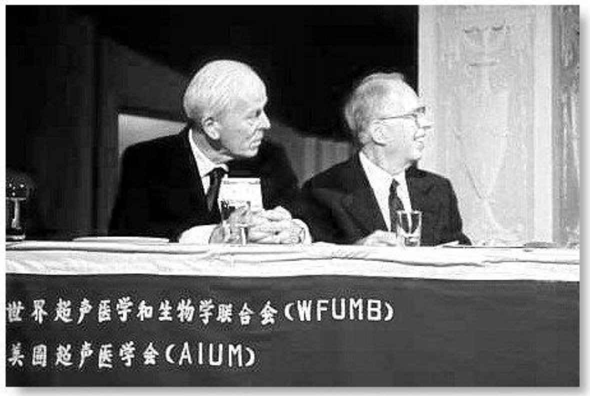

Pierre Curie
1859 - 1906


Karl Theodore Dussik


George D. Ludwig


John Wild c. 1953


John M Reid c.1970s



Drs. Inge Edler and Carl Hellmuth Hertz at the History of Ultrasound Symposium in Washington D.C. in October 1988


Professor Ian Donald
1910 - 1987

Newman PG, Rozycki GS. The history of ultrasound. Surg Clin North Am. 1998 Apr;78(2):179-95.

Surgeon performed ultrasound

REVIEW ARTICLE

ANNALS OF SURGERY
Vol. 228, No. 1, 16–28

Surgeon-Performed Ultrasound

Its Use in Clinical Practice

Grace S. Rozycki, MD, FACS

MANAGEMENT OF NONDIAGNOSTIC THYROID FINE-NEEDLE ASPIRATION BIOPSY: SURVEY OF ENDOCRINOLOGISTS

Israel B. Orija, MD, MRCP, Amir H. Hamrahian, MD, and S. Sethu K. Reddy, MD, FRCPC, FACP, FACE, MBA

Ultrasonography for the endocrine surgeon: A valuable clinical tool that enhances diagnostic and therapeutic outcomes

Mira Milas, MD,[a] **Antonia Stephen, MD,**[b] **Eren Berber, MD,**[a] **Kristin Wagner, MD,**[c] **Judiann Miskulin, MD,**[a] *and* **Allan Siperstein, MD,**[a] *Cleveland, Ohio, Boston, Mass, and Charlotte, NC*

The Laryngoscope
Lippincott Williams & Wilkins, Inc.

Parathyroid Adenoma Localization: Surgeon-Performed Ultrasound Versus Sestamibi

David L. Steward, MD; Gregory P. Danielson, MD; Chad E. Afman, MD; Jeffrey A. Welge, PhD

The Laryngoscope

Evaluation of the American College of Surgeons Thyroid and Parathyroid Ultrasound Course: Results of a Web-Based Survey

Giriraj K. Sharma, MD, MS; Robert A. Sofferman, MD; William B. Armstrong, MD

AMERICAN ACADEMY OF OTOLARYNGOLOGY–HEAD AND NECK SURGERY

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Practice Management

Resources

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- Coding Corner
- Clinical Indicators
- Position Statements
- Clinical Consensus Statements
- Socioeconomic Data
- Media and Public Outreach

Quality Improvement

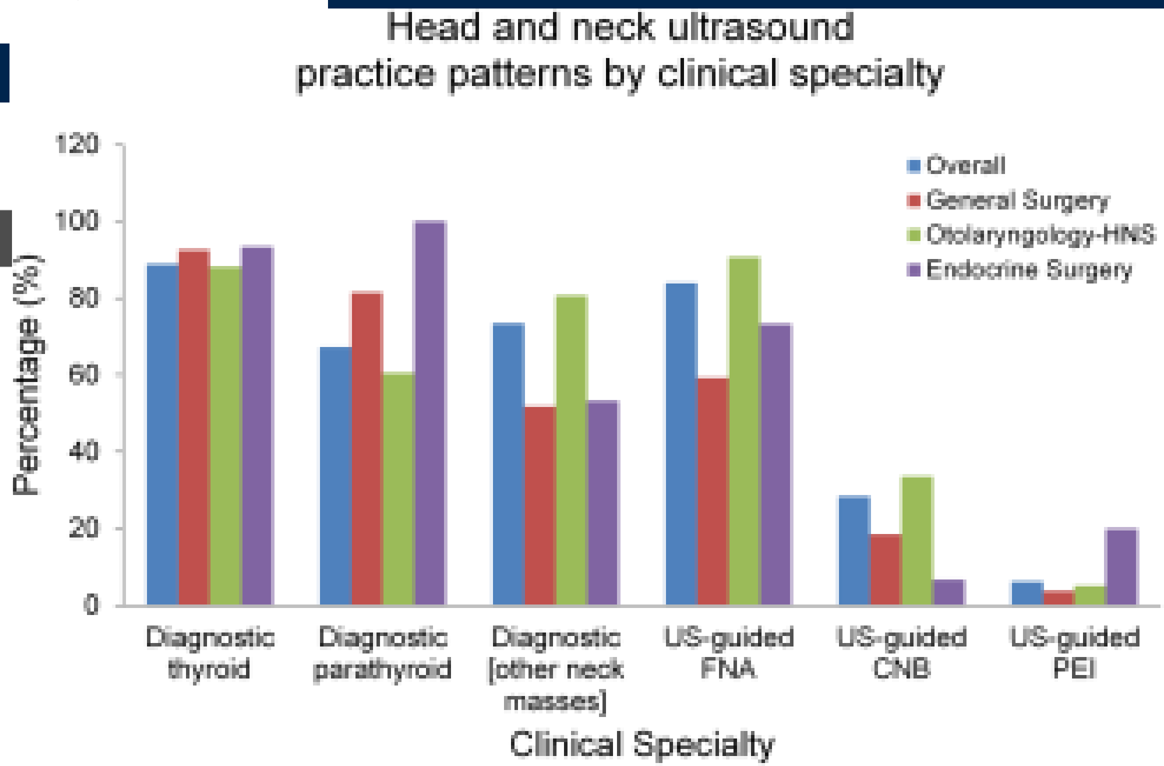
Clinical Data Registry

Position Statement: Surgeon Performed Neck Ultrasound

Position Statement, Reimbursement

The AAO-HNS supports surgeons performing ultrasound of the head and neck, including ultrasound-guided fine needle aspiration for diagnostic purposes. Neck ultrasound is not an extension of the physical exam, but rather a discrete diagnostic procedure.

Drafted 11/11/2015
Submitted for Review 11/30/2015
Adopted 3/20/2016



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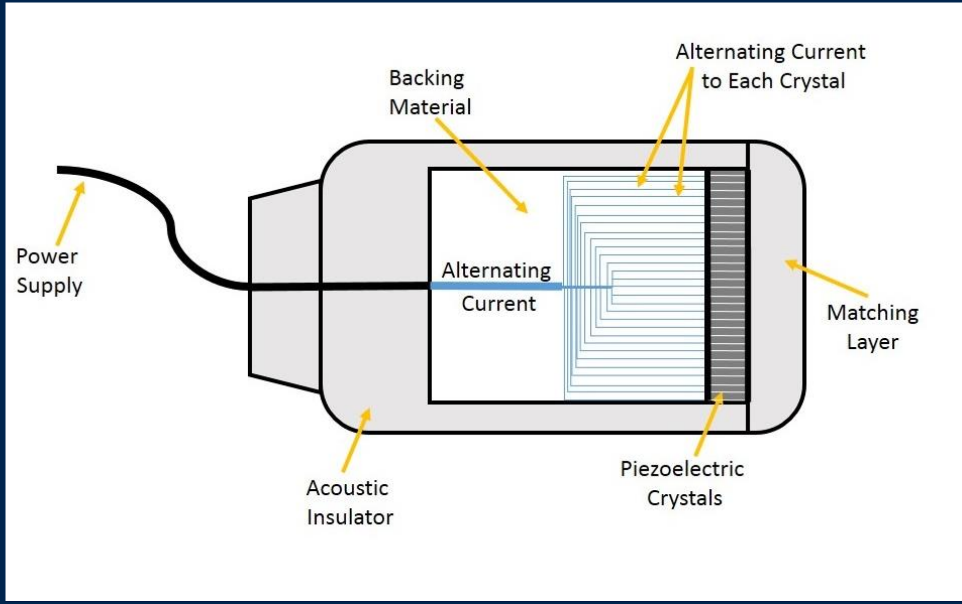
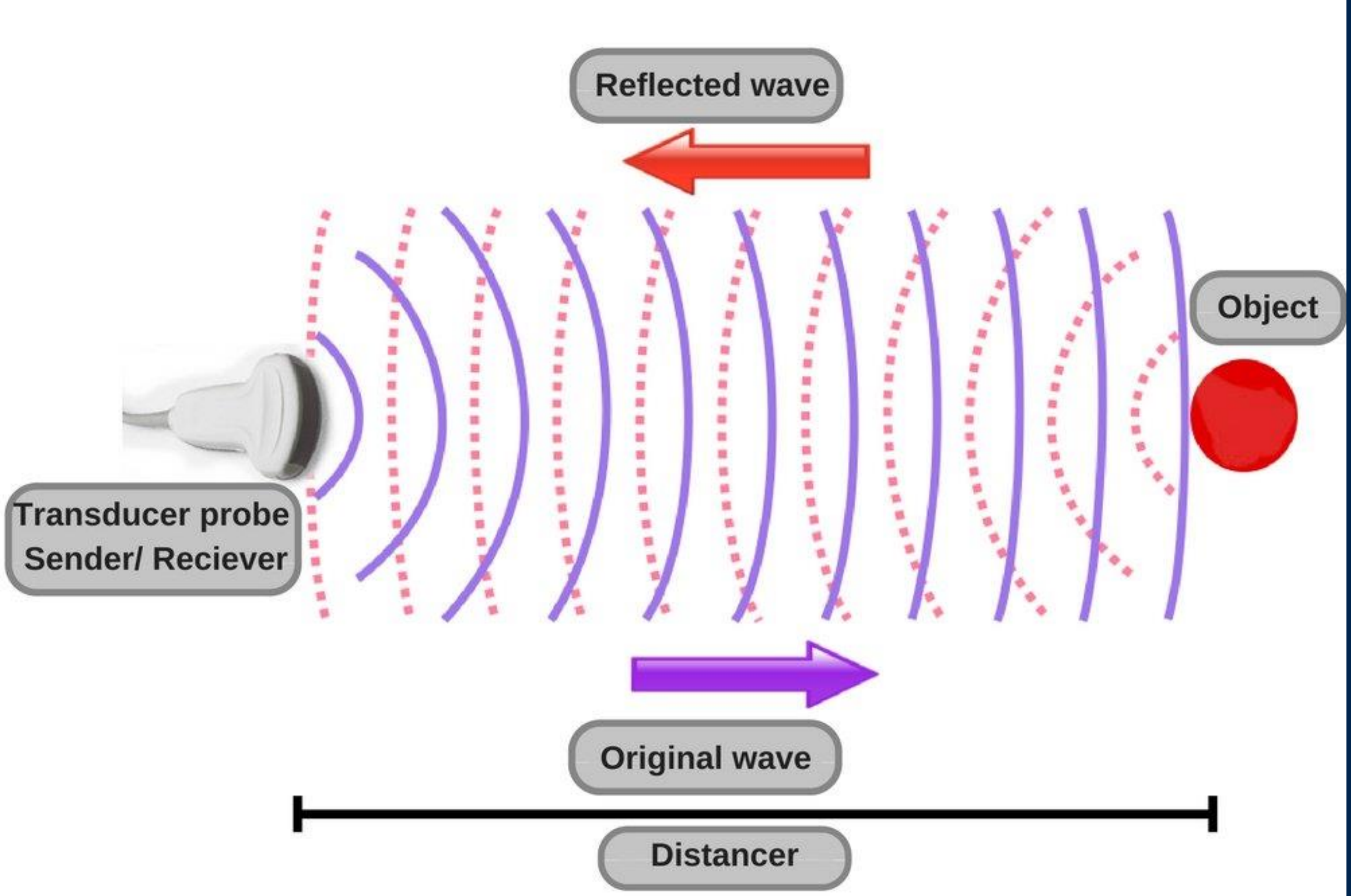
Principles of Ultrasound

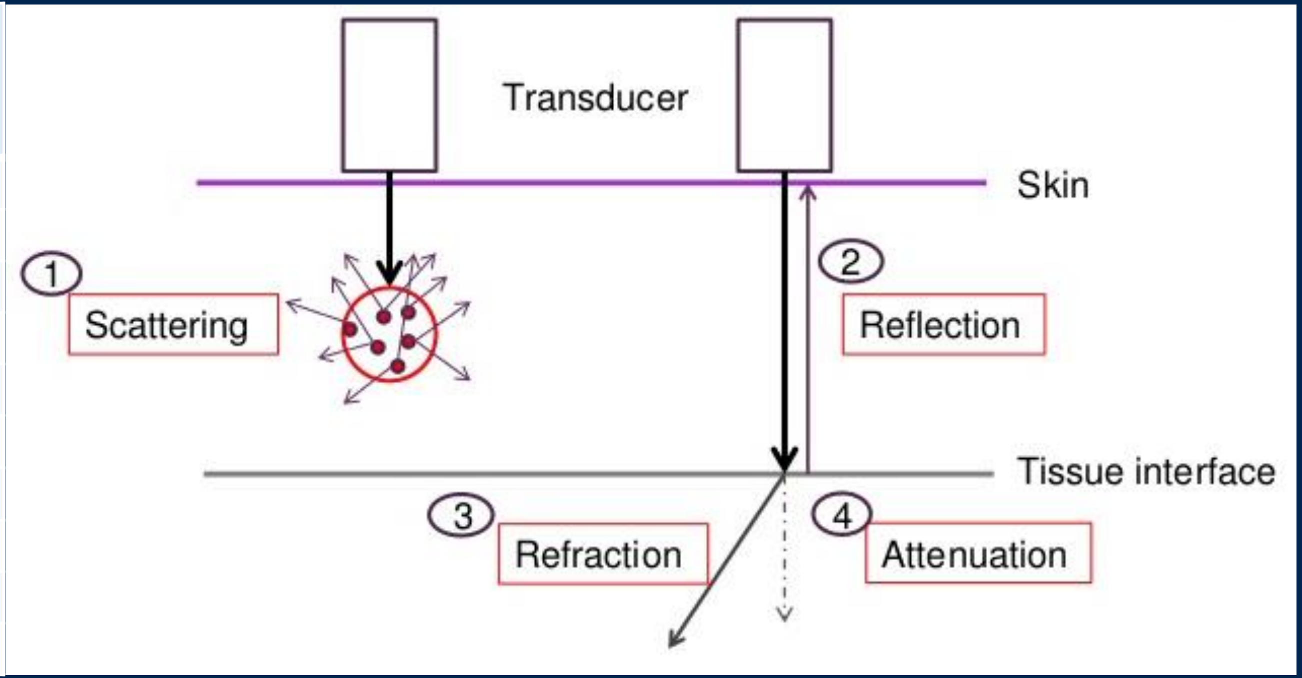




http://www.vaultrasound.com/educational-resources/ultrasound-physics/transducers/
https://www.scienceabc.com/innovation/how-ultrasound-scanning-sonography-3d-sonogram-work-pregnancy-due-date.html

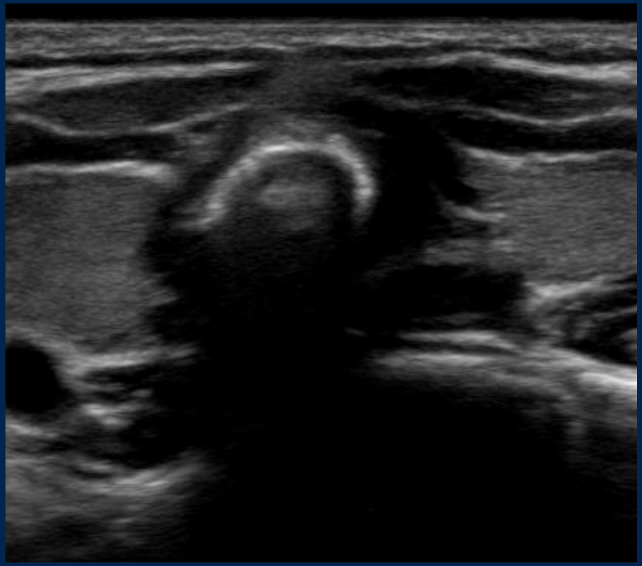
Principles of Ultrasound

Medium	Velocity (m/s)	Acoustic Impedance (10^6 Rayls)	Attenuation Coefficient (dB/cm at 1MHz)
Air	331	0.0004	1.64
Water			0.002
Blood			0.18
Fat	1450	1.34	0.63
Brain	1541		0.6
Liver	1549	1.65	0.5-0.94
Kidney	1561	1.63	1.0
Muscle	1585	1.71	1.3-3.3
Soft Tissue	1540		0.54
Bone	3000-5000	7.8	5



Artifacts

- Air Artifact
- Acoustic shadowing
- Acoustic enhancement
- Reverberation
- Refraction
- Comet-tail
- Mirror-image
- Ghosting
- Beam-width
- Ring-down
- Speed displacement



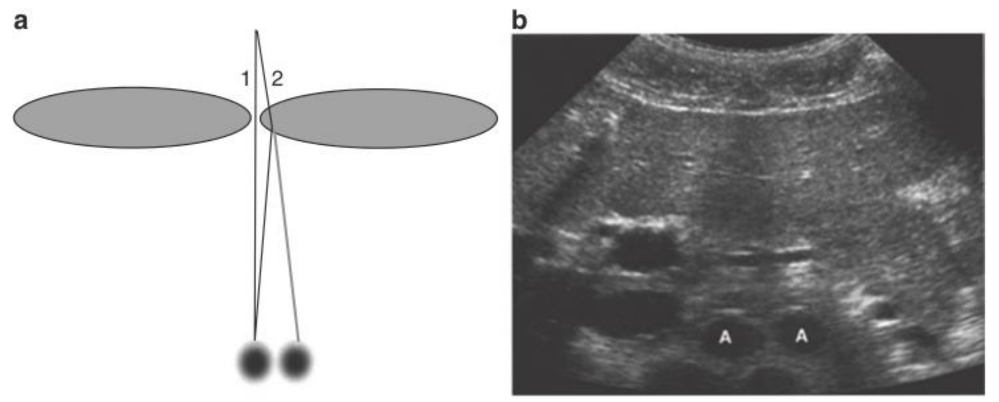


Figure 2.5. Refraction artifact. Diagram (**a**) shows how sound beam refraction results in duplication artifact. (**b**) is a transverse midline view of the upper abdomen showing duplication of the aorta (A) secondary to rectus muscle refraction. This figure was published in ref.[8] Copyright Elsevier (2004).

Outline

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Principles of Ultrasound

Vocal Fold Mobility in Infants

Laryngeal Lesions

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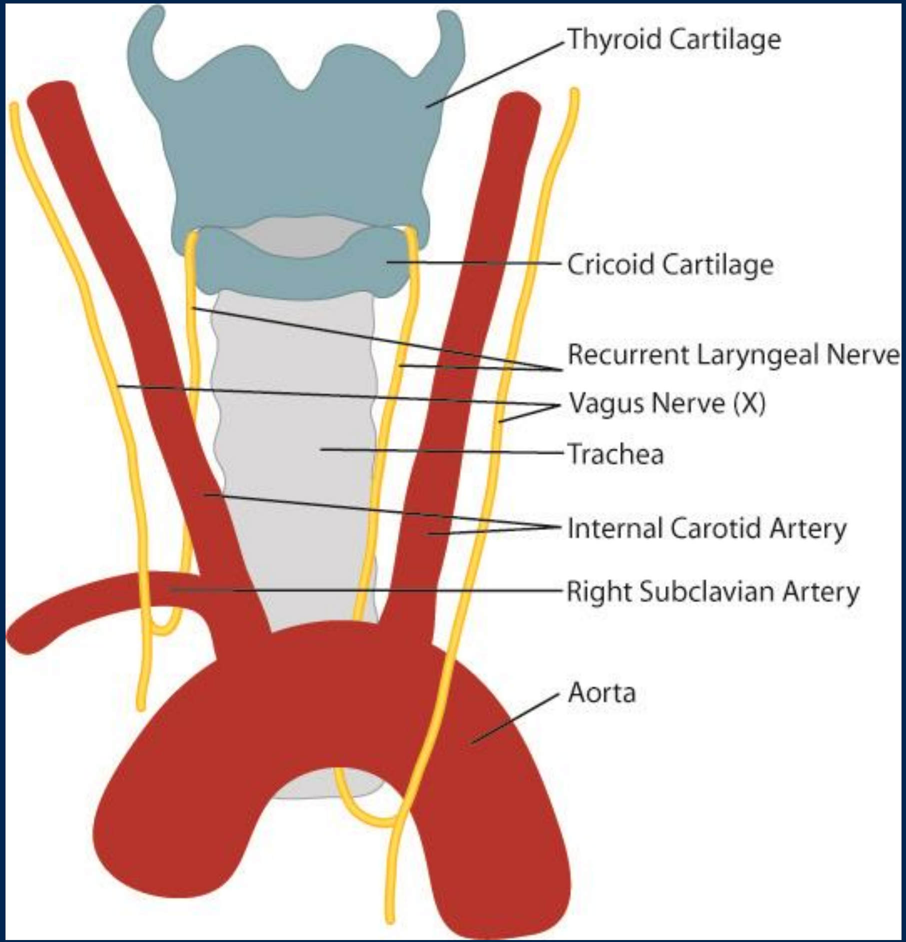
Vocal fold movement impairment (VFMI)

- Neuronal injury
  - 8.8-58.7% after infant aortic arch surgery
    - TCH – 27%
  - 12-22% after adult aortic surgery
    - BCM - 32% extent I/II aortic repair (unpublished data)
  - Thyroidectomy 1-2%
- Mechanical fixation
  - Posterior glottic stenosis, Cricoarytenoid joint fixation
- Morbidity of VFMI
  - Stridor (infants)
  - Aspiration
  - Impaired pulmonary toilet
  - Increased length of stay



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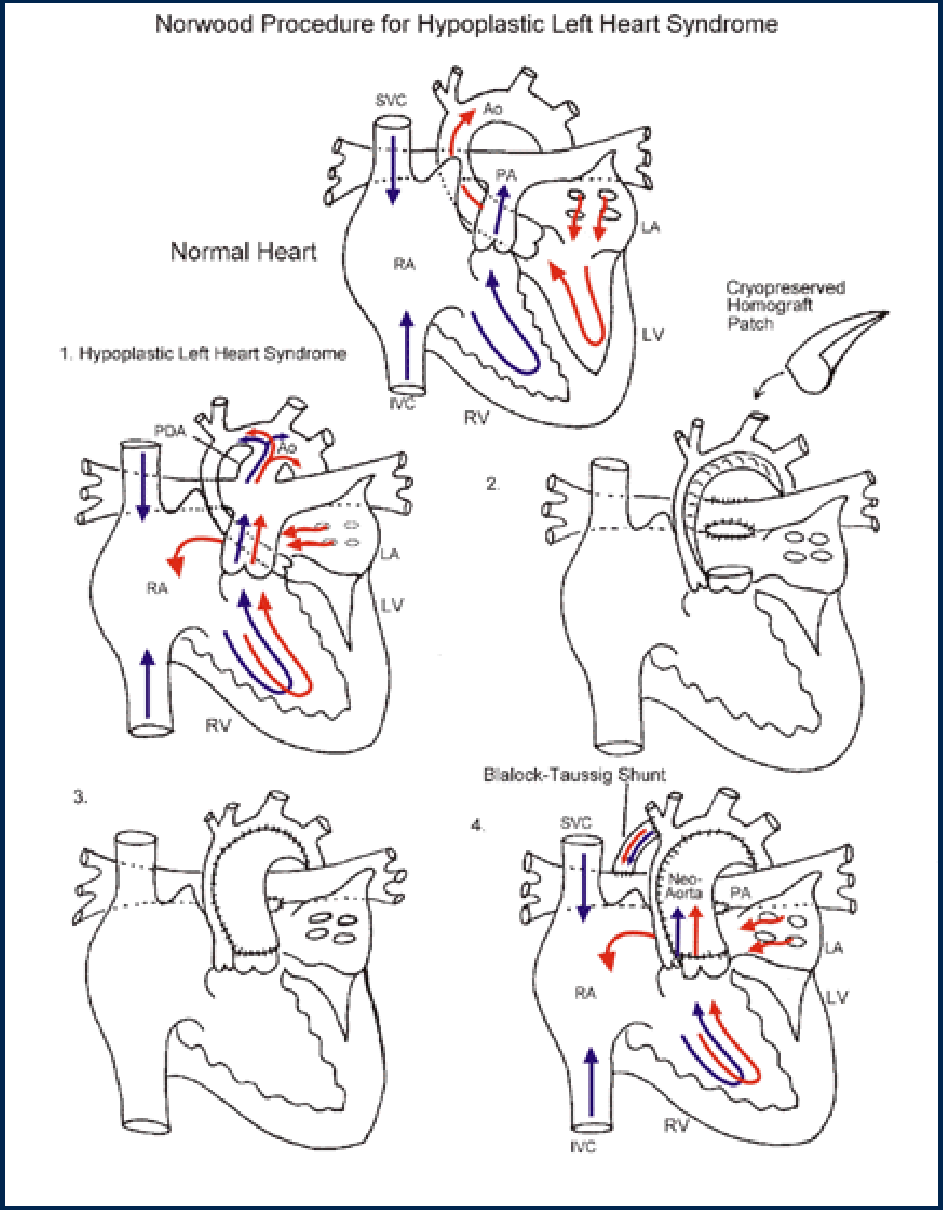
Teixido MT, Leonetti JP *Oto HNS*. Feb 1990;102(2):140-144.
Ohta N, et al. *Journal of vascular surgery*. Apr 2006;43(4):721-728.
Itagaki T, et al. *The Annals of thoracic surgery*. Jun 2007;83(6):2147-2152.

Background

- Morbidity of FNL
  - Epistaxis 1%
  - Bradycardia 2%
  - Physiologic shifts
    - BP, pulse, O_2 sat

- Congenital heart disease
  - De Oliveira: Early circulatory collapse in 24% of children after Norwood
    - 64% mortality rate for those patients



Friedman EM. *Ann Otol Rhinol Laryngol* 1997; 106:199-209.
Grundfast KM, Harley E. *Otolaryngol Clin North Am* 1989; 22:569-597.
Fan LL, Flynn JW. *Laryngoscope* 1981; 91:451-456.
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Ongkasuwan J et al. *Laryngoscope*; 122:1331-1334.
Paul BC et al. *Ann Otol Rhinol Laryngol* 2012; 121:708-713.
De Oliveira NC et al. *Circulation* 2004; 110:II133-138.
Berger RM et al. *Lancet* 2012; 379:537-546.
Ongkasuwan J, et al. *Laryngoscope* 2016.

Background

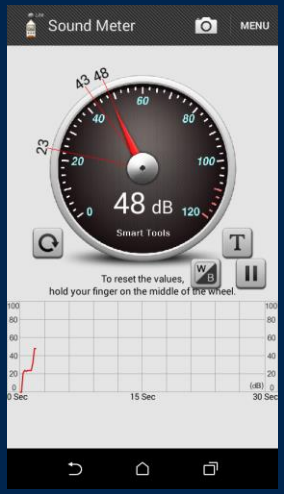
- Limitations of Flexible Nasolaryngoscopy (FNL)
  - Extensive movement
  - Excess secretions
  - Retroflexed or omega epiglottis
  - Floppy arytenoids

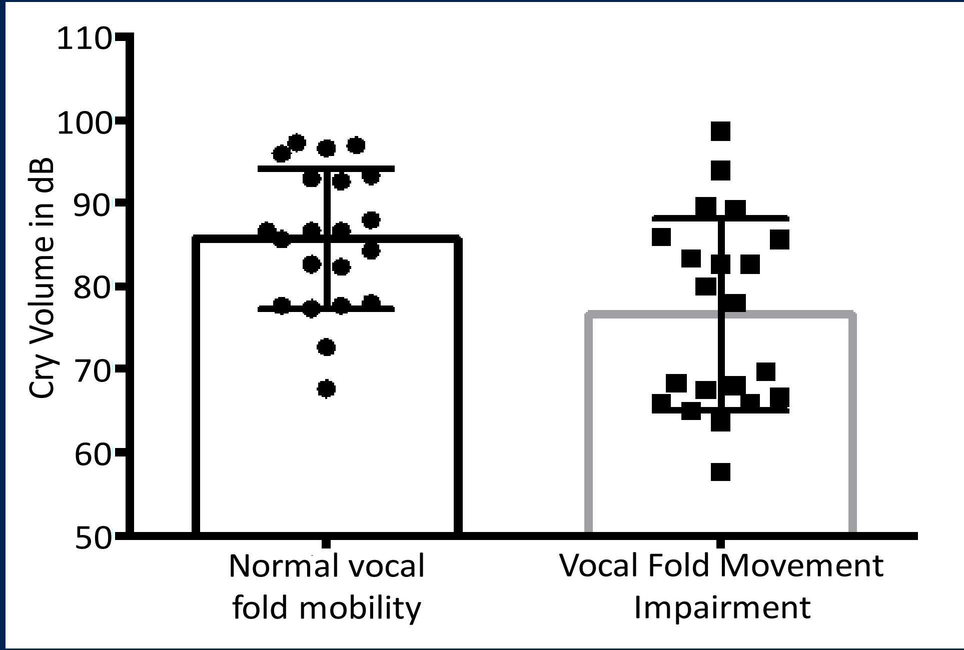
- Intrarater reliability vocal fold mobility in infants
  - Normal vs. VFMI κ=0.6667
  - paresis vs. paralysis κ= 0.4937
- Intra-rater reliability ranged from moderate to perfect agreement (κ = 0.4783-1)

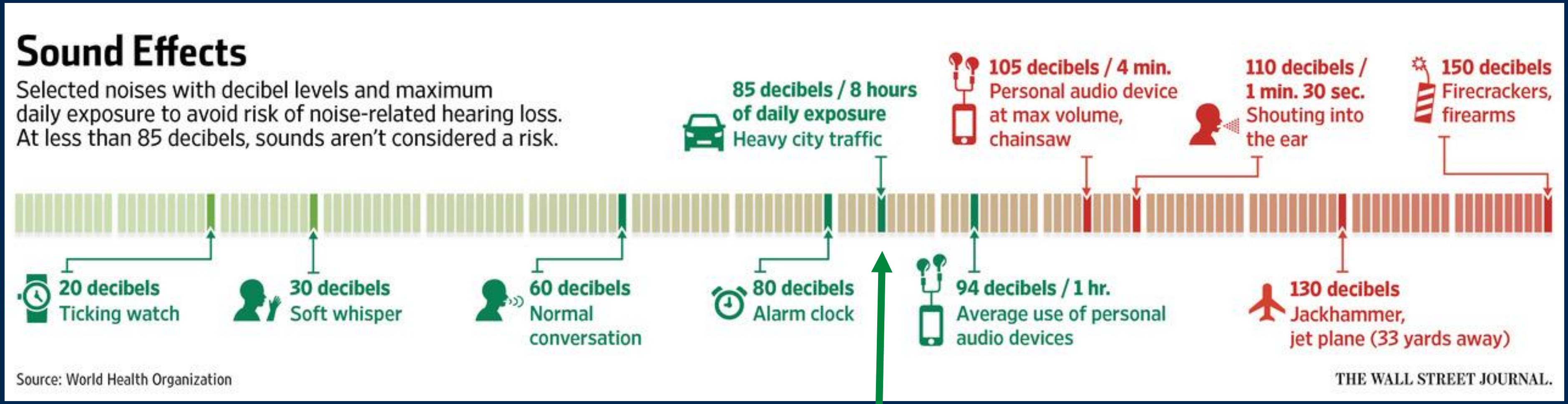
Cry volume in vocal fold paralysis

	Normal	VFMI	p	Correlation to dB
Gender (female)	13	7	0.066	0.219
Age at scope (days)	30	33	0.219	0.406
Duration intubation (days)	4.43	5.60	0.094	0.796
Volume (dB)	85.72	76.60	0.0058	

- 42 NICU and CVICU post-extubation infants
  - 21 with and 21 without VFMI
- Smartphone app
  - Sound Meter (ver 1.6), Smart Tools Co.)
  - 12 inches from patient's head
  - Peak measurements x3 (in dB) while patient crying



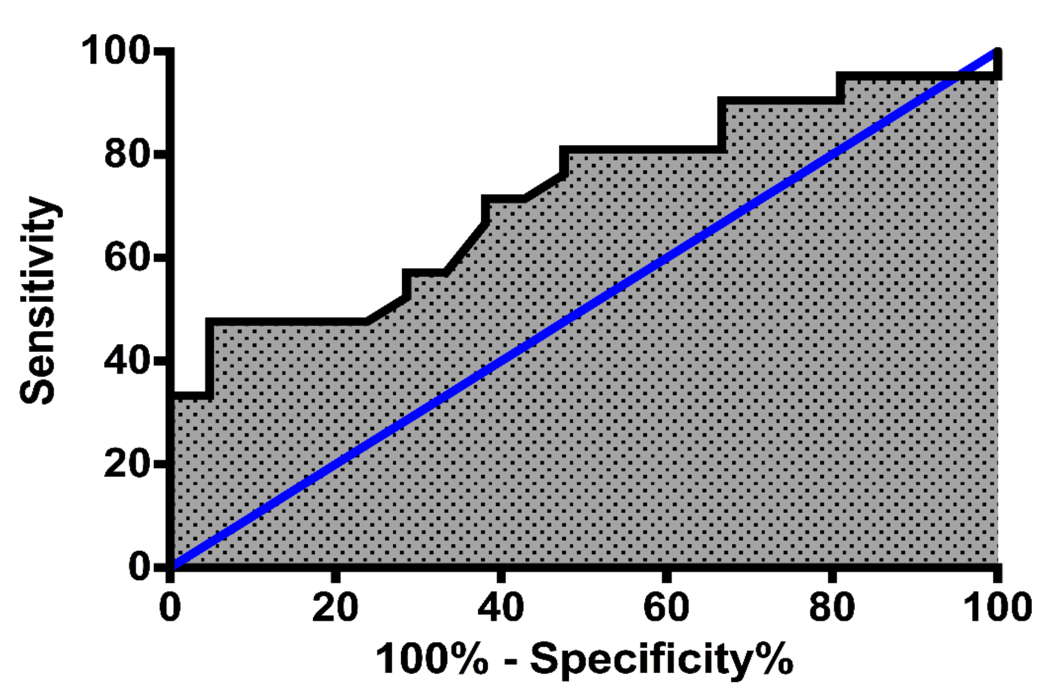




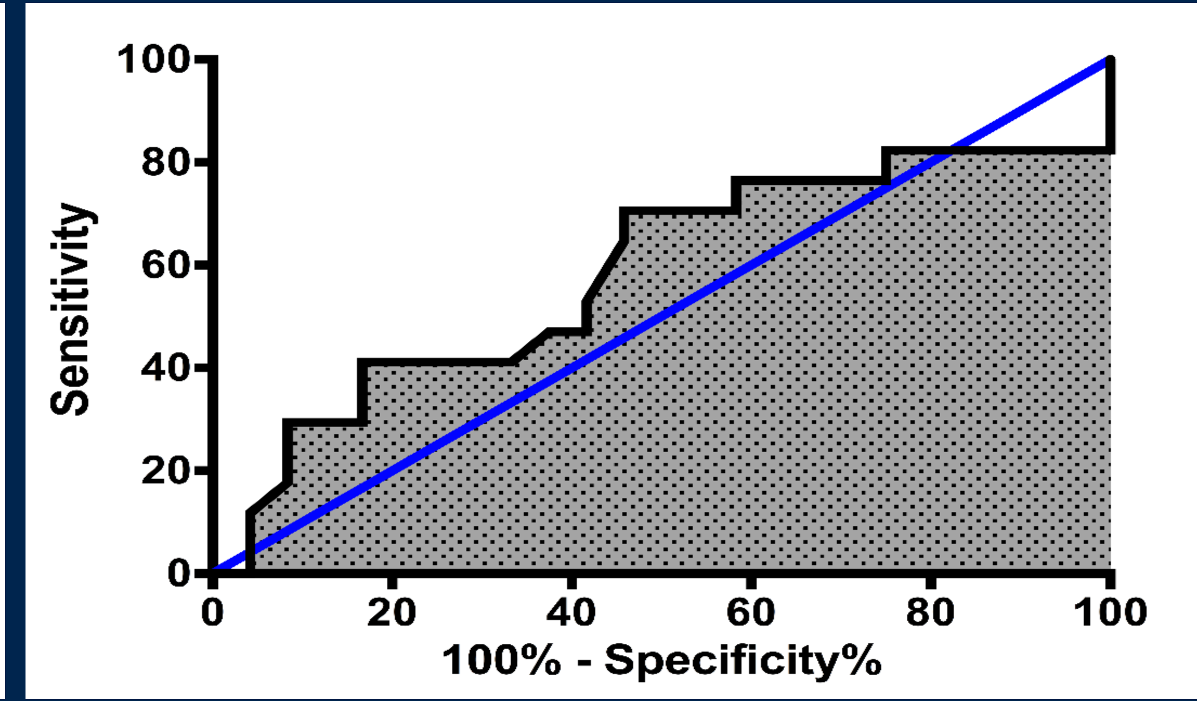
Infant with normal vocal fold mobility after extubation

Results

- Receiver Operating Characteristic Curve



Cry volume vs. VFMI
Area under the ROC = 0.721



Cry volume vs. Aspiration
Area under the ROC curve = 0.583

Results

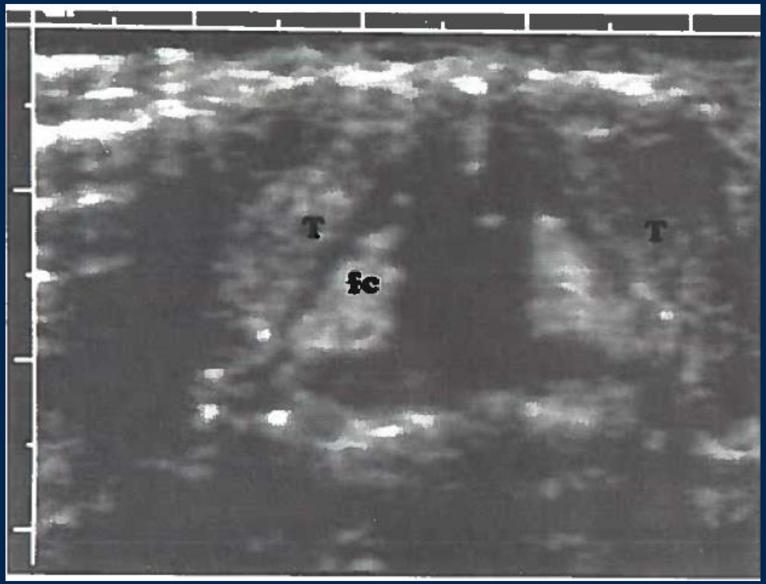
Mean Cry Volume (dB)	Vocal Fold Movement Impairment		Aspiration	
	Sensitivity (%)	Specificity (%)	Sensitivity (%)	Specifcity (%)
60	4.76	100	0	95.83
65	14.28	100	11.76	95.83
70	47.61	95.23	41.18	83.33
75	47.61	90.48	41.18	79.17
80	57.14	71.42	47.06	58.33
85	71.42	57.14	70.59	50
90	90.47	33.33	82.35	25
95	95.24	19.05	82.35	8.33

History of Laryngeal Ultrasound

- 1987
  - 5MHz probe

Sonographic Anatomy of the Larynx, With Particular Reference to the Vocal Cords*

B. Nagesh Raghavendra, MD, Steven C. Horii, MD, Deborah L. Reede, MD, William M. Rumancik, MD, Mark Persky, MD, R. Thomas Bergeron, MD



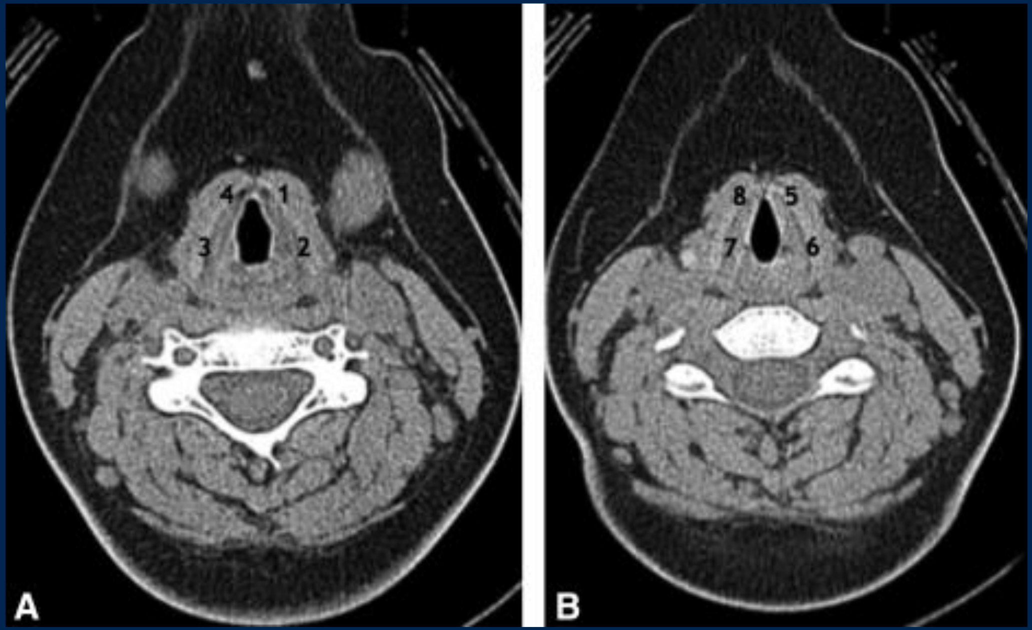
- Adults: Laryngeal Ultrasound (LUS) vs. FNL
  - Sensitivities 67% - 93.3%
  - Specificities from 89% - 97.8%

  - Hu et al. 2010 (6-13MHz)
    - visualization of endolarynx
      - > age 60 years 38.1%
      - <18 years 100%

Wong KP, et al.. *Surgery*; 154:1158-1164; discussion 1164-1155.
Wong KP, et al. *Annals of surgical oncology* 2015; 22:1774-1780.
Amis RJ, et al. *Middle East J Anesthesiol*; 21:493-498.
Sidhu S, et al. *ANZ J Surg* 2001; 71:737-739.
Wong KP, et.al. Surgery 2014; 156:1590-1596; discussion 1596.
Hu et. al. J Ultrasound Med; 29:1023-1030.

Calcification

- Based on CT
  - Thyroid cartilage calcifies by 1.5% to 4% per year.
  - Posterolateral to anteromedial direction
  - mean patient age thyroid cartilage denser than soft tissue (300 HU)
    - 40 yrs (standard deviation 7.71)
- Frequency?
  - 12-5 MHz vs 9-3 MHz
- Other factors?
  - Gender
  - Race
  - BMI



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Wenaas AE, Tran B, Ongkasuwan J. The progression of thyroid cartilage calcification as it relates to the utilization of laryngeal ultrasound. *Laryngoscope*. 2016 Apr;126(4):913-7
Woo JW, Park I, Choe JH, Kim JH, Kim JS. Comparison of ultrasound frequency in laryngeal ultrasound for vocal cord evaluation. *Surgery*. 2016 Nov 18.
Kandil E, Deniwar A, Noureldine SI, Hammad AY, Mohamed H, Al-Qurayshi Z, Tufano RP. Assessment of Vocal Fold Function Using Transcutaneous Laryngeal Ultrasonography and Flexible Laryngoscopy. *JAMA Otolaryngol Head Neck Surg*. 2016 Jan;142(1):74-8

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Vocal Fold Mobility in Infants

- LUS vs. FNL in Children
  - E. Friedman, 1997 (7MHz)
    - Agreement 87% to 94%
    - Weighted kappa values between 0.75 to 0.91
  - Vats et al., 2004 (7.5MHz)
    - LUS vs. FNL in infants <12 mo age
    - Concordance rate 77.7%

Ann Otol Rhinol Laryngol 106:1997

ROLE OF ULTRASOUND IN THE ASSESSMENT OF VOCAL CORD FUNCTION IN INFANTS AND CHILDREN

ELLEN M. FRIEDMAN, MD
HOUSTON, TEXAS

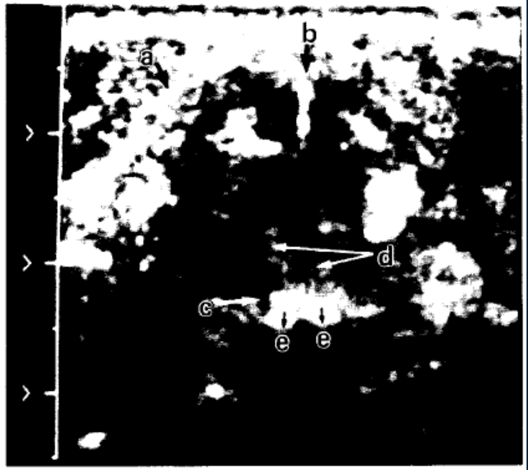

Fig 1. Ultrasound image of normal larynx. a — thyroid cartilage, b — anterior commissure, c — ventricle, d — true vocal cord, e — arytenoids.

The Journal of Laryngology & Otology
June 2004, Vol. 118, pp. 429–431

Laryngeal ultrasound to assess vocal fold paralysis in children

A. VATS, F.R.C.S., G. A. WORLEY, F.R.C.S., R. DE BRUYN, F.R.C.R., H. PORTER, M.B.B.S., D. M. ALBERT, F.R.C.S., C. M. BAILEY, F.R.C.S.

Friedman EM. Role of ultrasound in the assessment of vocal cord function in infants and children. Ann Otol Rhinol Laryngol 1997; 106:199-209.
Vats A, Worley GA, de Bruyn R, Porter H, Albert DM, Bailey CM. Laryngeal ultrasound to assess vocal fold paralysis in children. J Laryngol Otol 2004; 118:429-431.

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Purpose

- #1
  - Compare LUS to FNL in recently extubated post-surgical CVICU neonates and the ability to identify VFMI
- #2
  - Compare the physiologic impact of FNL versus LUS on blood pressure, pulse, and oxygen saturation
- #3
  - Determine LUS measurements that can determine mobility

Methods

- 46 consecutive CVICU post-op infants
  - 23 with and 23 without VFMI
- Exclusion criteria
  - FNL could not be performed or was non-diagnostic
  - Tracheotomy
  - Inability to extend the neck
- GE Logic E9 ultrasound, 51 mm length 15 MHz linear probe
- LUS reviewed by 2 pediatric radiologists blinded to mobility

Results

Variable	Asymmetry (N = 23)	Symmetry (N = 23)	P-Value
	Mean ± std	**Mean ± std**	
Age (days)	38.5 ± 59.2	97 ± 319	0.93
Days on Ventilator	4.57 ± 2.33	5.74 ± 8.08	0.3
	Count (%)	**Count (%)**	
Type of Surgery			0.073
Aortic arch repair	12 (60.0)	8 (40)	
Norwood	4 (50.0)	4 (50.0)	
PDA ligation	1 (100)	0 (0)	
other	7 (41.2)	10 (58.8)	
Gender			0.77
Female	12 (54.6)	10 (45.5)	
Male	11 (45.8)	13 (54.2)	
O2 support			0.46
No	6 (66.7)	3 (33.3)	
Yes	17 (46.0)	20 (54.0)	

Results #1

- Identification of VFMI
  - Intra-rater reliability for LUS κ=0.94
  - Inter-rater reliability LUS κ=0.78
  - LUS vs. FNL κ=0.78

		95% Confidence Interval	
Sensitivity	0.83	0.60	0.94
Specificity	0.95	0.75	1
Positive Predictive Value	0.95	0.73	1
Negative Predictive Value	0.84	0.63	0.95

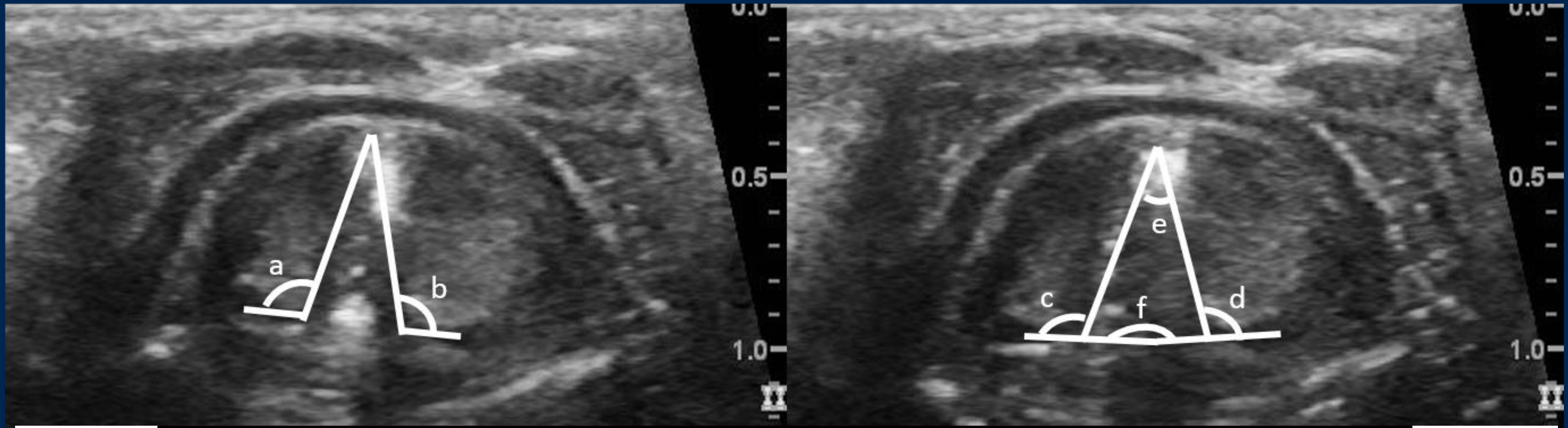
Results #2

- Physiologic Impact

	Mean (std)		
Change in	**FNL**	**LUS**	**P-Value**
SBP	6.7 (14.8)	4.8 (11.1)	0.55
DBP	8.8 (12.8)	3.6 (9.2)	**0.01**
HR	16.0 (20.1)	8.1 (12.3)	**0.004**
O_2 Sat	-3.3 (6.3)	-0.2 (4.1)	**0.001**

Results #3

- Measurements



	Asymmetry (N = 23)	Symmetry (N = 23)	
Label	**Mean ± SD**	**Mean ± SD**	**P**
glottic angle	35.7 ± 15.6	40.1 ± 13.8	.23
interarytenoid angle abd	141 ± 14.7	144 ± 12	.53
Right VF-AA angle abd	120 ± 22.8	121 ± 17.9	.72
Right VF-AA angle add	88.6 ± 24	85.8 ± 17.7	.11
Left VF-AA angle abd	94.5 ± 37.2	108 ± 36.1	**.019**
Left VF-AA angle add	95.9 ± 8.58	92.4 ± 5.57	.2

Results #3

- Measurements

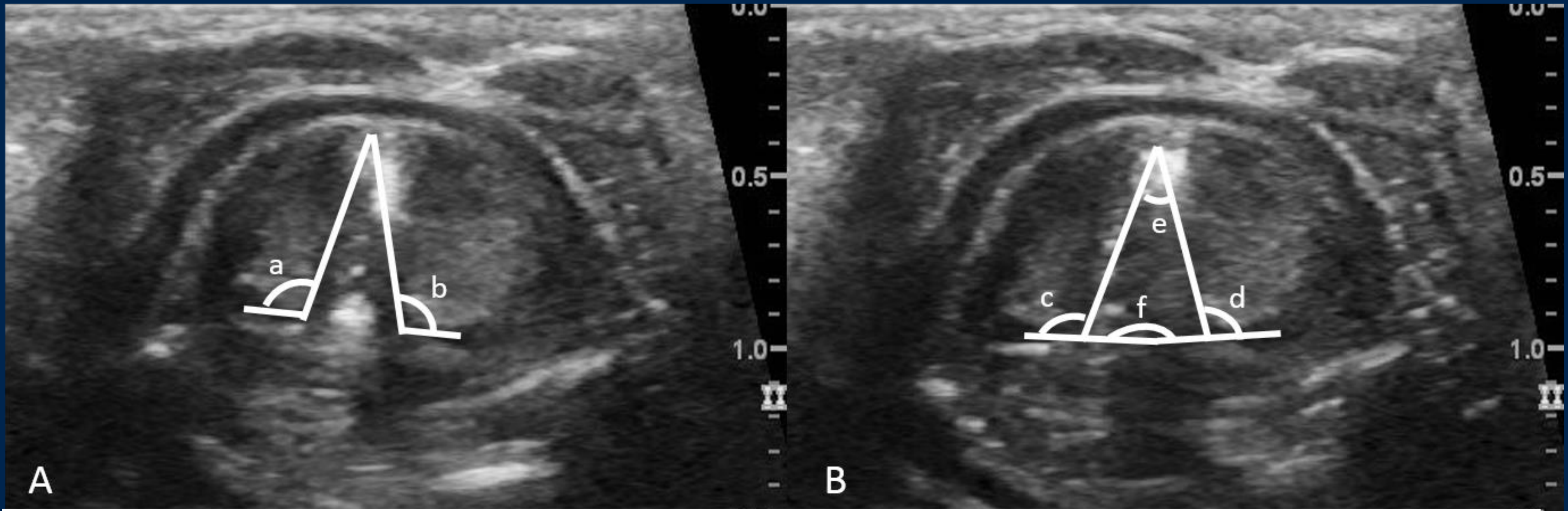


Table VII: VF-AA angle in abduction </= 120^{o} as predictor of asymmetry on FNL

		95% Confidence Interval	
Sensitivity	0.91	0.70	0.98
Specificity	0.68	0.45	0.85
Positive Predictive Value	0.75	0.55	0.89
Negative Predictive Value	0.88	0.62	0.98

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Laryngeal Lesions

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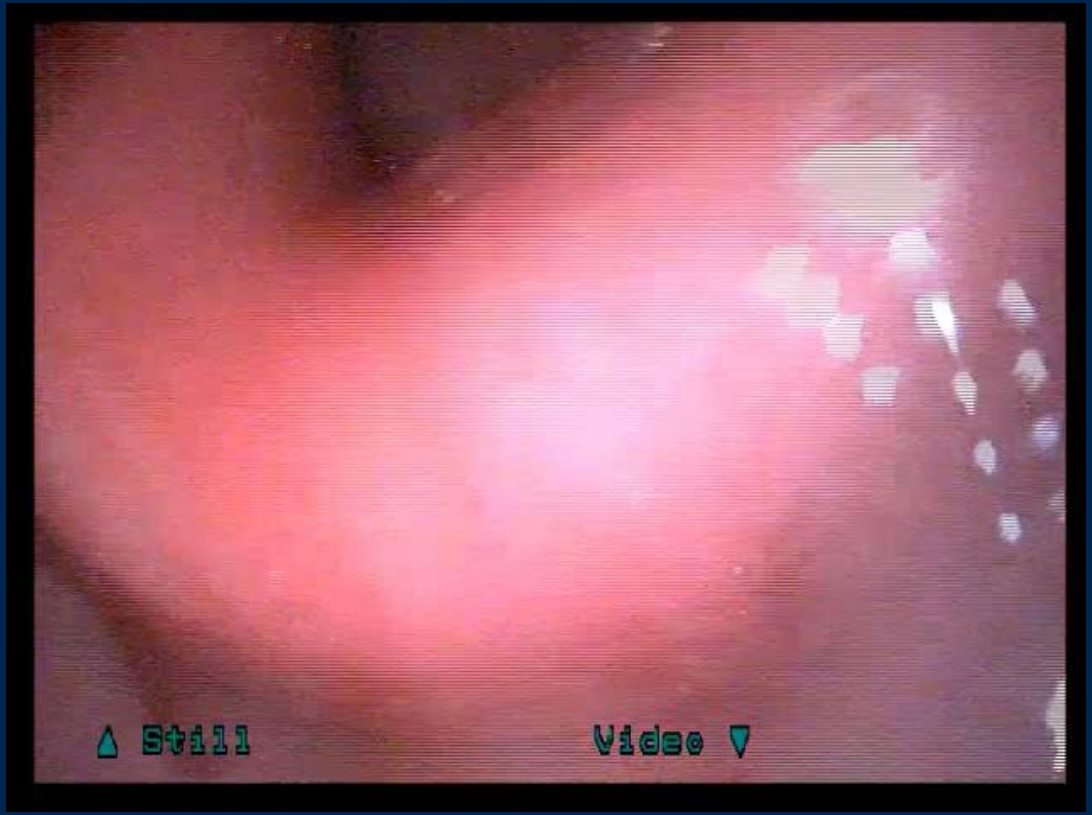
Background

- FNL
  - Causes changes in heart rate, blood pressure, and oxygen saturation
  - 25% of adults report gagging
  - 10% have dyspnea
  - For children: 2 or more adults to restrain the child

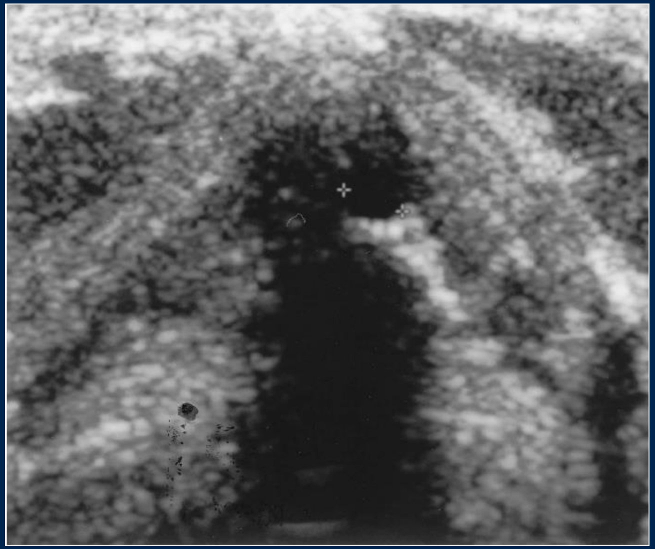
- Rigid transoral 70 degree laryngoscopy
  - 18% 3 year olds
  - 66% of 6 and up

Ongkasuwan J, Yung KC, Courey MS. The physiologic impact of transnasal flexible endoscopy. Laryngoscope; 122:1331-1334.
Ongkasuwan J, Ocampo E, Tran B. Laryngeal ultrasound and vocal fold movement in the pediatric cardiovascular intensive care unit. Laryngoscope 2016.
Paul BC, Rafii B, Achlatis S, Amin MR, Branski RC. Morbidity and patient perception of flexible laryngoscopy. Ann Otol Rhinol Laryngol 2012; 121:708-713.


Still
Video

Laryngeal Ultrasound and Vocal Fold Lesions

- Adults
  - Rubin et al. (5-10 MHz probes, 29 patients)
  - Sirikci et al. (5MHz probe, 14 patients)
    - Lesions > 2mm in size that project into the lumen



- Pediatric
  - Bisetti et al. (7.5-12MHz probe)
    - 16 children (mean age 7.5 years) cysts, nodules could be seen
  - Bryson et al. (probe type not specified)
    - 8 children (mean age 10.25 years) RRP
      - discrete, hyperechoic lesions

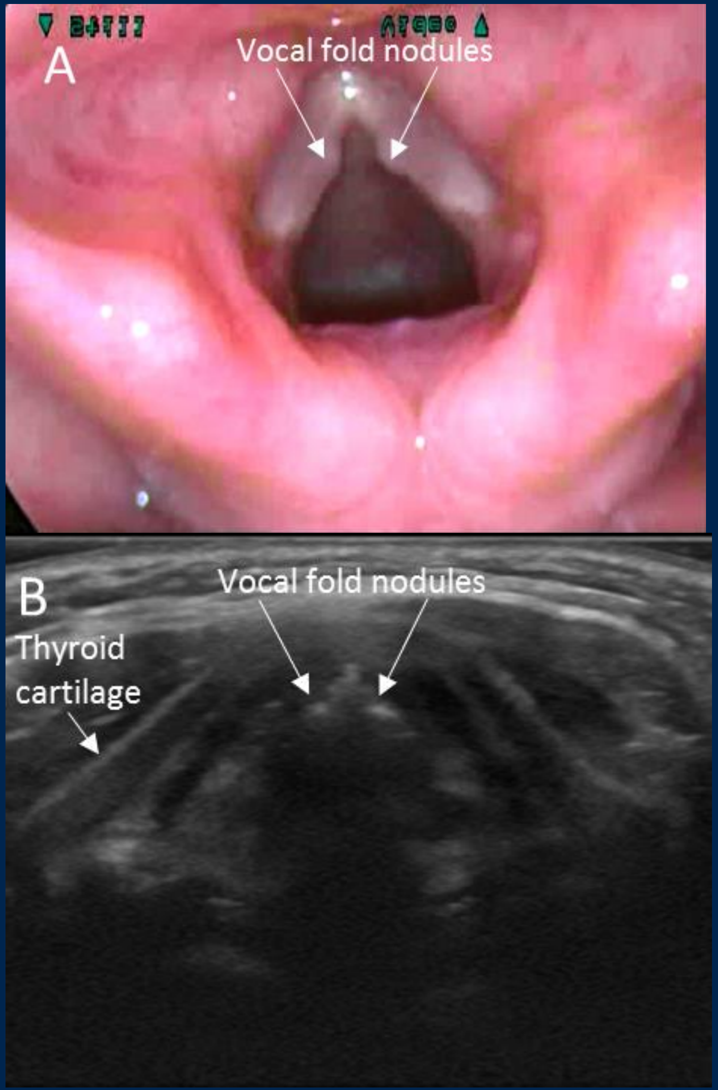
Sirikci A, Karatas E, Durucu C et al. Noninvasive assessment of benign lesions of vocal folds by means of ultrasonography. Ann Otol Rhinol Laryngol 2007; 116:827-831.
Rubin JS, Lee S, McGuinness J, Hore I, Hill D, Berger L. The potential role of ultrasound in differentiating solid and cystic swellings of the true vocal fold. J Voice 2004; 18:231-235.

Purpose

- #1
  - Compare LUS to FNL to identify vocal fold nodules vs. normal
- #2
  - Determine if ultrasound can be used to reliably measure nodule size and depth

Methods

- 46 patients
  - 23 with vocal fold nodules on laryngoscopy
  - 23 normals
- Exclusion criteria
  - Laryngoscopy could not be performed or was non-diagnostic
  - Tracheotomy
  - Inability to extend the neck
- GE Logic E9 ultrasound, 51 mm length 15 MHz linear probe
- LUS reviewed by 2 pediatric radiologists blinded to nodule status



Results

- #1
  - Compare LUS to FNL to identify vocal fold nodules
- #2
  - Determine if ultrasound can be used to reliably measure nodule size and depth

TABLE II.
Sensitivity and Specificity.

	Sensitivity (95% CI)	Specificity (95% CI)
LUS vs. strobe*	100 (85-100)	87 (66-97)
Radiologist 1	100 (82-100)	74 (51-89)
Radiologist 2	96 (76-99)	100 (82-100)

TABLE III.
Consistency of Vocal Fold Nodules Measurements on Laryngeal Ultrasound.

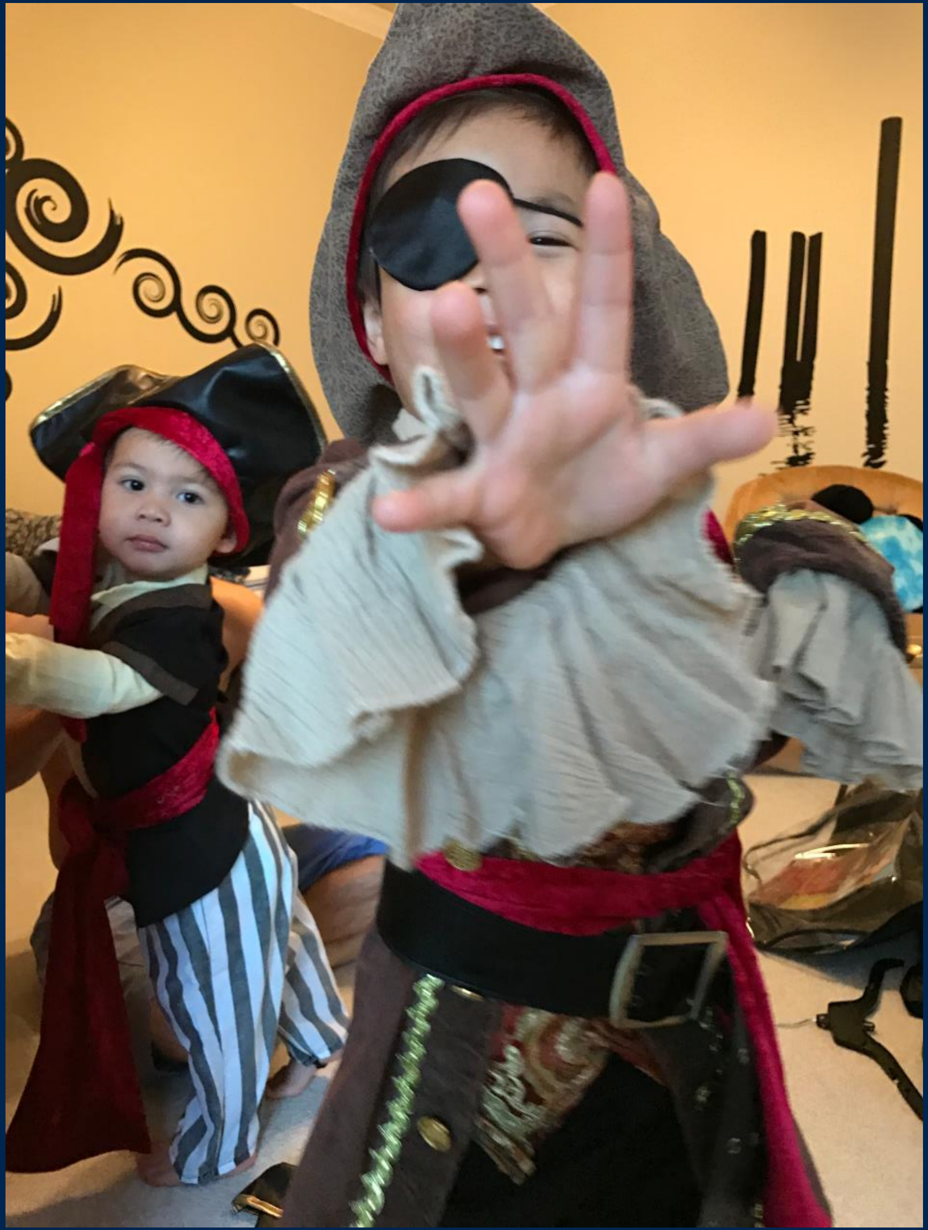
Measurement	Pearson Correlation Coefficient	*P* Value
Right AP	0.075	.75
Right lateral	0.280	.23
Left AP	−0.123	.61
Left lateral	0.313	.18

AP = anterior-posterior.

Discussion

- Small size studies
- No real time physiologic data
- Have not determined if it can distinguish between various lesions
- Cannot assess laryngeal closure

- High resolution can be used for young children
- ? May need lower resolution for 40’s and up



QUESTIONS?