Update on Instrumental Dysphagia Assessment

Joseph Murray PhD, CCC-SLP

Disclosures

- Financial
  - None
- Non-Financial
  - None

Blonsky, E. R., Logemann, J. A., Boshes, B., & Fisher, H. B. (1975). Comparison of speech and swallowing function in patients with tremor disorders and in normal geriatric patients: a cinefluorographic study. *Journal of Gerontology*, *30*(3), 299-303

- 1971
  - Developed to evaluate oropharyngeal swallowing in PD patients
- Assess effect of L-dopa treatment
- Protocol
  - 2 swallows each
  - 1 ml thin liquid
  - 1-3 ml of pudding
  - ¼ Lorna Doone cookie coated with barium pudding

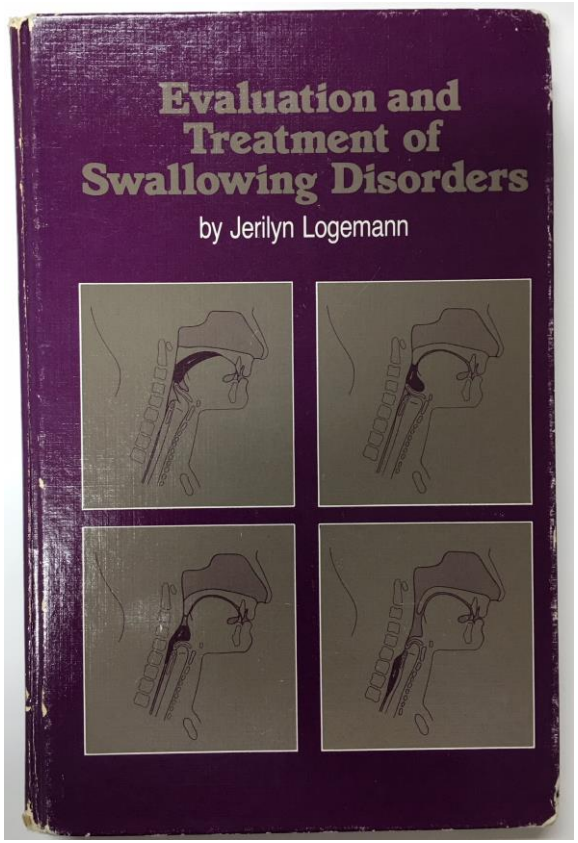
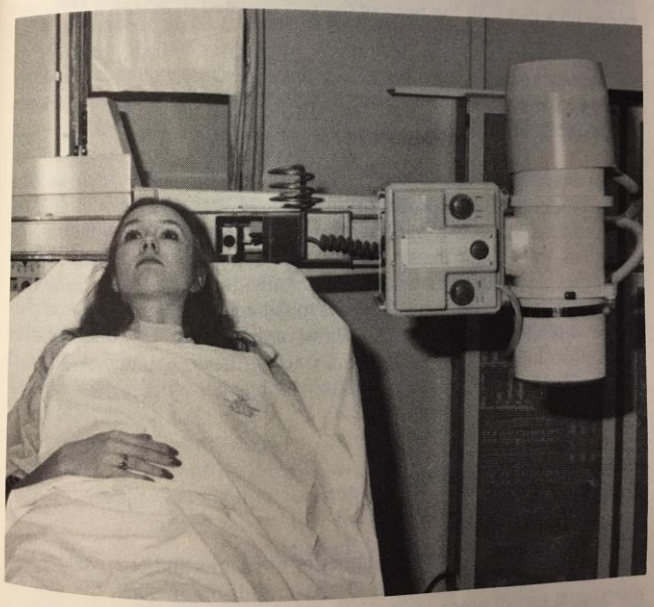

Evaluation and Treatment of Swallowing Disorders
by Jerilyn Logemann

FIGURE 4-2
Patient lying on a cart with the head elevated so that the upper aerodigestive tract can be viewed laterally.



VFSS Utility

- The “gold-standard" or “criterion” for observation and identification of oropharyngeal swallowing abnormalities
- Tests the effectiveness of direct compensatory interventions
- Observes the long-term effects of:
  - Rehabilitation
  - Experimental therapies

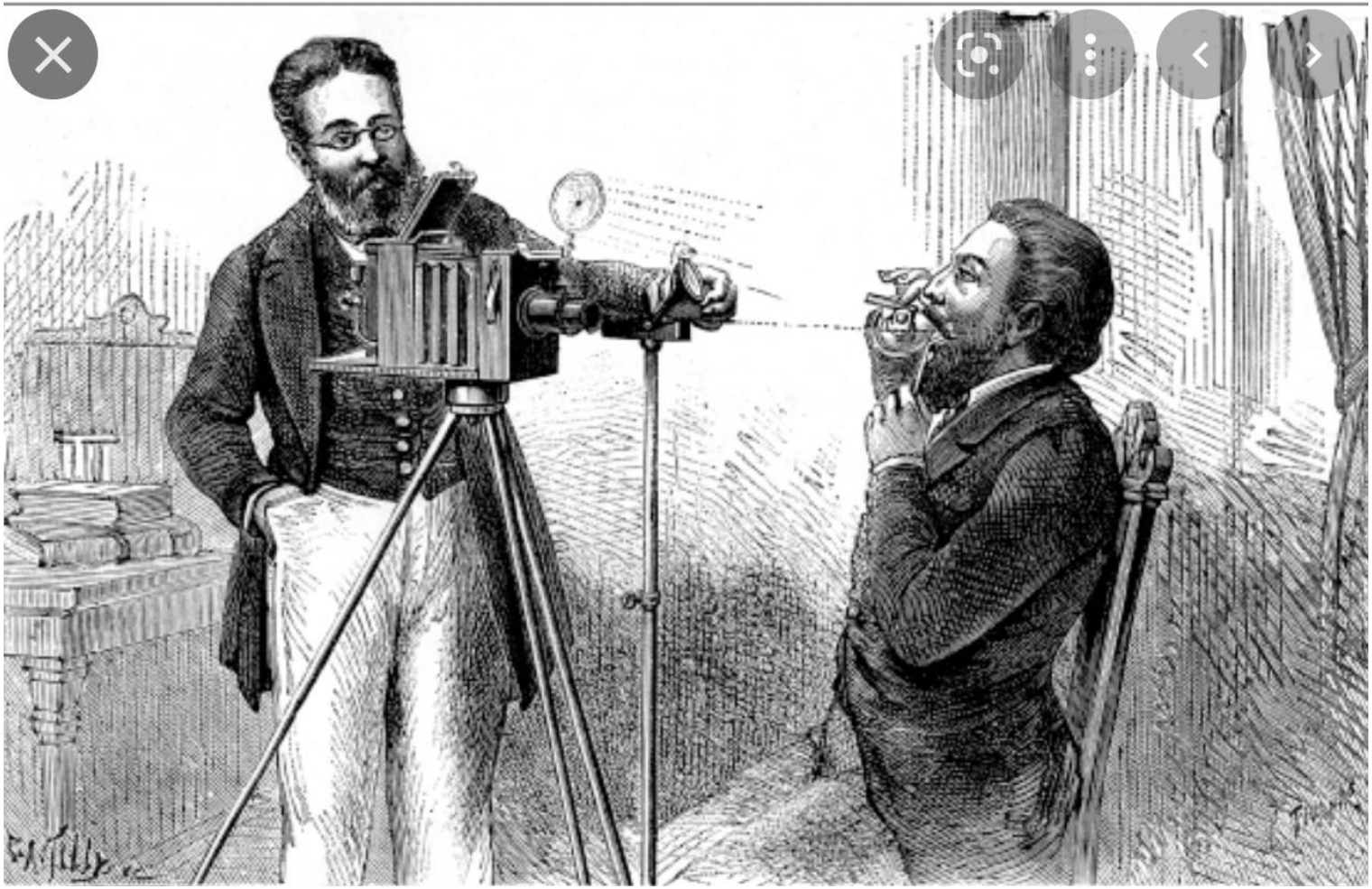


Fig 1

Fig 2

Fig 3

Fig 4

Fig 5

Drawing of the same laryngoscopic image as that of which photograph shown in Fig 5 was taken

Fig 6

A Simple Method of Laryngeal and Other Cavity Photography

George B. Ferguson, MD, and
Woodrow J. Crowder, Durham, NC

A simple method of attaching a reflecting mirror to the modified lens system of a movie camera has permitted laryngeal and other cavity photography by an indirect means.

Extension tubes with a standard 4-inch telephoto lens allow the laryngeal image to nearly fill the 16-mm frame.

A satin-finished, No. 6 mirror with anod-

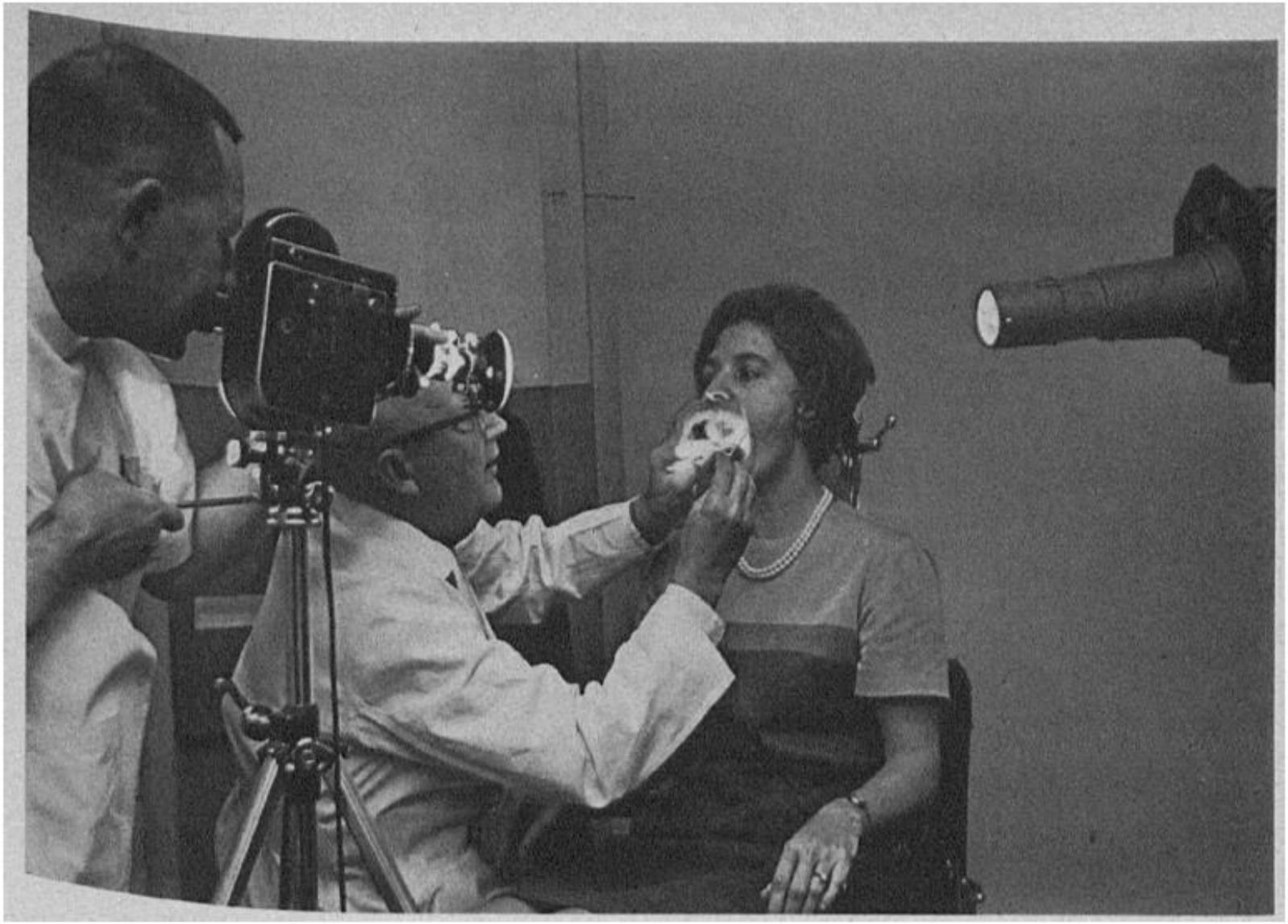


Fig 3.—Demonstration of method of laryngeal photography.

Flexible Fiberoptic Laryngoscopy

- Sawashima & Hirose (1968)
  - Sawashima, M., & Hirose, H. (1968). New laryngoscopic technique by use of fiber optics. *The Journal of the Acoustical Society of America*, *43*(1), 168-169.
- First application to swallowing
  - Langmore, S. E., Kenneth, S. M., & Olsen, N. (1988). Fiberoptic endoscopic examination of swallowing safety: a new procedure. *Dysphagia*, *2*(4), 216-219.

Dysphagia 2:216–219 (1988)

Dysphagia

Fiberoptic Endoscopic Examination of Swallowing Safety: A New Procedure

Susan E. Langmore, Ph.D.,[1] Kenneth Schatz, M.A.,[1] and Nels Olsen, M.D.[2]

Swallowing Disorders Clinic, [1] Audiology and Speech Pathology Service, [2] Otorhinolaryngology Service, Veterans Administration Medical Center, Ann Arbor, Michigan, USA

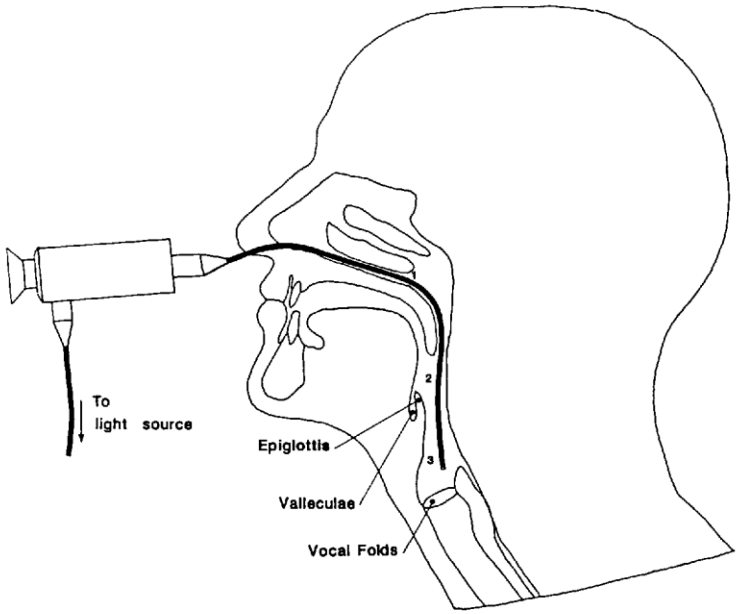
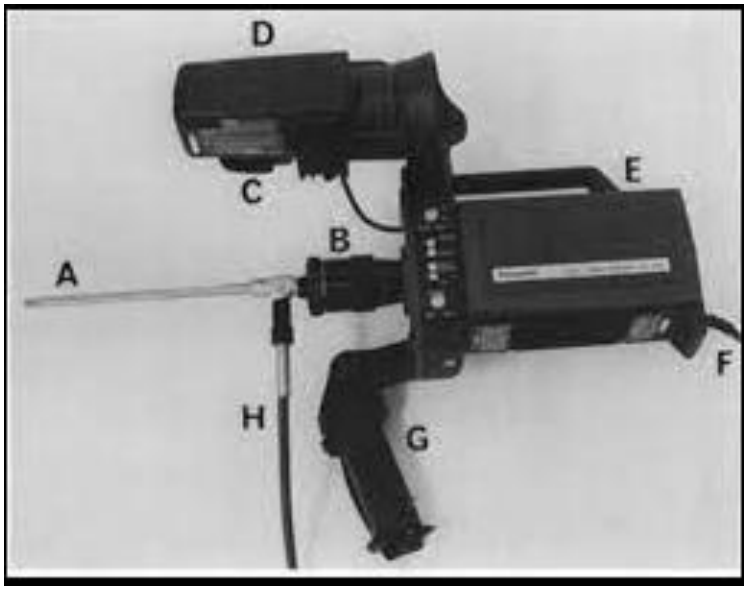


Fig. 1. Properly positioned endoscope for assessment of swallowing.


D
C
E
B
A
F
H
G

Langmore, S., Schatz, K. & Olson, N. “Endoscopic and videofluoroscopic evaluations of swallowing and aspiration.”

Annals of Otology, Rhinology & Laryngology, Vol. 100, 1991, pp. 678-681.

- Compared FEES to VFSS in 21 Patients
- Specificity good
    - Premature spillage
    - Residuals
    - Laryngeal penetration
    - Aspiration

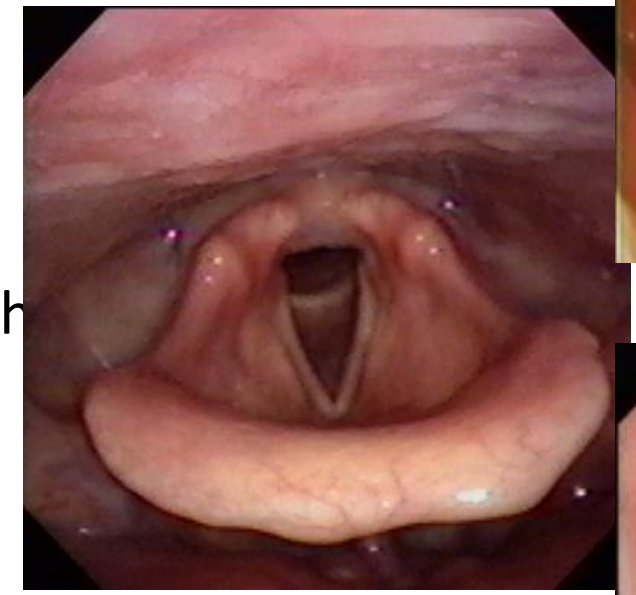
Number of Publications	Fluoroscopy	FEES
1960	2	0
1970	10	0
1980	3	1
1990	30	2
2000	61	39
2010	77	39
2015	103	64
2016	110	82
2017	109	75
2018	110	113
2019	116	135
2020	131	146
2021	73	173

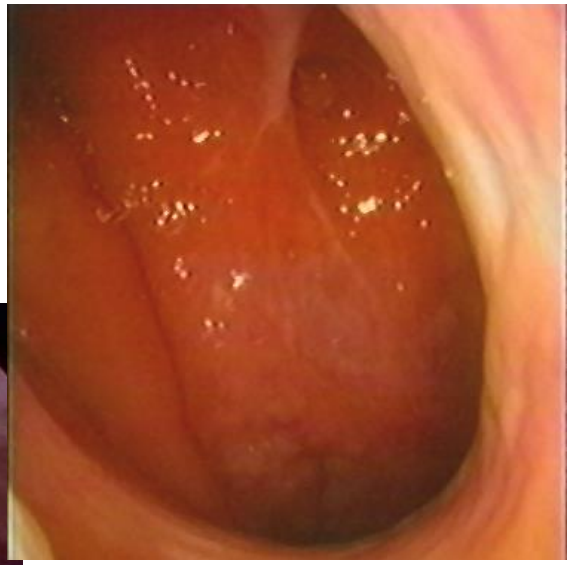
How Does One Choose?

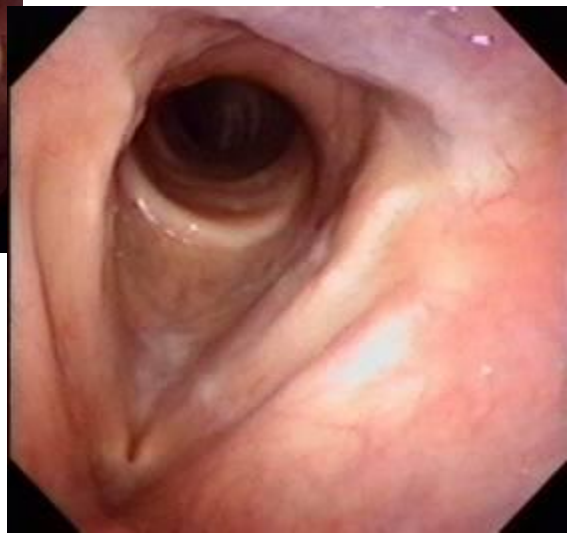
- Projection of possible findings from clinical will guide the choice of instrumentation.
- **The field of view should determine the instrumentation to be used.**
- Choose the instrument that will provide a field of view that reveals the most salient findings.

Field of View

- Typical endoscopic image will include:
  - Nasal cavity
  - Nasopharynx
  - Hypopharynx
  - Endolarynx
  - Anterior wall of trach





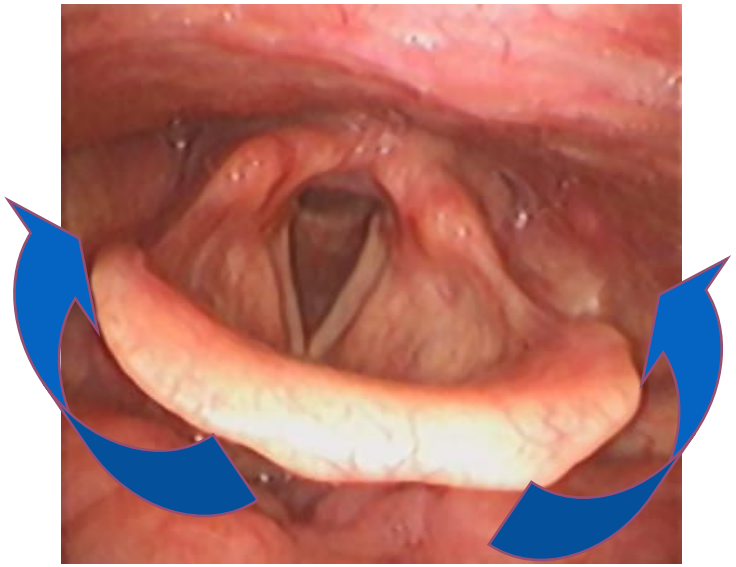


simul entry nasoph ort and anatomy.mpg

simultaneous 5cc a.mpg

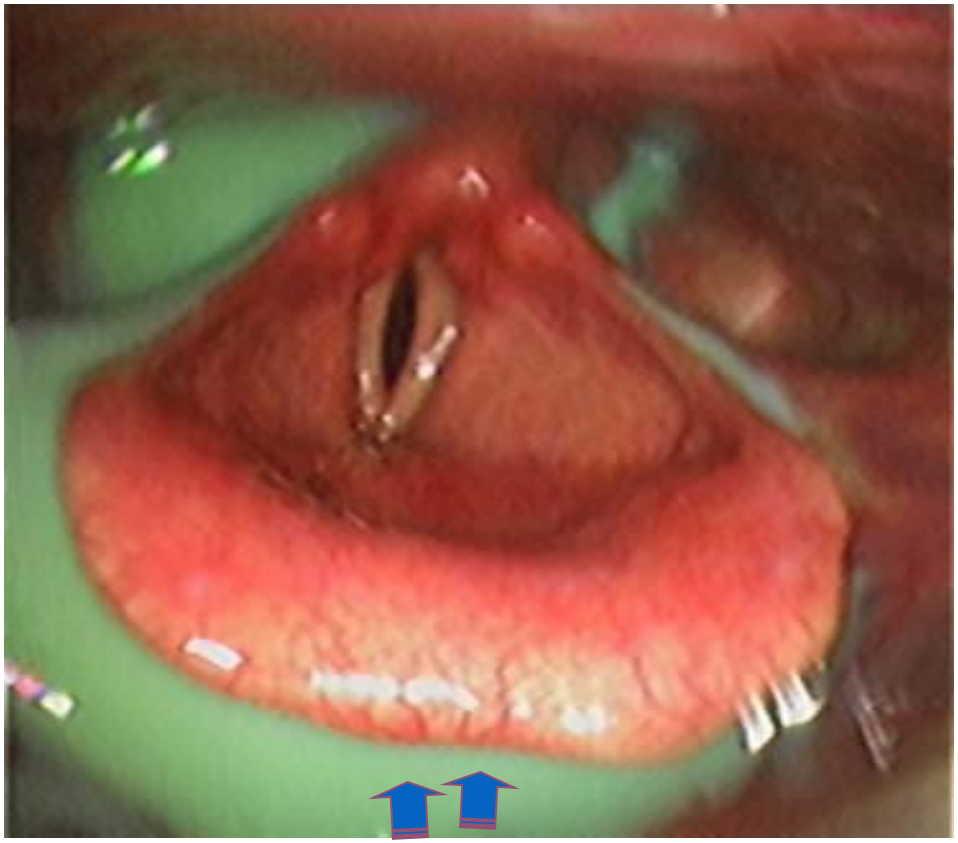
anatomy hq.mpg

Laryngeal Anatomy



- Larynx rises above floor of pharynx
- Natural barrier to lower airway
- Shield effect
  - Deflects food and liquid around airway

Laryngeal Anatomy



Scope Position Visualization

Feature	Nasal	NP Port	High	Home	Low
Nasal turbinates	✓				
Nasopharyngeal port	✓	✓			
Velum		✓	✓		
Tongue base			✓	✓	
Epiglottis			✓	✓	
Valleculae			✓	✓	
Pyriform sinuses			✓	✓	
Pharyngeal constriction			✓	✓	
Anterior cricoid			✓	✓	✓
Arytenoid			✓	✓	✓
Vocal folds				✓	✓
Cricothyroid membrane				✓	✓
Anterior tracheal wall				✓	✓
UES				✓	✓

Segmented View of Swallow

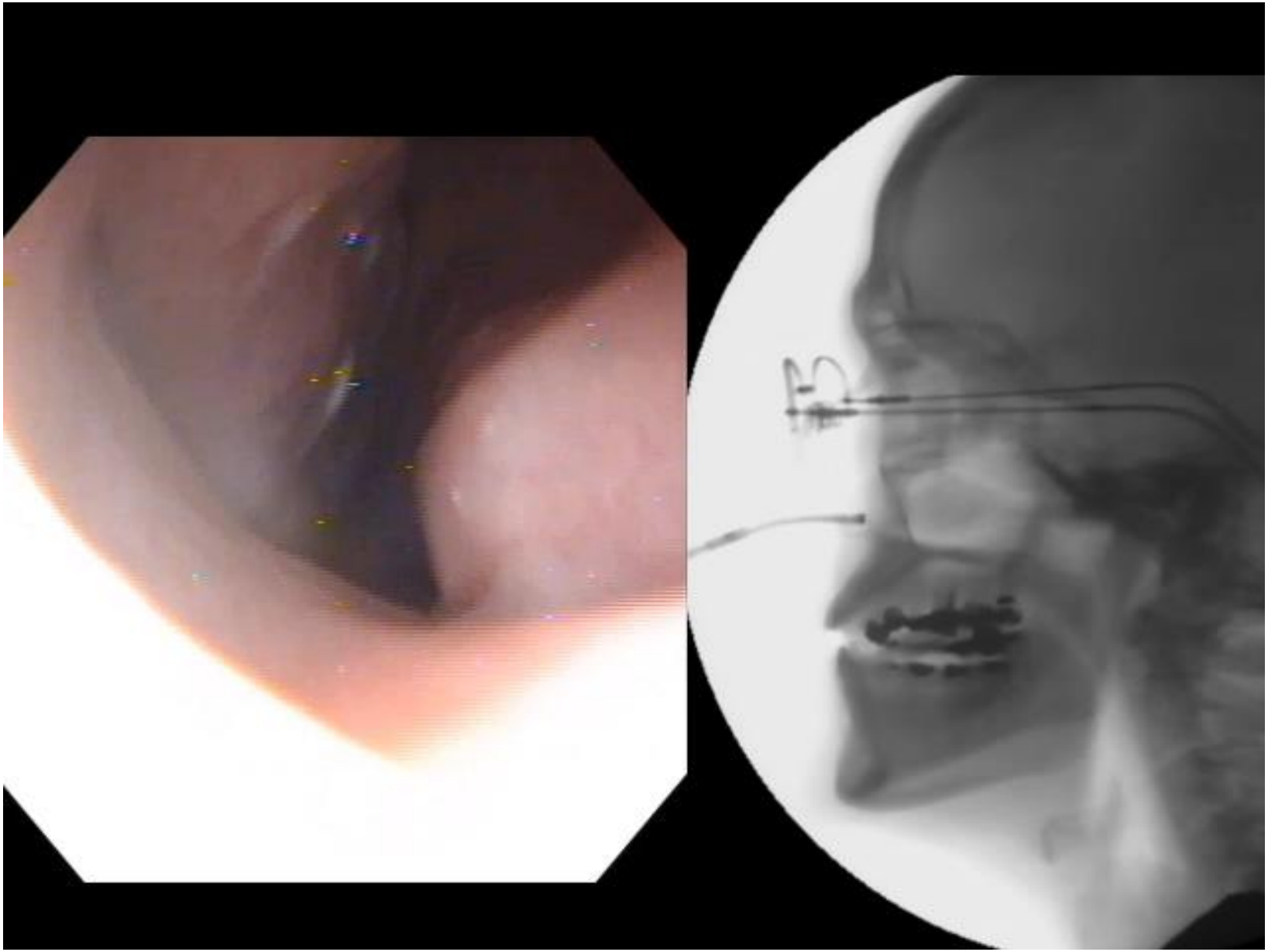
Pre-swallow segment

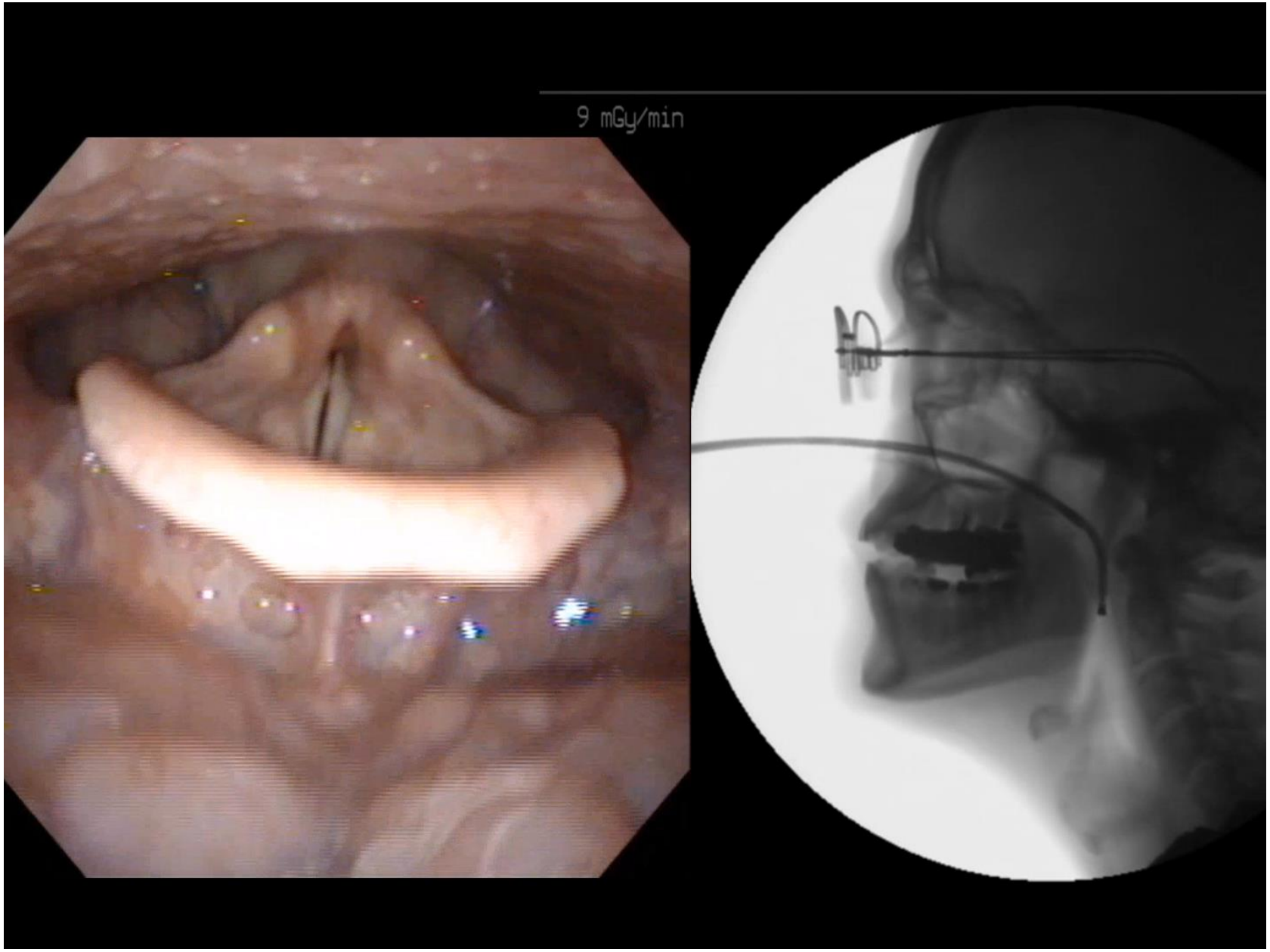
- Tongue base movement
  - Mastication and bolus manipulation
- Bolus advancement to pharynx

- Mid-swallow segment
  - White-out
    - Tongue or velar trapping of scope against posterior pharyngeal wall
    - Preference for velar trapping

- Post-swallow segment
  - Return to rest
    - Velum drops
    - Epiglottis inverted
    - Pharynx constricted

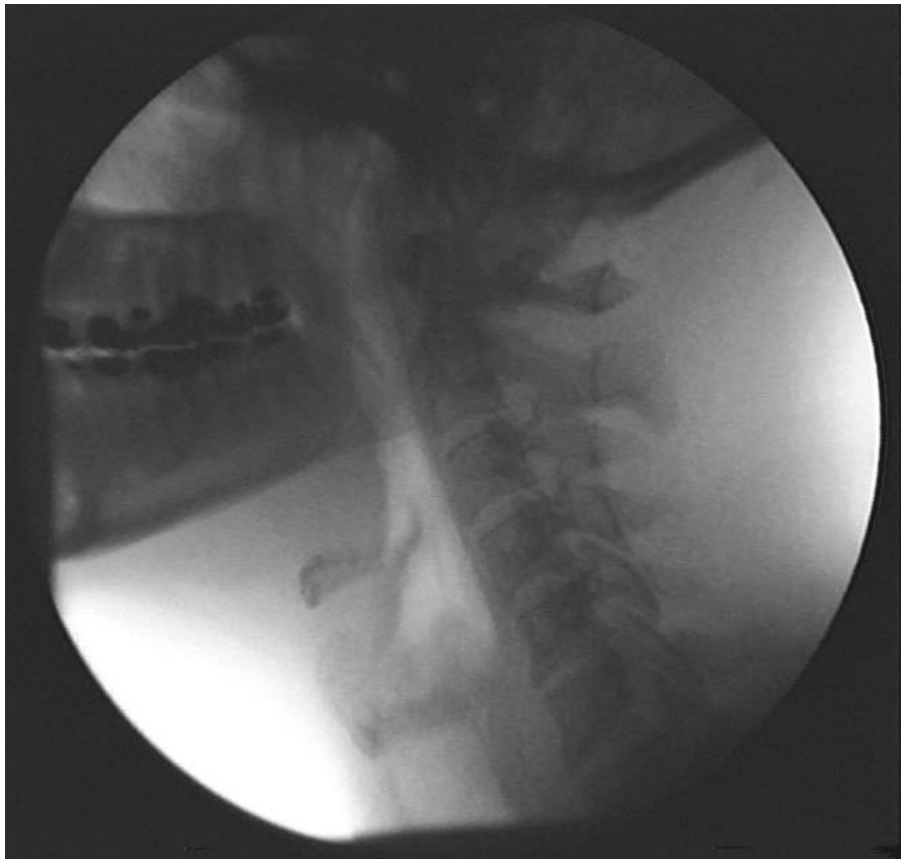
Pre-Swallow Segment Bolus Flow




9 mGy/min

Field of View

- Typical fluoroscopic image will include:
  - oral cavity
  - pharynx
  - portions of the striated esophagus

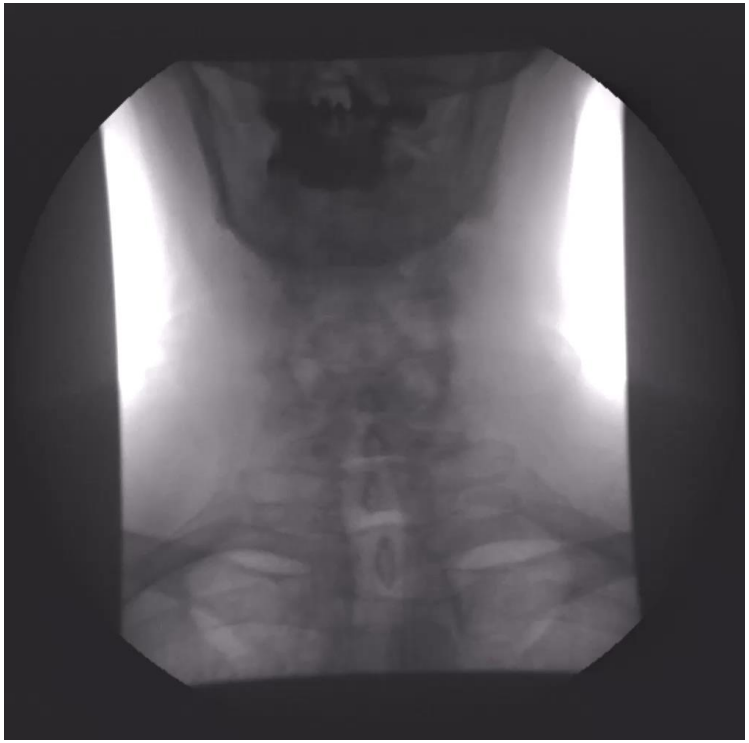


VideoV-4
Review of anatomy and landmarks of the lateral view

Lateral Projection

Feature	Morphology (at rest)	Movement	Function
Cervical spine	✓		
Hypopharynx	✓		
Tongue	✓	✓	✓
Velum	✓	✓	✓
Pharyngeal constrictors		✓	✓
Epiglottis	✓	✓	✓
Arytenoid	✓	✓	✓
Vocal folds		✓	✓
Hyoid	✓	✓	✓
Thyroid	✓	✓	
Cricoid	✓	✓	
Valleculae	✓		✓
Pyriform sinuses			✓
Upper esophageal sphincter		✓	✓
Striated esophagus		✓	✓

VideoV-6
Review of anatomy and landmarks of the AP view



Anterior-Posterior Projection

Feature	Morphology (at rest)	Movement	Function
Nasopharynx	✓		
Cervical spine	✓		
Hypopharynx	✓		
Tongue	✓	✓	✓
Velum			
Pharyngeal constrictors			
Epiglottis		✓	✓
Arytenoid			
Vocal folds	✓	✓	✓
Hyoid			
Thyroid			
Cricoid			
Valleculae	✓		✓
Pyriform sinuses	✓	✓	✓
Upper esophageal sphincter	✓	✓	✓
Striated esophagus	✓	✓	✓

VideoV-7
Review of anatomy and landmarks of the oblique view

Oblique Projection

Feature	Morphology (at rest)	Movement	Function
Cervical spine	✓		
Hypopharynx	✓		
Tongue	✓	✓	✓
Velum	✓	✓	✓
Pharyngeal constrictors		✓	✓
Epiglottis	✓	✓	✓
Arytenoid	✓	✓	✓
Vocal folds		✓	✓
Hyoid	✓	✓	✓
Thyroid	✓	✓	
Cricoid	✓	✓	
Valleculae	✓		✓
Pyriform sinuses	✓	✓	✓
Upper esophageal sphincter		✓	✓
Striated esophagus		✓	✓

Radiography 29 (2023) 284–290

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Narrative Review

The use of videofluoroscopy (VFS) and fibreoptic endoscopic evaluation of swallowing (FEES) in the investigation of oropharyngeal dysphagia in stroke patients: A narrative review

K. Helliwell [a, *], V.J. Hughes [b, 1], C.M. Bennion [b, 1], A. Manning-Stanley [b, 1]

[a] Calderdale and Huddersfield NHS Foundation Trust, Calderdale Royal Hospital, Salterhebble, Halifax, HX3 0PW, UK
[b] Department of Diagnostic Radiography, School of Health Sciences, University of Liverpool, Johnston Building, Brownlow Hill, L69 3GB, UK

Table 2
The sensitivity and specificity values in FEES, when VFS was used as the reference standard using semi-solid boluses. These values are based on the overall sensitivity and specificity values of the examination type and the values based on how effective the method is at identifying aspiration.[23,33]

Type of bolus	Author	Type of Evaluation	Index test	Reference standard	Sensitivity	Specificity
Semi-solid boluses	Fattori 2016[23]	Overall	FEES	VFS	0.85	0.66
Semi-solid boluses	Fattori 2016[23]	Aspiration	FEES	VFS	0.33	0.87
Liquid boluses	Fattori 2016[23]	Overall	FEES	VFS	0.84	0.77
Liquid boluses	Fattori 2016[23]	Aspiration	FEES	VFS	0.37	0.87
Liquid boluses	Park 2015[33]	Aspiration thick liquids	FEES	VFS	1.0	0.78
Liquid boluses	Park 2015[33]	Aspiration thin liquids	FEES	VFS	0.83	0.65
Liquid boluses	Park 2015[33]	Aspiration thick liquids	VFS	FEES	0.33	1.0
Liquid boluses	Park 2015[33]	Aspiration thin liquids	VFS	FEES	0.29	0.96

Table 3
Comparison of two study methods[23,33] evaluating sensitivity and specificity of VFS and FEES.

	Fattori et al.[23]	Park et al.[33]
Patient type	Dysphagic patients of mean time period 1.5 years	Patients suspected of OD
Sample size	60 dysphagic patients (34 of these neurological dysphagia)	73 of which 23 were excluded.
Methodology	Initial test was always FEES. VFS was initially used as a reference standard because it is the gold standard test. However, FEES was also used as a reference standard. The operators were blinded to the results of the previous tests.	Both VFS and FEES performed on the same day. VFS performed initially and FEES within 24 h by an endoscopist blinded to the VFS outcome.
How thick/thin liquids are defined	**FEES** Utilised two or more semi-solid (jellied drink) or liquid boluses for each patient (water mixed with methylene blue for easier detection). **VFS** Utilised 98.45% barium sulphate contrast, diluted in 65 ml water to create a liquid consistency and in 30 ml water to create a semi-solid bolus. For both densities the patient took three sips of 5 cc.	**FEES** 5-ml yogurt was used for viscous food followed by 5 ml indigocarmine dye-mixed water for liquid food. **VFS** 5 ml liquid barium (barium sulphate) blended yogurt was used for semi-solid food representation, followed by 5 ml liquid barium diluted with water for the liquid bolus.
Amount used in each sample	5cc (5 ml)	5 ml

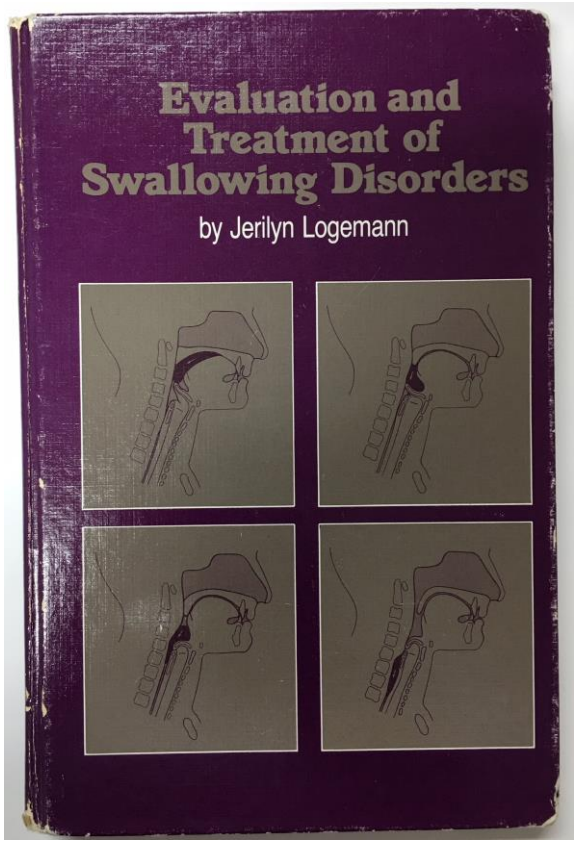
Table 4

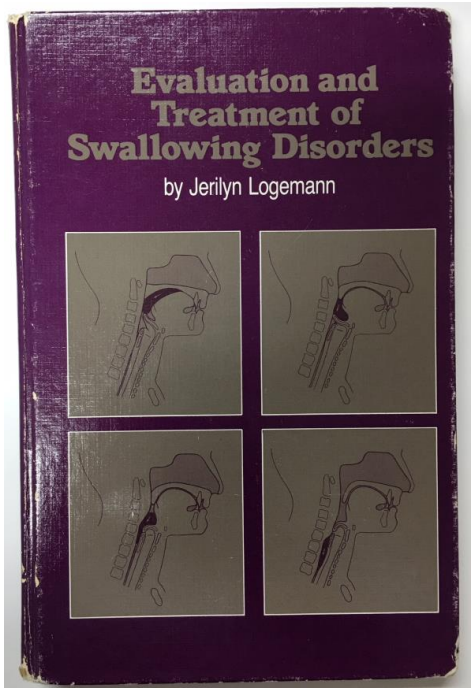
Rates of detection of aspiration by videofluoroscopy (VFS) and fibreoptic endoscopic evaluation of swallowing (FEES). Identified using both viscous and liquid foods.[33]

Variable	Aspiration		
	VFS	VFS and FEES	p-value
Viscous food	5/50 (0.10)	15/50 (0.30)	<0.001
Liquid food	6/40 (0.15)	18/40 (0.45)	<0.001

Imaging the Abnormal Swallow

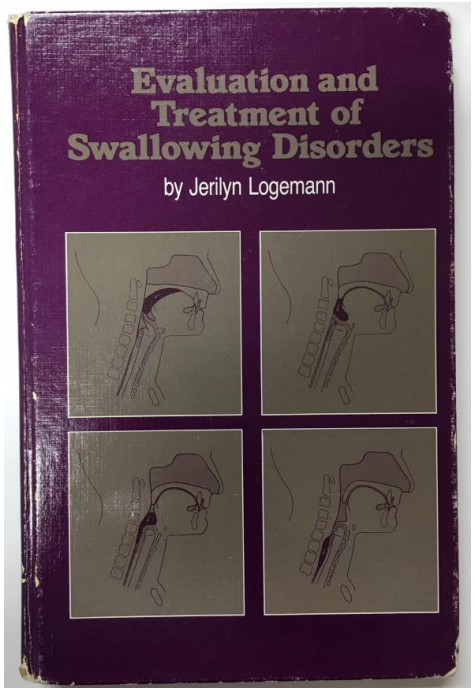
Technical Issues


Evaluation and Treatment of Swallowing Disorders
by Jerilyn Logemann



esophagus during swallowing. The fluoroscopic image, recorded on movie film and called *cinefluoroscopy*, allowed examination of movement patterns of the bolus and of particular structures in slow motion and frame-by-frame. The movie film could be exposed at various speeds up to 60 frames per second. (Ardran & Kemp, 1951, 1952, 1956; Sloan, Ricketts, Brummett, Bench & Westover, 1965; Sokol, Heitmann, Wolf, & Cohen, 1966; Wictorin, Hedegard, & Lundberg, 1971).

More recently, fluoroscopic studies have been recorded on videotape (videofluoroscopy), which also permits frame-by-frame analysis employing a video recorder-player with frame-by-frame analysis capability (Yotsuya, Nonaka, & Yoshinobu, 1981; Yotsuya, Saito, & Yoshinobu, 1981). By recording numbers on each frame of the videotape using a video counter timer, the swallowing studies can be repeatedly examined in slow motion or frame-by-frame, and the specific frame numbers of greatest interest can be easily located and examined. Because swallowing occurs very rapidly, with normal oral and pharyngeal transit times each taking a maximum of 1 second, slow motion analysis is most helpful in defining movement disorders. Almost any videotape recorder can be attached to



cinefluoroscopy. Framing is possible, nonetheless, utilizing a Thalner Electronics Video Counter Timer, which places a number in the corner of the videoscreen, each number reflecting one frame of the videotape. Since video is framed at 30 frames per second, when numbers are placed at the rate of 30 per second, each number represents one frame of the video. Several video cassette recorder players are capable of frame-by-frame or stop motion tape advance. Thus, when a tape with numbered frames is played on one of these recorders, frame-by-frame analysis of the movement pattern is possible, similar to analysis of motion picture film. An additional advantage to *video*fluoroscopy in the analysis of deglutition is the ease of patching any video recorder player into fluoroscopic equipment. Such a hookup need not be permanent, and, in fact, video equipment from the education department of a hospital may be borrowed for the time required (30 to 60 minutes) to complete two to three videofluoroscopic studies. Such equipment is generally available in all hospitals and fluoroscopic units are among the most common types of radiographic equipment. Thus, even many smaller hospitals have the capability to do detailed videofluoroscopic studies of deglutition.

The fluoroscopic procedure designed to examine the

Fluoroscopy Rate

- *Fluoroscopy rate*
  - Number of images produced by the fluoroscope /second.
    - Analog fluoroscopy:
      - Either ON or OFF
      - Image was continuous when ON
    - Digital fluoroscopy
      - Pulses at set rate
        - 30 // 15 // 7.5 // 4 // 2
      - Fluid movement on playback at 30 images/sec

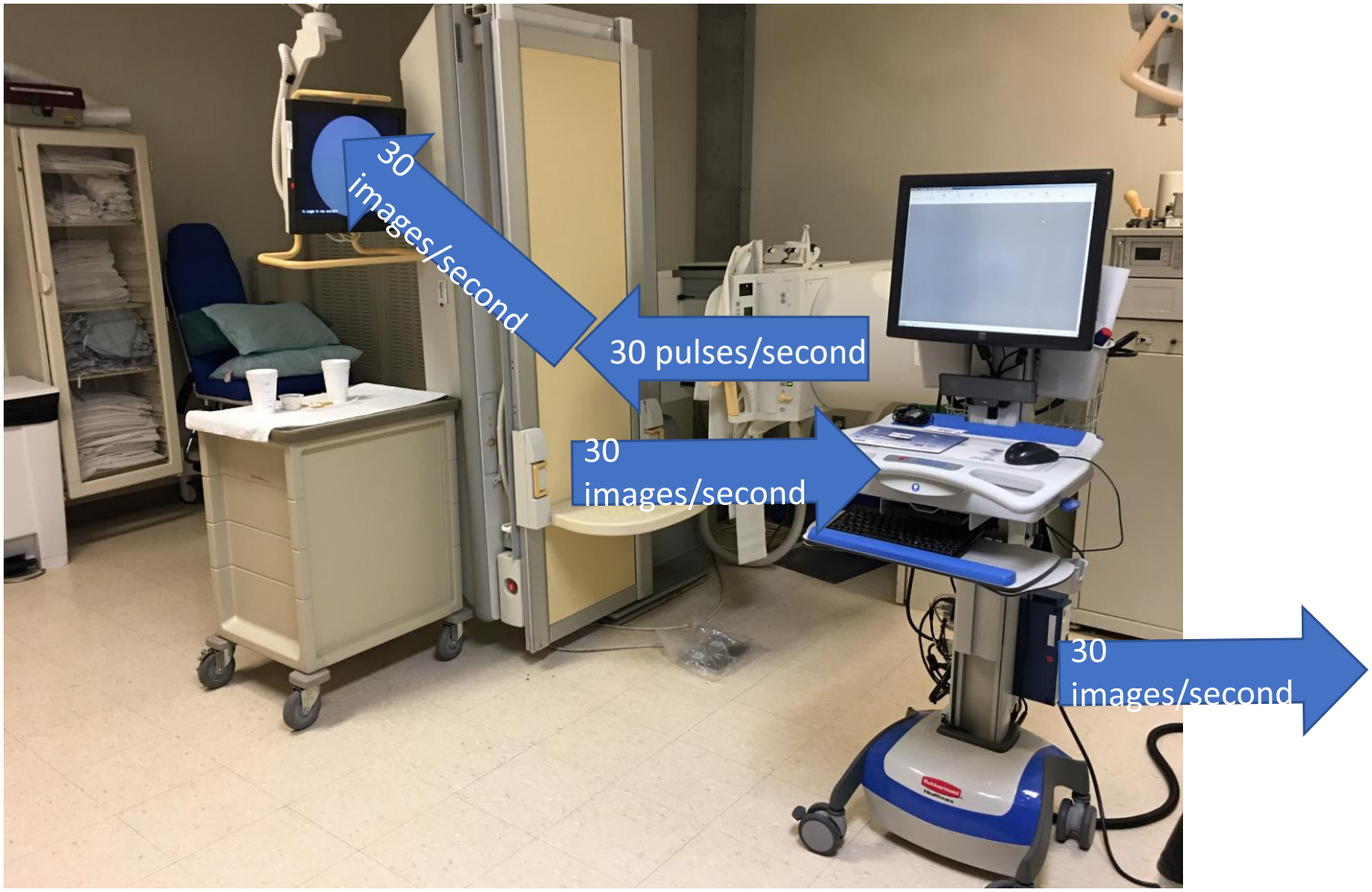
Frame Rate

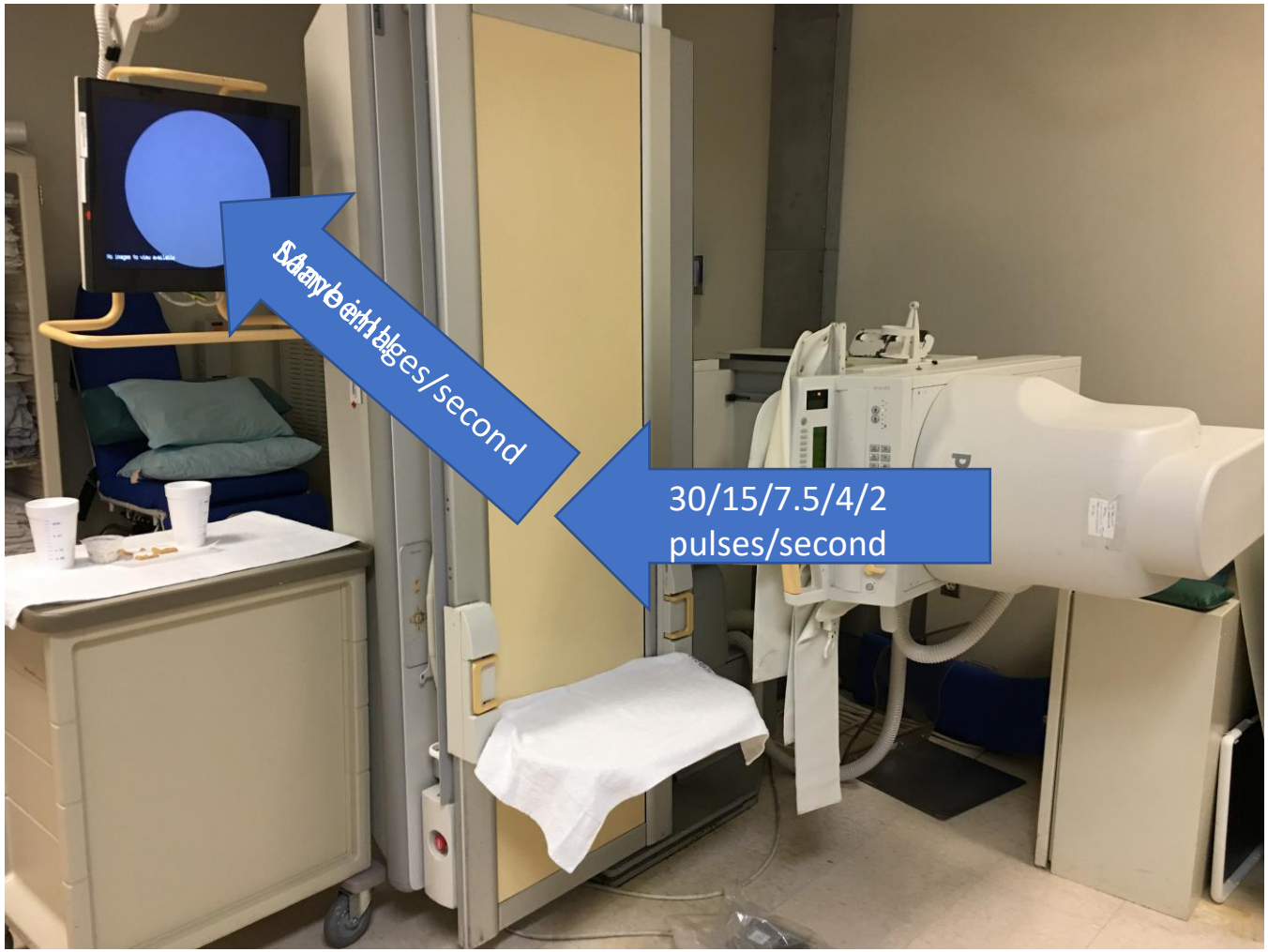
- **How many images are forwarded to the display?**
  - **National Television System Committee (NTSC)**
    - 30 images (frames)/second
  - **Phase Alternation Line (PAL)**
    - 25 images (frames)/second

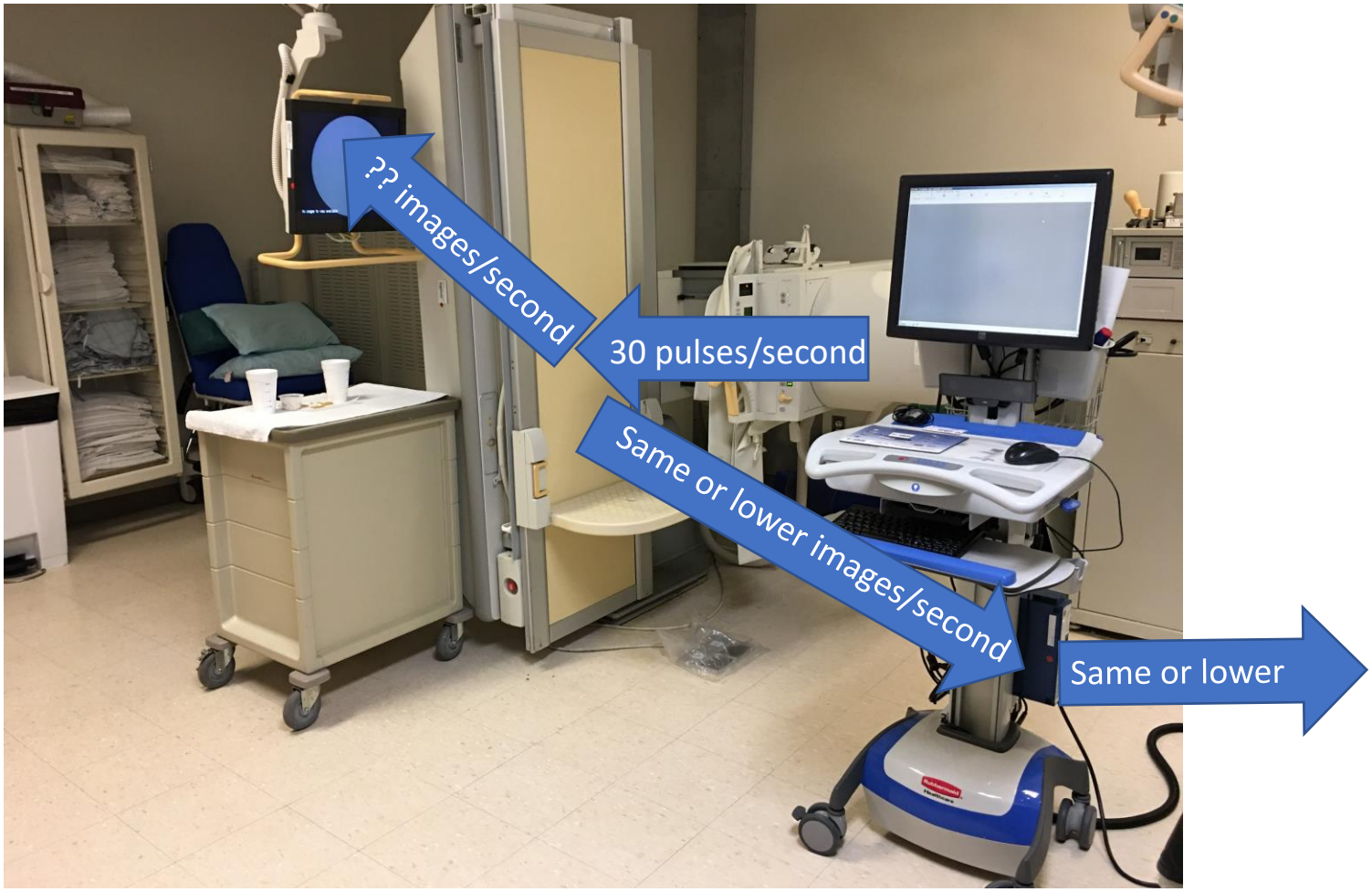
- Screen density can vary depending on manufacturer
  - Many variables and settings
    - Ideally 30 frames/second
    - Scaled symmetrical image

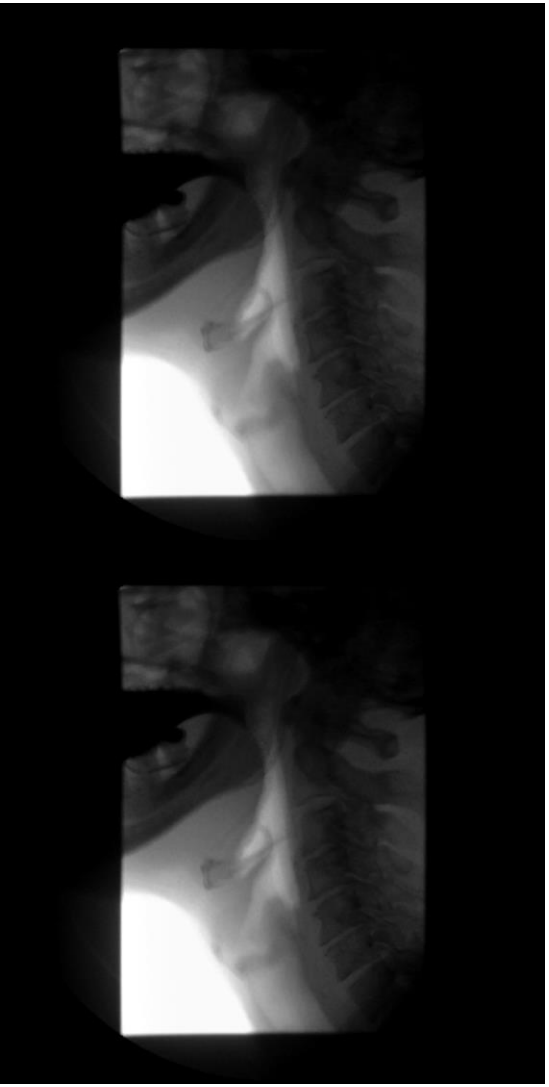
Image Storage and Retrieval

- Ideally
  - Exact 30 frame/sec recording of 30 pulse/sec study
    - Local storage on hard drive
  - In suite review with patient after study
  - Upload or download via **Picture Archiving and Communication System** (**PACS**) in the **Digital Imaging and Communications in Medicine (DICOM)** format
  - Centralized access to storage and download
    - Remote access of archived system via **PACS**
- Less-ideal
  - Recording is limited by system storage capacity
  - Archiving and retrieval limited by IT constraints


30 images/second
30 pulses/second
30 images/second
30 images/second

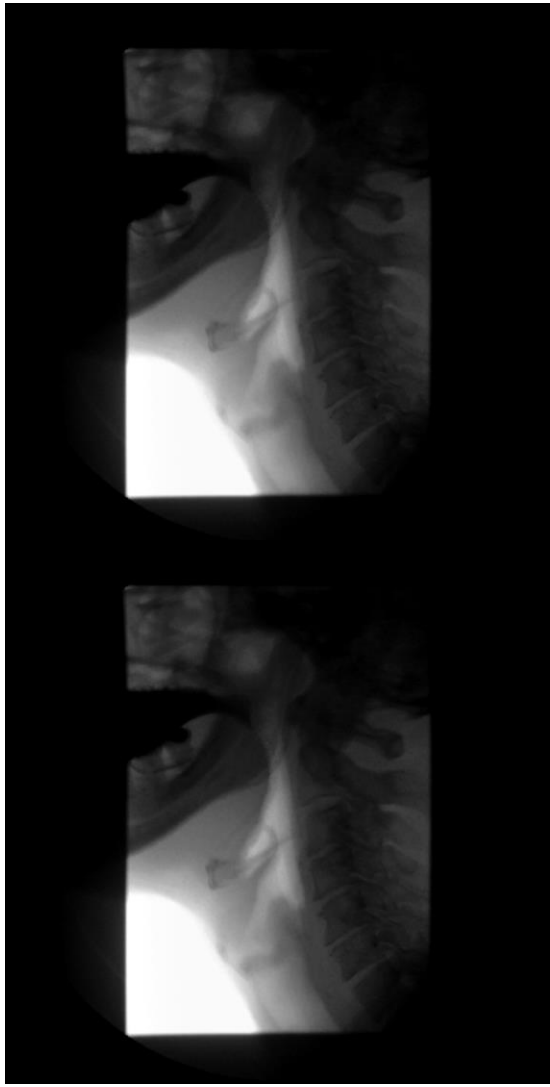

30/15/7.5/4/2
pulses/second


?? images/second
30 pulses/second
Same or lower images/second
Same or lower



30 PPS

15 PPS

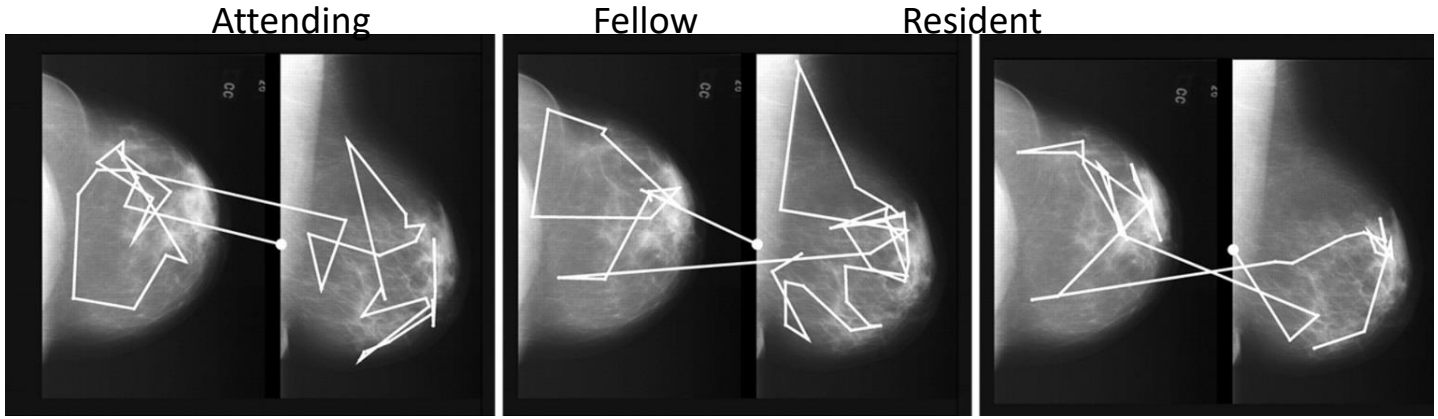


7.5 PPS

4 PPS

Controlling Error: Methodical Review

- First 10 seconds of mammogram review



Kundel, H. L. et al. Radiology 2007;242:396-402

Radiology

Search and Find vs. Holistic Perception

- Kundel et al. (2007) Mammogram search
  - Brain function responsible for facial recognition and brain function involved in recognition of radiographic abnormalities may be linked
  - Less-expert observers unable to draw on the initial holistic perception
  - Left to search the image to discover image features that may be abnormal
  - Concluded that exclusive use of the search-to-find strategies lead to slower identification and more errors

Controlling Error
Methodical Review VFSS

- Different visualization
  - Mammography
    - Static
  - VFSS
    - Dynamic
- No universally recognized methodical review
- Using a standardized method that forces discrete scoring helps!
  - MBSimp

MBS Measurement Tool for Swallow Impairment—MBSImp: Establishing a Standard

Bonnie Martin-Harris · Martin B. Brodsky · Yvonne Michel · Donald O. Castell · Melanie Schleicher · John Sandidge · Rebekah Maxwell · Julie Blair

Dysphagia (2008) 23:392–405

Table 1 Physiologic swallowing components

1. Lip closure	(Lip C)
2. Hold position/tongue control	(HP)
3. Bolus preparation/mastication	(BP)
4. Bolus transport/lingual motion	(BT)
5. Oral residue	(OR)
6. Initiation of the pharyngeal swallow	(IPS)
7. Soft palate elevation	(SPE)
8. Laryngeal elevation	(LE)
9. Anterior hyoid motion	(HM)
10. Epiglottic movement	(EM)
11. Laryngeal closure	(LC)
12. Pharyngeal stripping wave	(PSW)
13. Pharyngeal contraction	(PC)
14. PES opening	(PESO)
15. Tongue base retraction	(TBR)
16. Pharyngeal residue	(PR)
17. Esophageal clearance in the upright position	(EC)

Preliminary Investigation of the Effect of Pulse Rate on Judgments of Swallowing Impairment and Treatment Recommendations

Heather Shaw Bonilha · Julie Blair · Brittni Carnes · Walter Huda · Kate Humphries · Katlyn McGrattan · Yvonne Michel · Bonnie Martin-Harris

Dysphagia (2013) 28:528–538

- Compared 30- to simulated 15-
  - MBSImp
- 6 components with differing judgments

Table 4 Percent of scores that differed when judged from 30-pps and simulated 15-pps recordings for each of the six physiological components where differences were found

Component	1 (%)	2 (%)	3 (%)	4 (%)	5 (%)
Initiation of pharyngeal swallow	56	0	38	11	67
Anterior hyoid excursion	0	0	0	22	0
Epiglottic movement	0	0	13	0	0
Pharyngeal contraction	0	0	50	0	0
PE segment opening	0	13	0	0	0
Tongue base retraction	0	0	0	11	0

For example, 56 % of the scores for initiation of pharyngeal swallow scores were different when comparing 30 versus simulated 15 pps for patient 1

Dysphagia (2020) 35:296–300
https://doi.org/10.1007/s00455-019-10027-8

ORIGINAL ARTICLE

Can We Reduce Frame Rate to 15 Images per Second in Pediatric Videofluoroscopic Swallow Studies?

Julie Layly[1] · Franck Marmouset[2] · Guillaume Chassagnon[1] · Philippe Bertrand[3,4] · Dominique Sirinelli[1,4] · Jean-Philippe Cottier[3,4] · Baptiste Morel[1,4]

Received: 15 March 2019 / Revised: 30 April 2019 / Accepted: 31 May 2019 / Published online: 5 June 2019

- Methods:
  - Two judges viewed 190 swallowing loops viewed at 15 and 30fps from N=32 consecutive pediatric patients

- Judgements:
  - Physiological swallowing components
  - Initiation of pharyngeal swallow
  - Anterior hyoid excursion
  - Epiglottic movement
  - Pharyngeal contractions
  - Pharyngeal–esophageal segment opening
  - Tongue base retraction
  - PAS

- Normal=144 loops
- Disordered=46 loops
  - Penetration=23
  - Aspiration=23

Methods:
Two judges viewed 190 swallowing loops viewed at 15 and 30fps from N=32 consecutive pediatric patients

Judgements:

- Physiological swallowing components
  - Initiation of pharyngeal swallow
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  - Epiglottic movement
  - Pharyngeal contractions
  - Pharyngeal–esophageal segment opening
  - Tongue base retraction
- PAS

Normal=144 loops
Disordered=46 loops

- Penetration=23
- Aspiration=23

Results:
3 false positive
3 false negative
(All were grade 2 and 3 penetrations)

Sensitivity= 93% (CI 0.82–0.98)
Specificity= 98% (CI 0.94–0.99)

Positive Predictive Value = 93%
Negative Predictive Values = 98%.

Cohen'Kappa coefficient between the interpretation of each swallowing at 15 and 30 fps was "almost perfect"
(κ = 0.95; CI 0.88–0.99).

Conclusion

Our consensual interpretation of pediatric swallowing disorders observed during VFSS performed with 15 frames per second on 190 swallowings did not lead to clinical change.

Kelly, A., Drinnan, M., Leslie, P., (2007) Assessing Penetration and Aspiration; How do Videofluoroscopy and Fiberoptic Endoscopic Evaluation of Swallowing Compare?

Laryngoscope, 117:1723-1727

- Prospective, Single Blinded
- 15 Simultaneous VFSS and FEES
- 15 Independent Raters used PAS
- PAS scores higher for FEES (<.001)
- Mean difference between FEES and VFSS
  - 1.15 points
- Penetration and aspiration percieved to be more severe with FEES

Assessing Penetration and Aspiration: How Do Videofluoroscopy and Fiberoptic Endoscopic Evaluation of Swallowing Compare?

Effects of Examination (VF vs. FEES) and Four Other Factors on Penetration Aspiration Scale Scores.

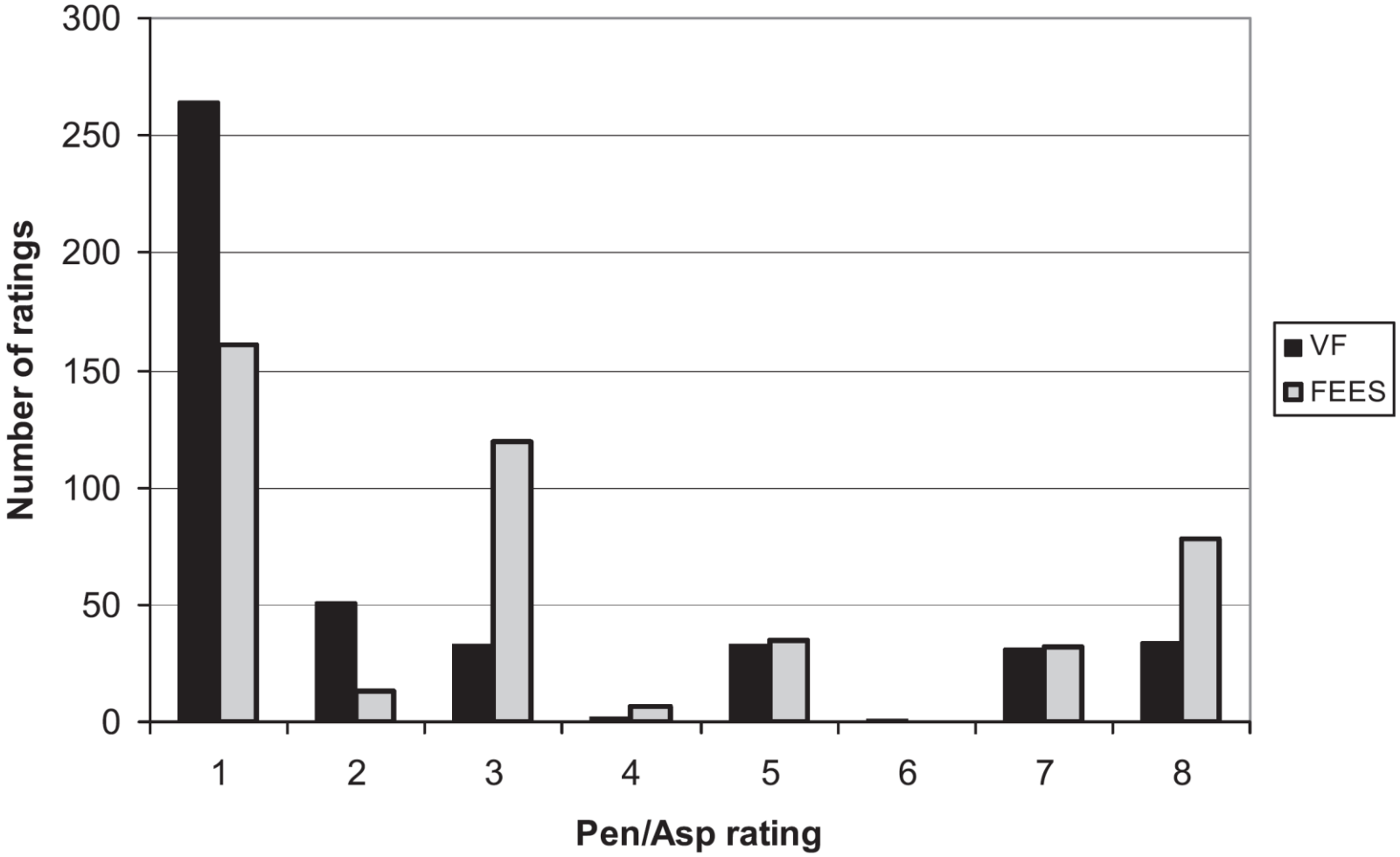
Factor	Mean Pen/Asp Score	*P* Value
Exam		
VF	2.47	<.001
FEES	3.61	
Rating		
First	3.04	.881
Second	3.03	
Bolus		
Liquid	2.97	.032
Yogurt	3.11	
Rater		
Lowest mean score	2.67	<.001
Highest mean score	3.98	
Subject		
Lowest mean score	1.16	<.001
Highest mean score	7.27	

For rater and subject, the overall range of scores is shown. *P* value is from ANOVA, and indicates the probability that the effect is a result of chance alone.

FEES = fiberoptic endoscopic evaluation of swallowing; VF = videofluoroscopy; Pen/Asp = Penetration Aspiration.

The Laryngoscope
Volume 117, Issue 10, pages 1723-1727, 2 JAN 2009 DOI: 10.1097/MLG.0b013e318123ee6a
http://onlinelibrary.wiley.com/doi/10.1097/MLG.0b013e318123ee6a/full#fig1

Assessing Penetration and Aspiration: How Do Videofluoroscopy and Fiberoptic Endoscopic Evaluation of Swallowing Compare?



The Laryngoscope
Volume 117, Issue 10, pages 1723-1727, 2 JAN 2009 DOI: 10.1097/MLG.0b013e318123ee6a
http://onlinelibrary.wiley.com/doi/10.1097/MLG.0b013e318123ee6a/full#fig1

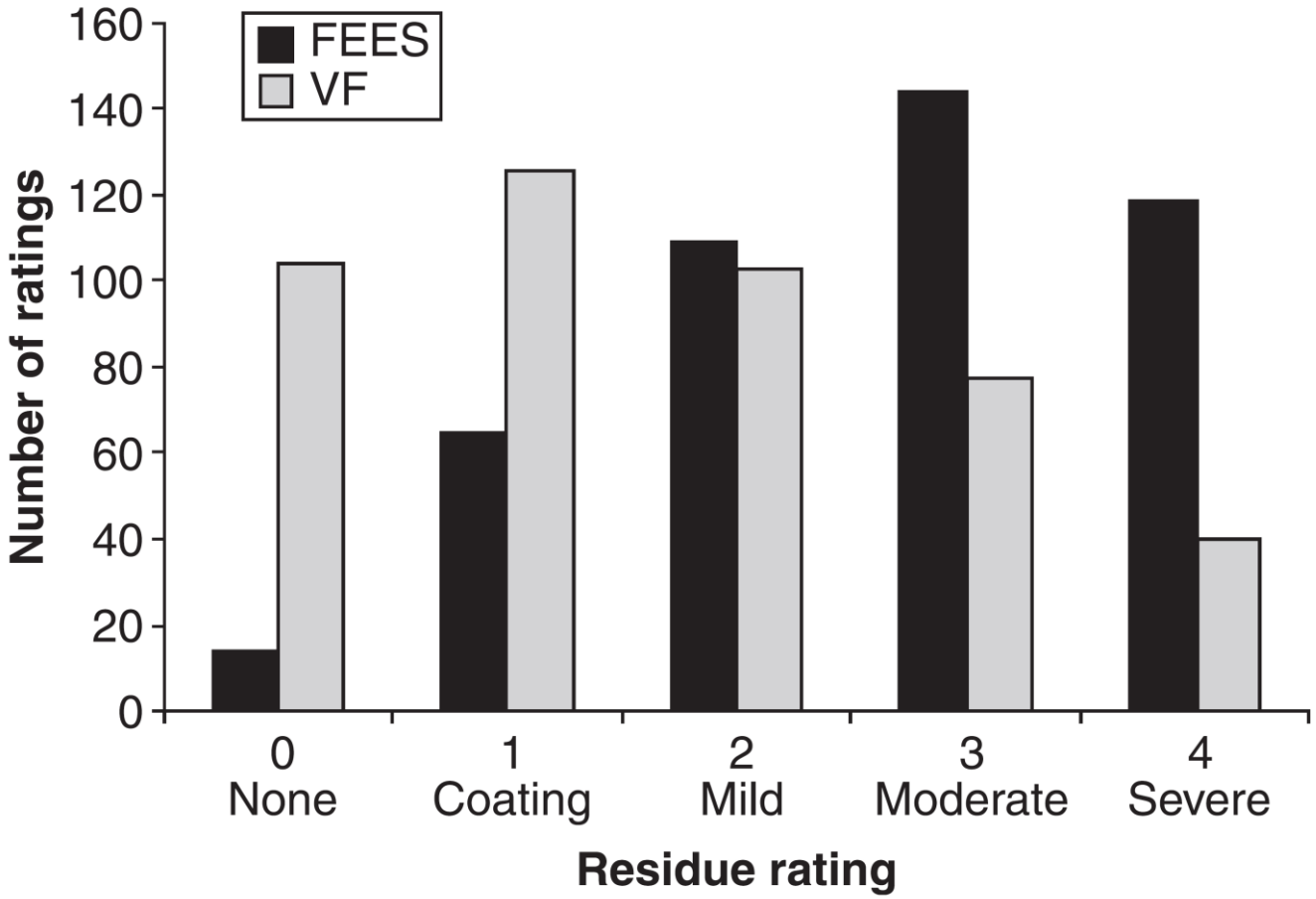
Kelly et al. (2007)

- Conclusions
  - Rater's judgmeent of the severity of the penetration or aspiration is affected by the type of examination performed
  - Raters consistently scored FEES higher on the PAS scale than VFSS
  - Serious implications for the interchangeable use of these examinations in clinical practice

Fibreoptic endoscopic evaluation of swallowing and videofluoroscopy: does examination type influence perception of pharyngeal residue severity?[1]

Kelly, A.M.,* Leslie, P.,† Beale, T.,* Payten, C.,* & Drinnan, M.J.‡
Clin. Otolaryngol. 2006, **31**, 425–432

- Prospective, single-blind assessment
- Simultaneous videofluoroscopy and FEES recordings
- Raters blinded
  - pairing of the videofluoroscopy and FEES
  - other raters' scores
- 15 Patients
- Simultaneous VFSS and FEES



Clin. Otolaryngol. 2006, **31**, 425–432

SIG 13

Commentary

What's the Evidence? A Commentary on FEES Research

Jessica M. Pisegna[a,b,c]

[a]Department of Head & Neck Surgery, Boston University School of Medicine, MA [b]Voice and Swallowing Center, Boston Medical Center, MA
[c]Sargent College, Boston University, MA

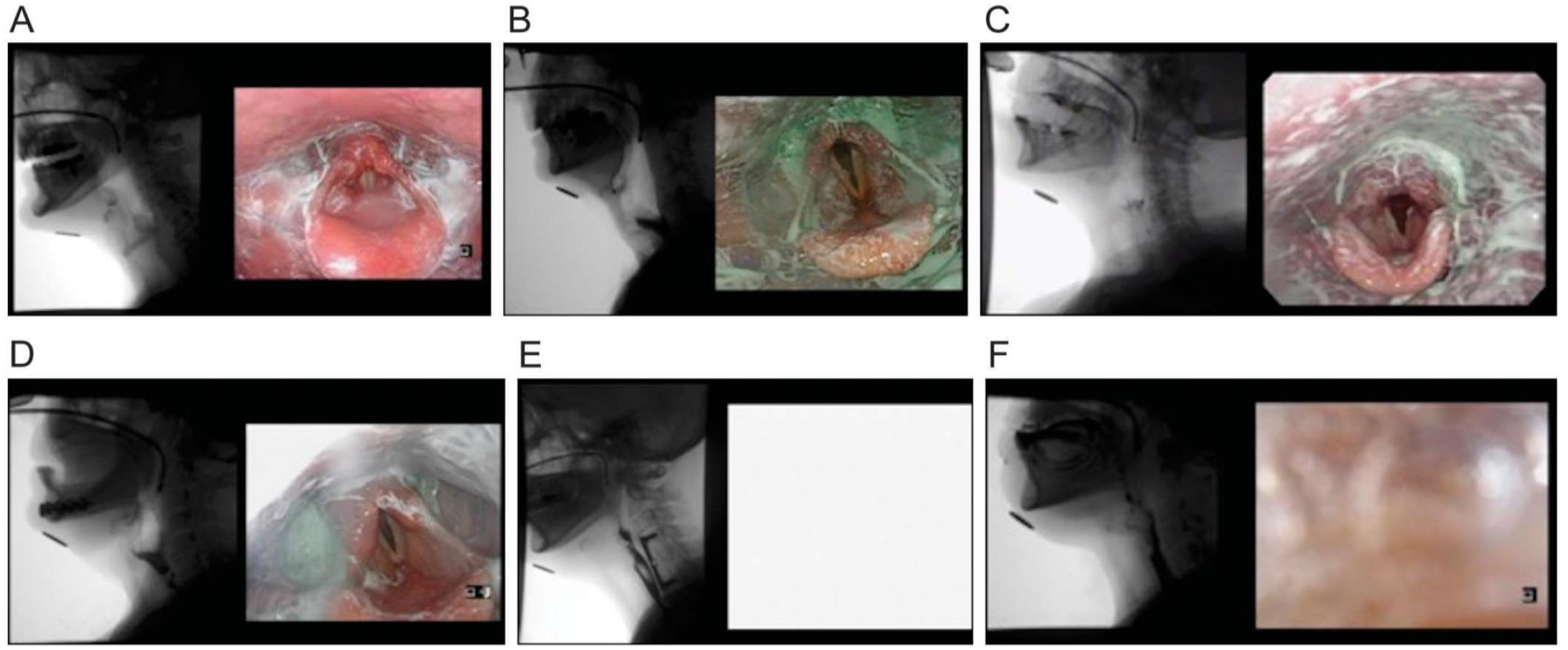
ARTICLE INFO

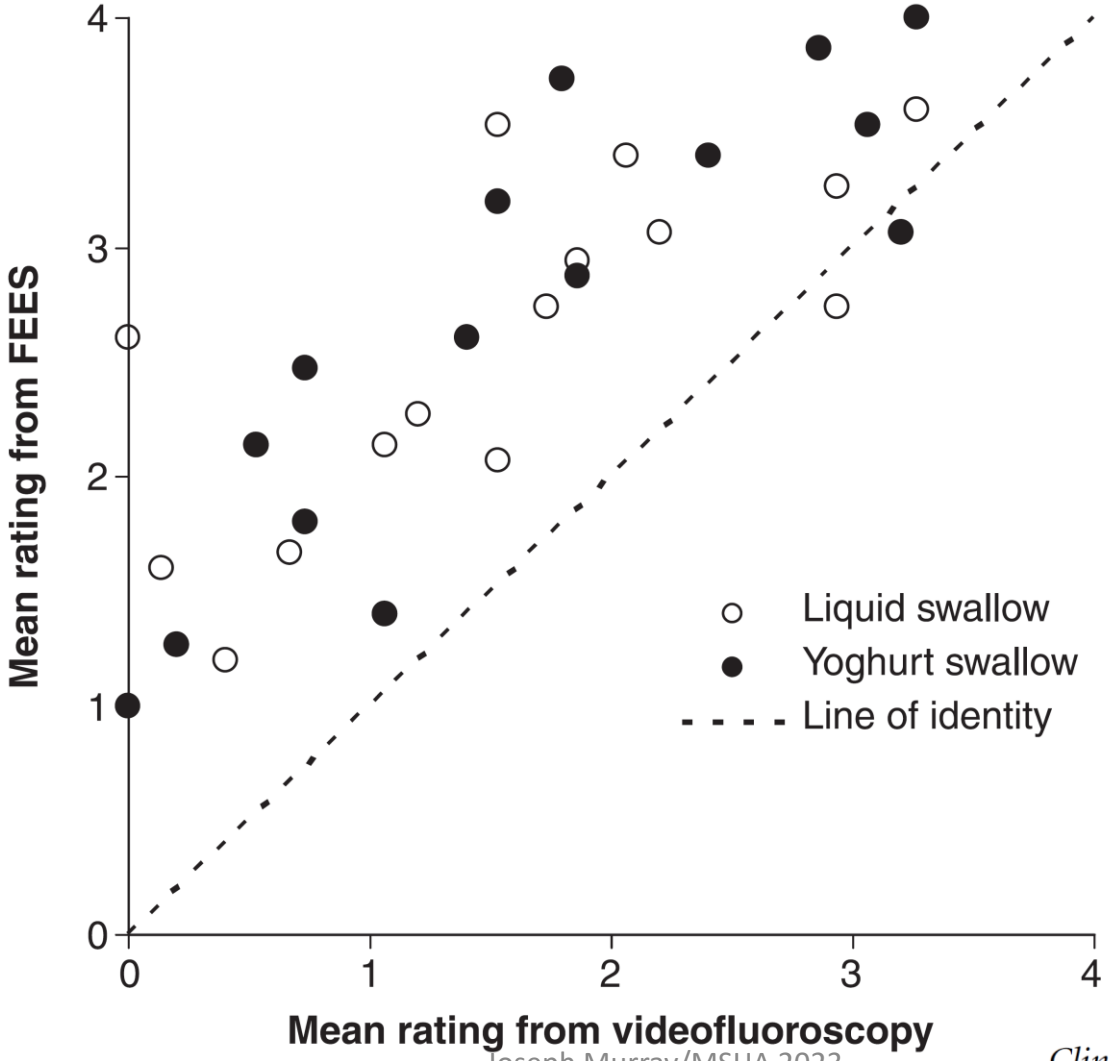
Article History:
Received June 28, 2022

ABSTRACT

Purpose: Fiberoptic endoscopic evaluation of swallowing (FEES) is a well-respected swallowing assessment, harking back to 1988 when it was first pub-

Figure 2. Example simultaneous study comparisons of modified barium swallow (MBS) versus Flexible Endoscopic Evaluation of Swallowing (FEES) and their Penetration–Aspiration Scale (PAS) scores for that swallow. If a PAS of ≥ 2 was noted, then an indication of when it was observed to occur was noted: before, during, or after the swallow. (A) MBS: rated as PAS 2 (during), FEES: rated as PAS 3 (during). (B) MBS: rated as PAS 4 (during), FEES: rated as PAS 5 (during). (C) MBS: rated as PAS 2 (during), FEES: rated as PAS 5 (during). (D) MBS: rated as PAS 2 (during), FEES: rated as PAS 3 (during). (E) MBS: rated as PAS 2 (during), FEES: rated as PAS 1. (F) MBS: rated as PAS 2 (during), FEES: rated as PAS 1.





Clin. Otolaryngol. 2006, **31**, 425–432

Dysphagia (2021) 36:96–107
https://doi.org/10.1007/s00455-020-10106-1

ORIGINAL ARTICLE

Measuring Vallecular Volume on Flexible Endoscopic Evaluation of Swallowing: A Proof of Concept Study

Kaylee Kim[1] · Jessica M. Pisegna[2,3] · Samantha Kennedy[1] · Susan Langmore[2]

- Compiled images from simultaneous FEES and MBS videos to create 3D images

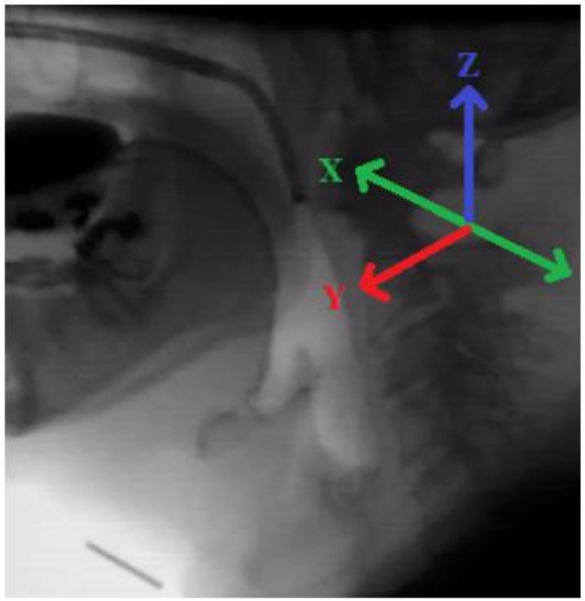
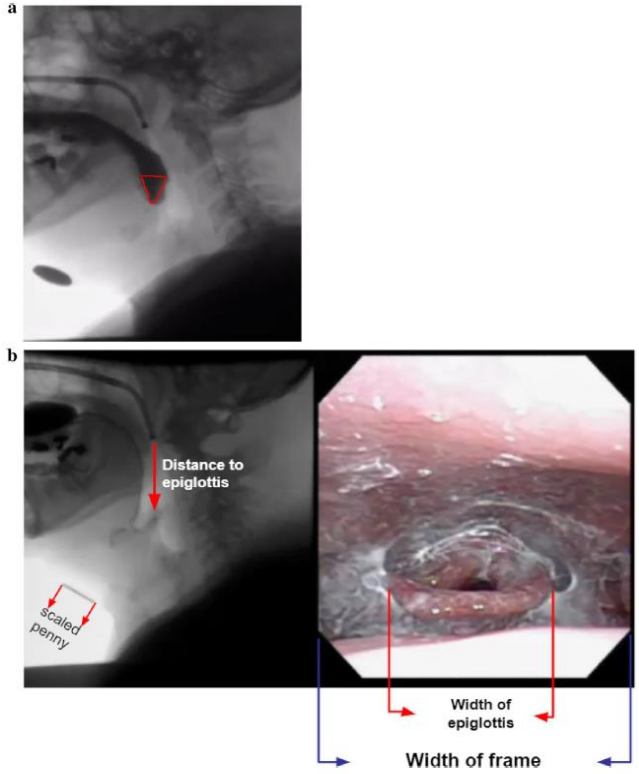


Fig. 2 The three-dimensional concept (3 axes) mapped onto the MBS video. Green arrow = X axis, red arrow = Y axis, blue arrow = Z axis

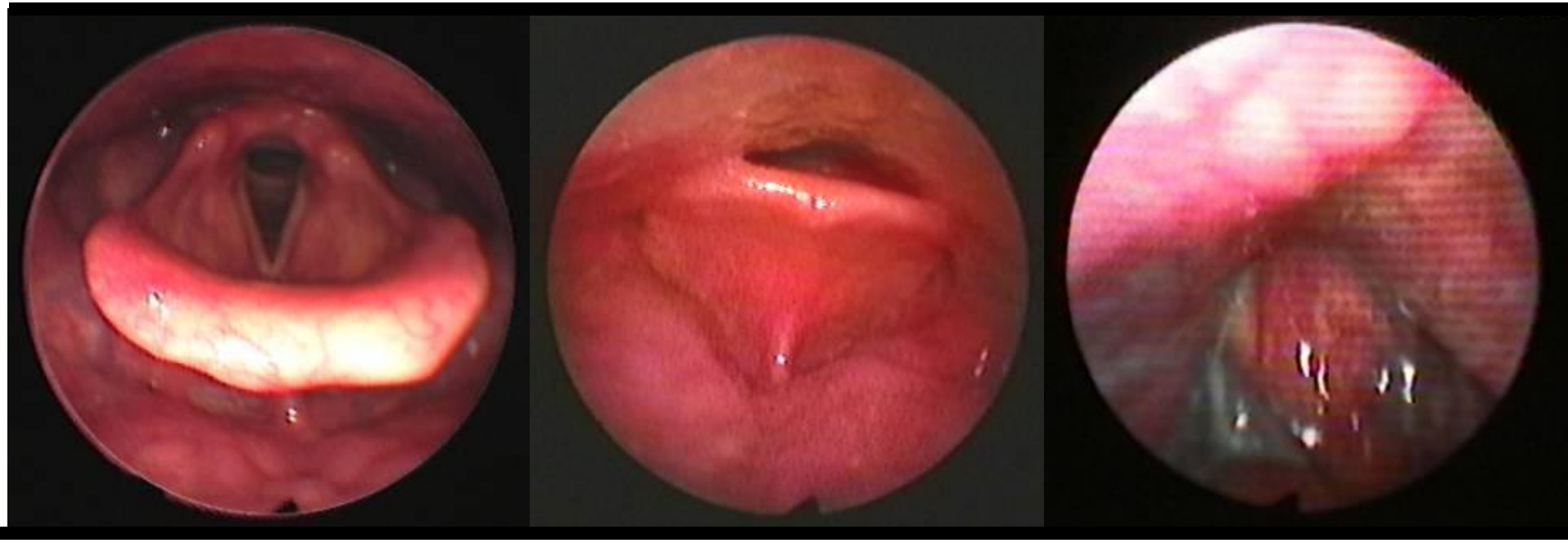


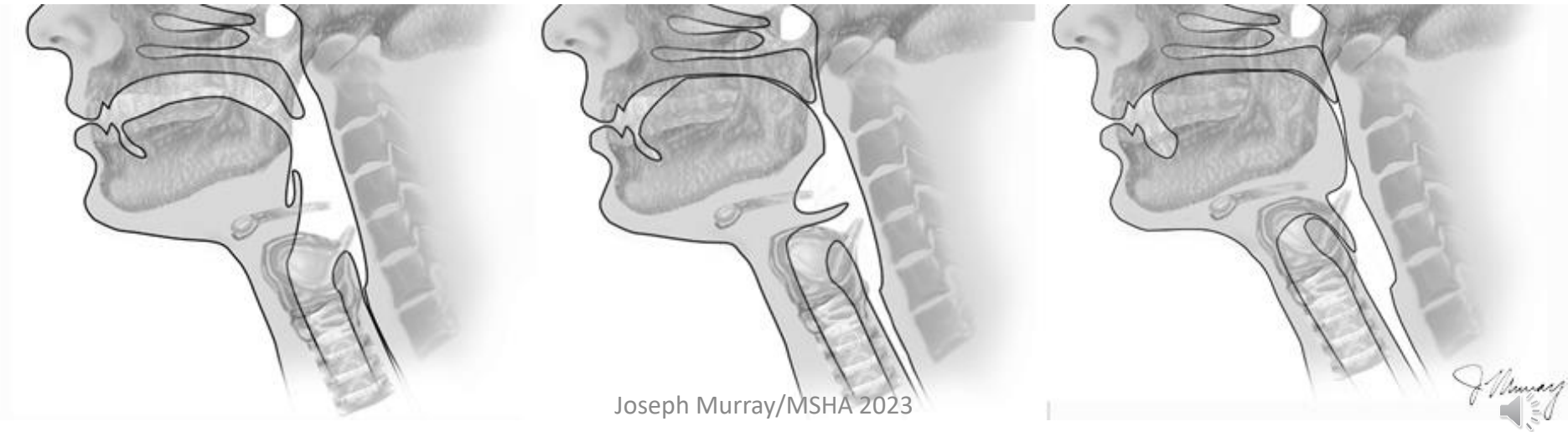
Kim (2021) Vallecular Volume Prediction

Table 10 Distribution of vallecular dimensions among study participants stratified by sex

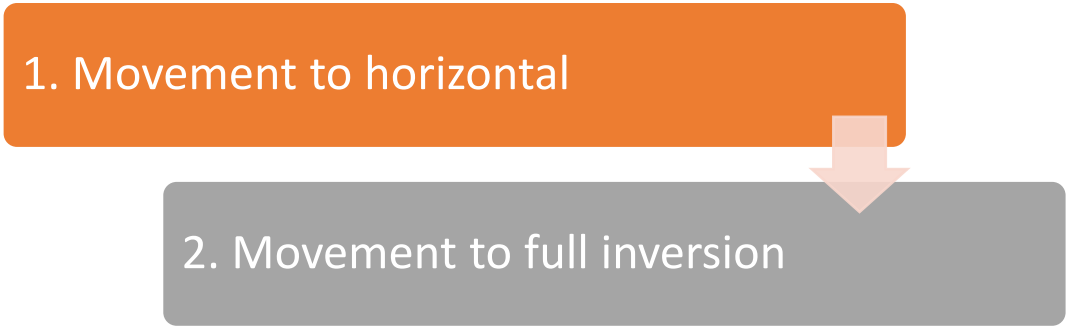
Sex	*N*	Mean epiglottic width, (SD) (mm)	*P* value	Mean vallecular volume, (SD) (mL)	*P* value
Male	18	18.52 (9.11)	0.773	1.74, (0.91)	0.195
Female	19	17.81 (4.97)		1.38 (0.74)	

Laryngeal elevation/Epiglottal Iversion



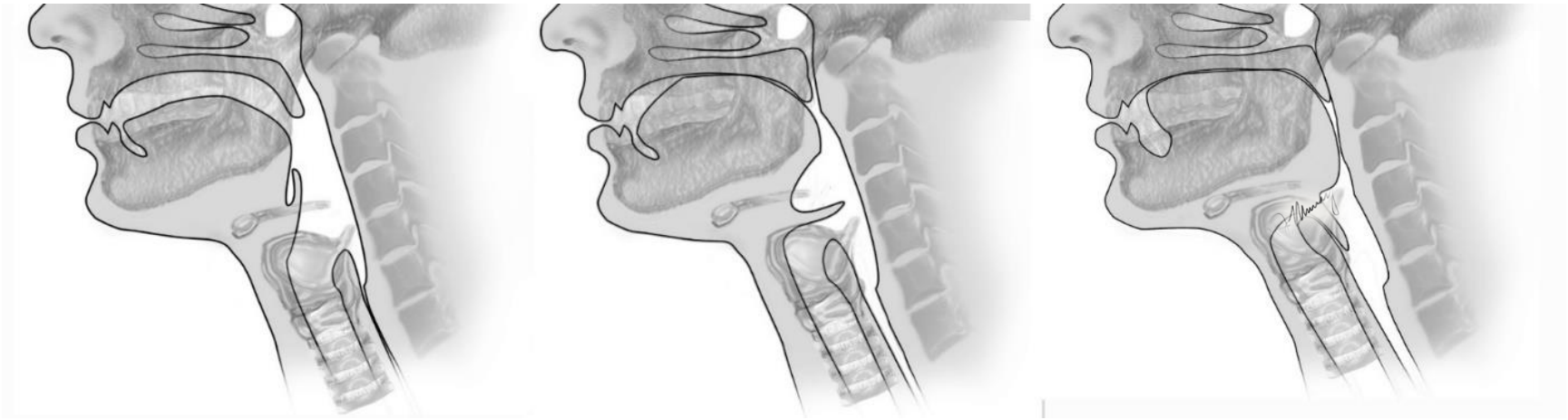


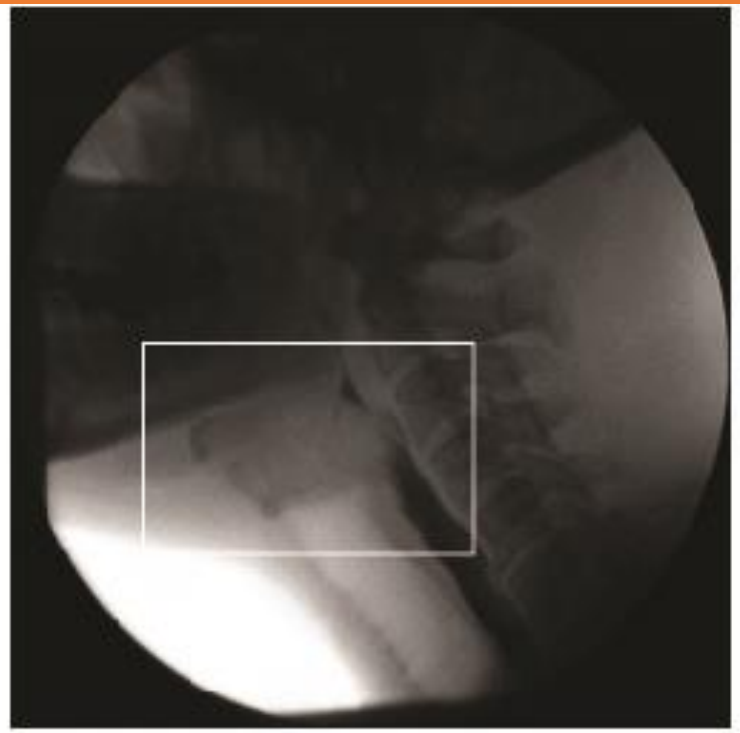
Epiglottal Inversion



- Mechanism for movement is unclear
- Likely multifactorial but closely related to
  - Tongue base retraction
  - Pharyngeal shortening/laryngeal elevation
  - Long pharyngeal muscles (styloglossus, hyoglossus)

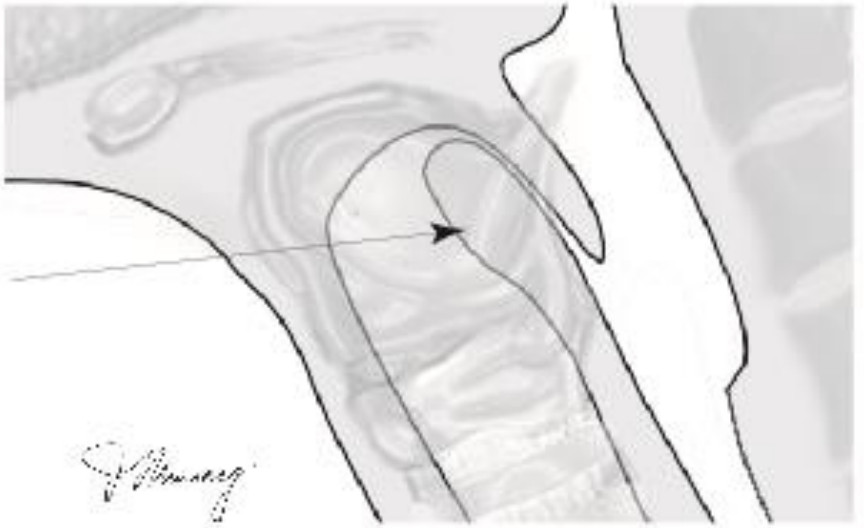
Laryngeal Elevation/Epiglottal Inversion





Area of inset

Arytenoid tilted forward



Video V-26
Normal epiglottic inversion

Abnormal Epiglottic Function

- Often present with vallecular retention
- Structural deficits
  - Congenital defect
  - Surgical resection
  - Edema
- Obstruction (cervical osteophytes)
- Poor muscular function
    - Tongue base retraction
    - Pharyngeal shortening/elevation

Video V-27
Abnormal inversion of epiglottis

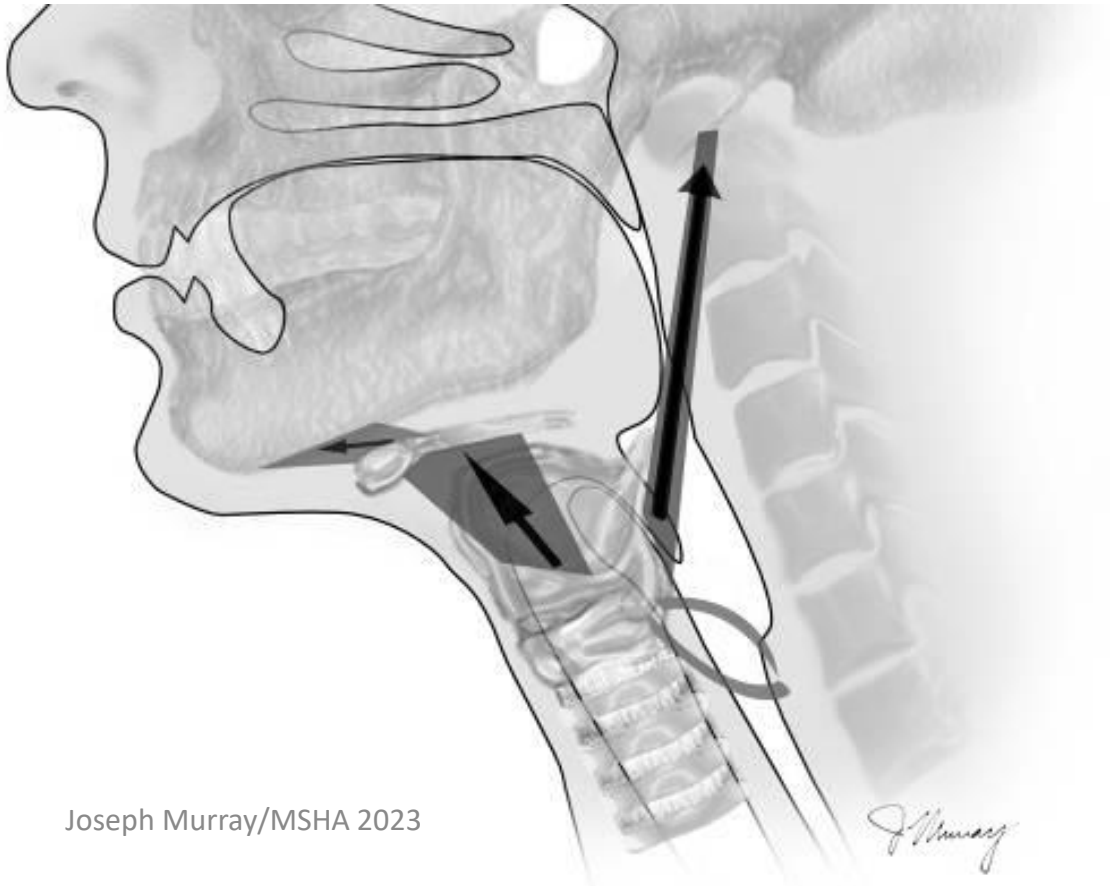
Hyolaryngeal Elevation

- As the hyolaryngeal complex elevates
  - Floor of the pharynx elevates with it resulting in a shortening of the pharynx.
- Elevation has two components:
  - Anterior movement
  - Superior movement

Pharyngeal Shortening/Laryngeal Elevation

Pharyngeal shortening

- Stylopharyngeal contraction

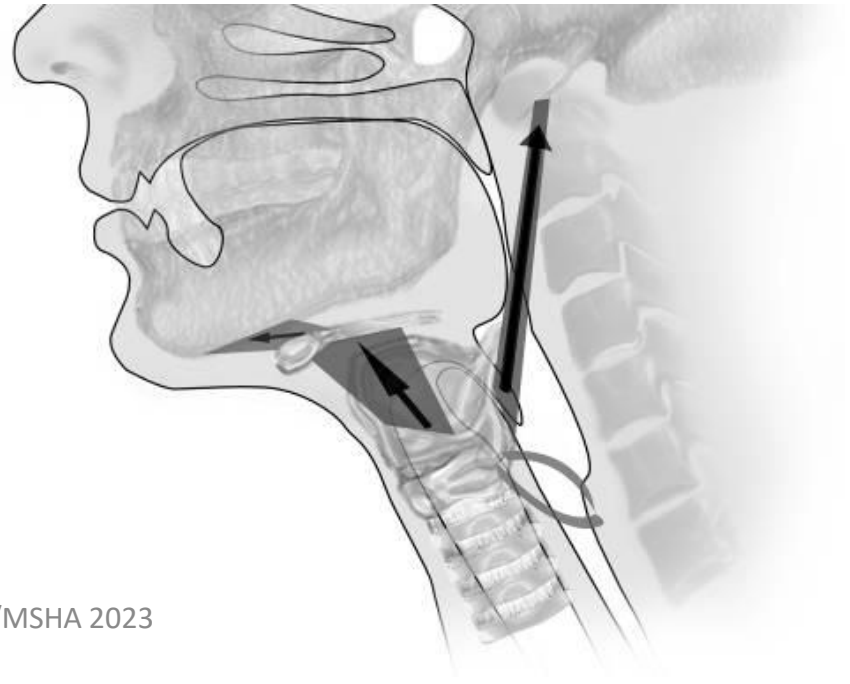


Laryngeal elevation

- Suprahyoid contraction
- Thyrohyoid contraction

Hyolaryngeal Elevation

- As the hyolaryngeal complex elevates
  - Floor of the pharynx elevates with it resulting in a shortening of the pharynx.
- Elevation has two components:
  - Anterior movement
  - Superior movement



Normal hyolaryngeal elevation

Hyolaryngeal Elevation

- Suprahyoid muscles contract after the mandible closes tightly
- Contraction from the immobile mandible allows
  - Vigorous fixation at full contraction of the suprahyoid muscles.
- Fixation of the hyoid and mandible together offer a firm base for the elevation of the thryoid and cricoid cartilages.

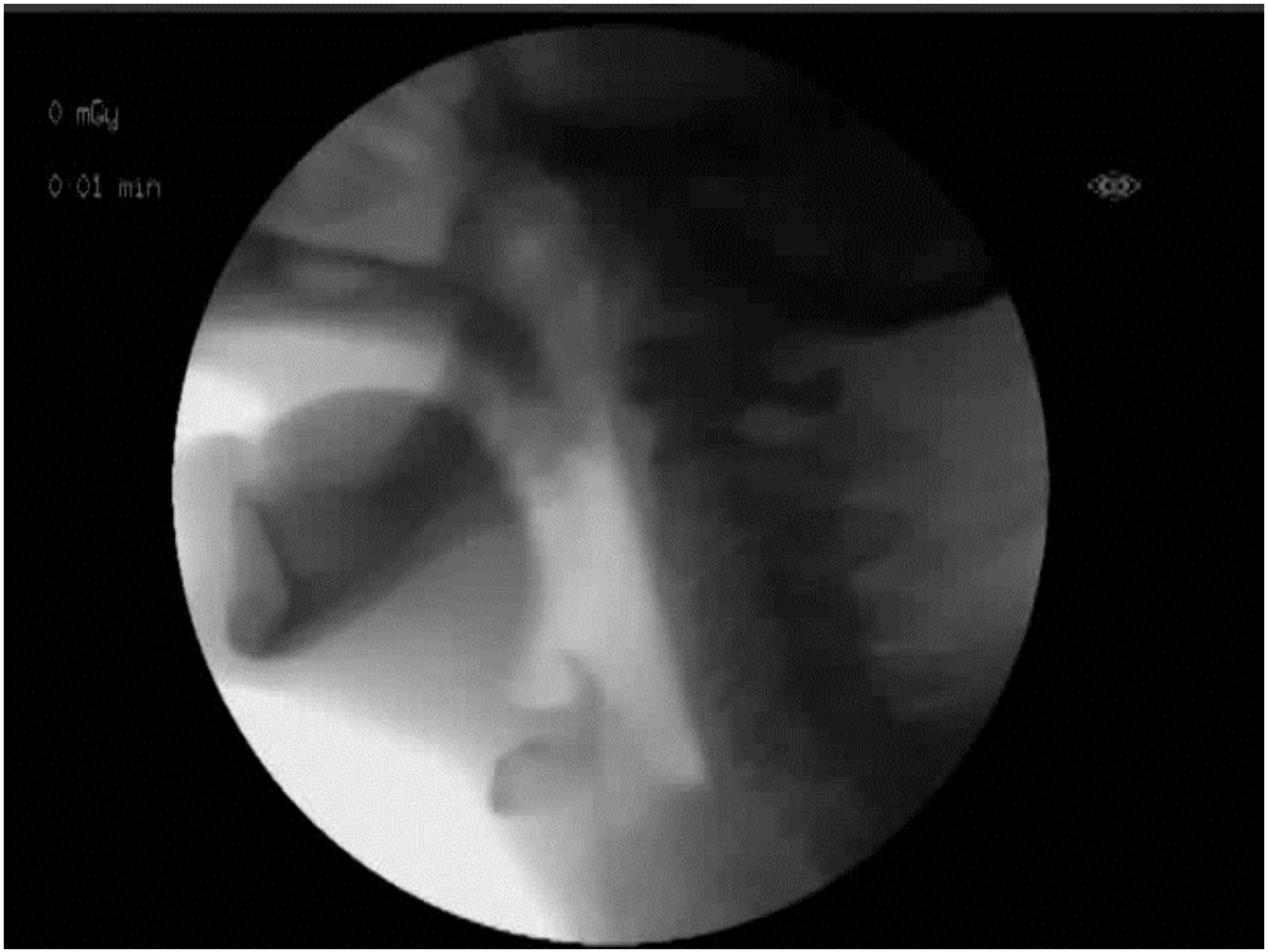
Objective Measures of Hyoloaryngeal Elevation

- Larynx moves approximately 2 – 2.5 centimeters, from rest to maximum elevation
  - (Dengel et al., 1991; Kahrilas, Lin, Chen, & Logemann, 1996; Kuhl, Eicke, Dieterich & Urban, 2003)
- Visually tracking hyoid and laryngeal elevation:
  - Inexact (at best!!!)
- Perlman, Van Daele, and Otterbacher (1995)
  - Correlation analysis comparing subjective and objective assessments of hyoid movement
    - Found that the correlation was not strong.
    - Evaluators were more likely to judge hyoid elevation to be inadequate when the anterior movement component was reduced

Objective Measures of Hyoloaryngeal Elevation

- Exact minimum amount of hyoid and laryngeal elevation necessary to adequately promote epiglottic inversion and UES opening is not known
  - (Chi-Fishman & Sonies, 2002)
- If it were known, it would very likely be difficult to determine the presence of a defect subjectively

A few examples of poor elevation



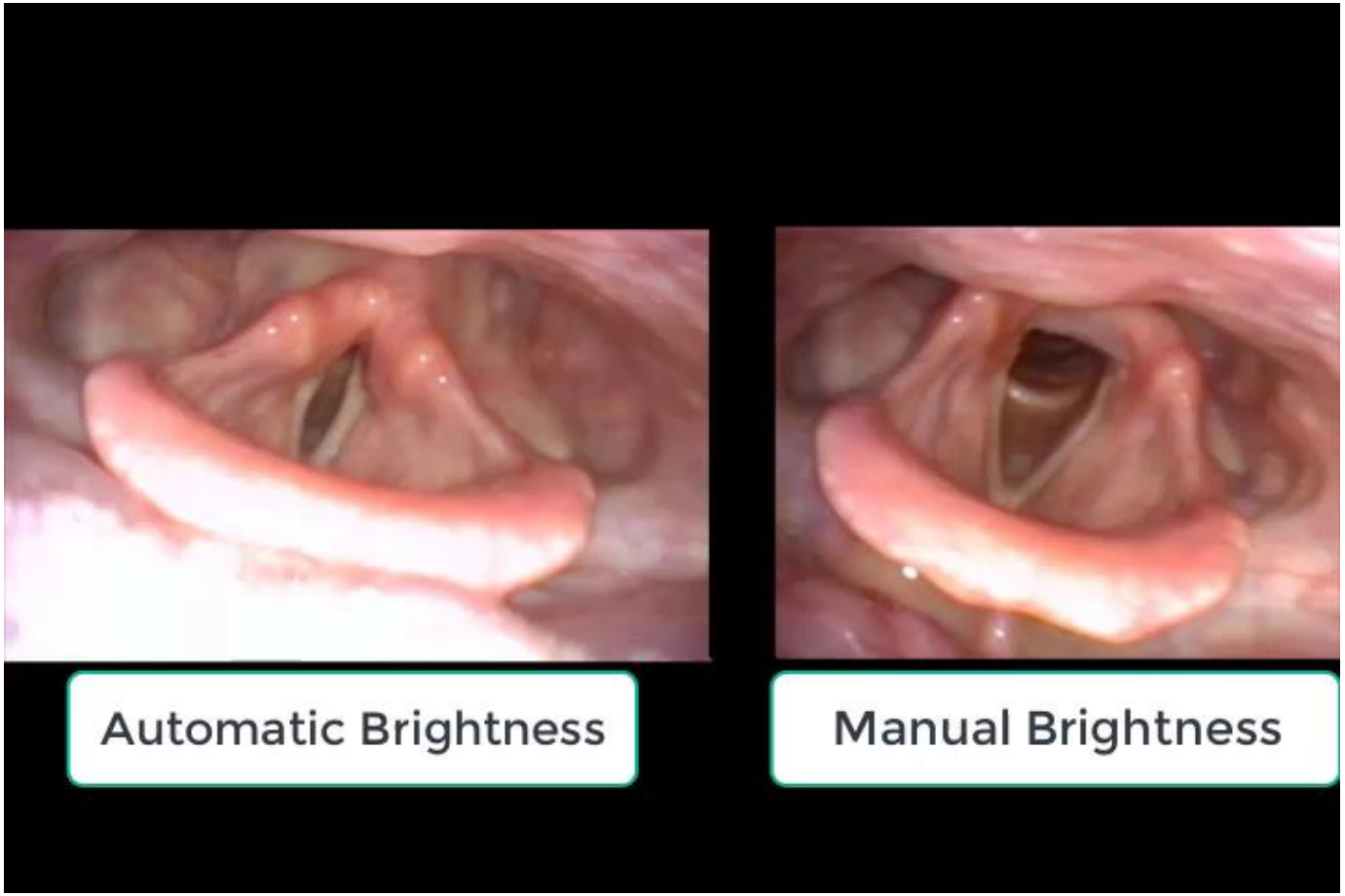
V-29 Poor laryngeal elevation.mpg

Tips and Tricks: Viewing Epiglottic Inversion

Video Processor Settings

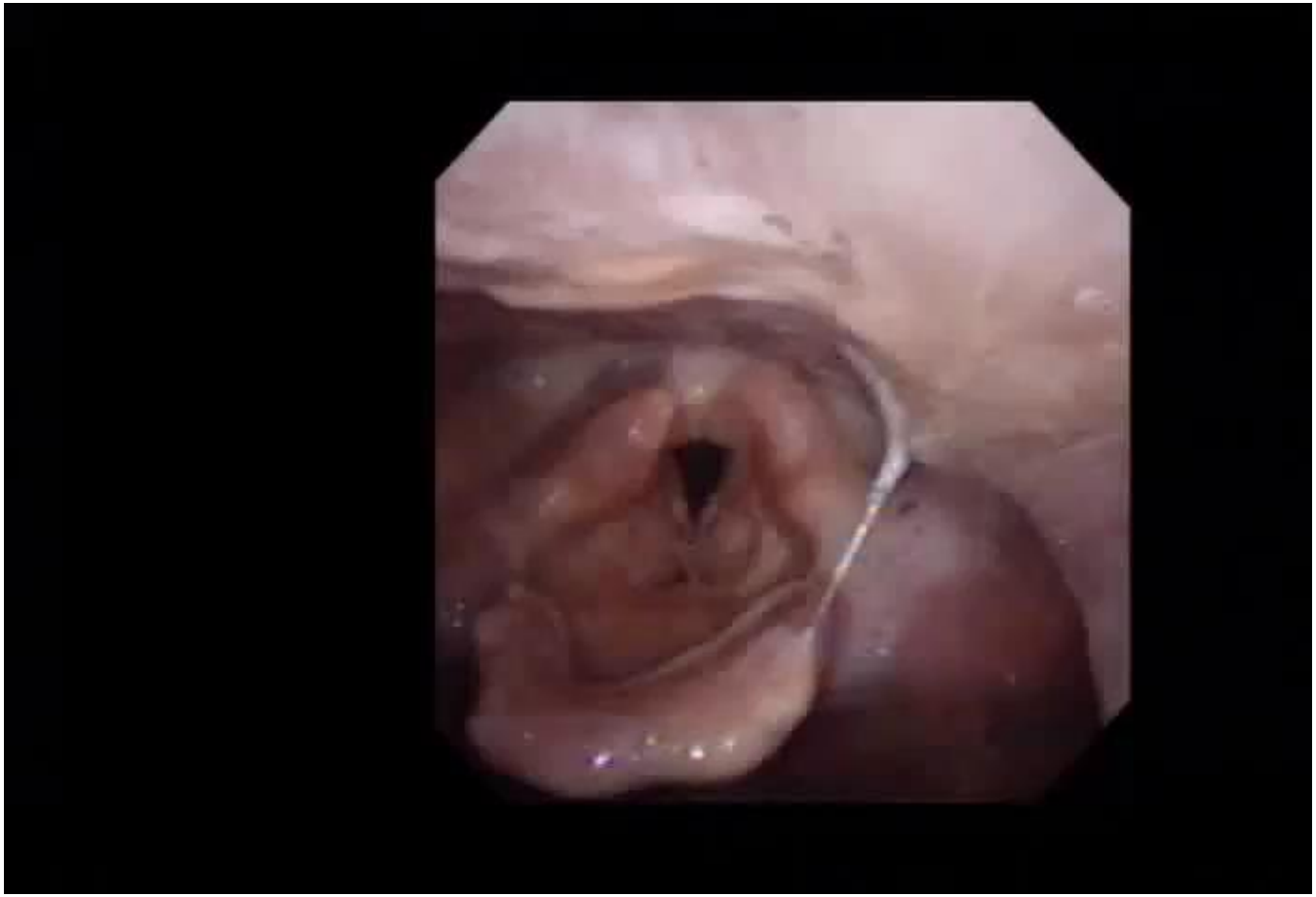
- Check Video Processor Settings!
  - Goal is not to get a close view of surface mucosa
  - Goal is to maximize visualization of swallow function
  - Best visualization of the post-swallow segment
- TURN-OFF!
  - Automated light brightness
  - Automated auto-iris
- Set light brightness to “MANUAL”

Tips and Tricks:
Viewing Epiglottal Inversion



Epiglottal Inversion

- Inversion dependent on
  - Hyolaryngeal elevation
  - Hyo-epiglottic ligament traction
- Visualization of inversion
  - Allows for inference of adequate elevation
- Visualization of lack of inversion
  - Allow for inference of poor elevation
    - Distal pharyngeal retention strengthens inference



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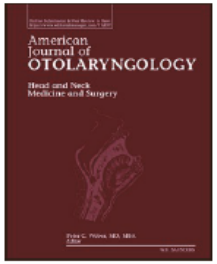

Absent epiglottic inversion as seen on flexible endoscopic evaluations of swallowing (FEES) is associated with a gestalt reduction in swallowing mechanics

Amr Jijakli [a], James C. Borders [b], Amy Gottlieb [b,c], Emily Ramirez [a], Rebecca Leonard [e], Susan E. Langmore [c], Joseph Murray [d], Jessica M. Pisegna [b,c,*]

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[b] *Department of Otolaryngology, Boston Medical Center, Boston, MA, United States of America*
[c] *Boston University Chobanian & Avedisian School of Medicine, Boston, MA, United States of America*
[d] *VA Ann Arbor Health Care System, Ann Arbor, MI, United States of America*
[e] *University of California at Davis, Davis, CA, United States of America*

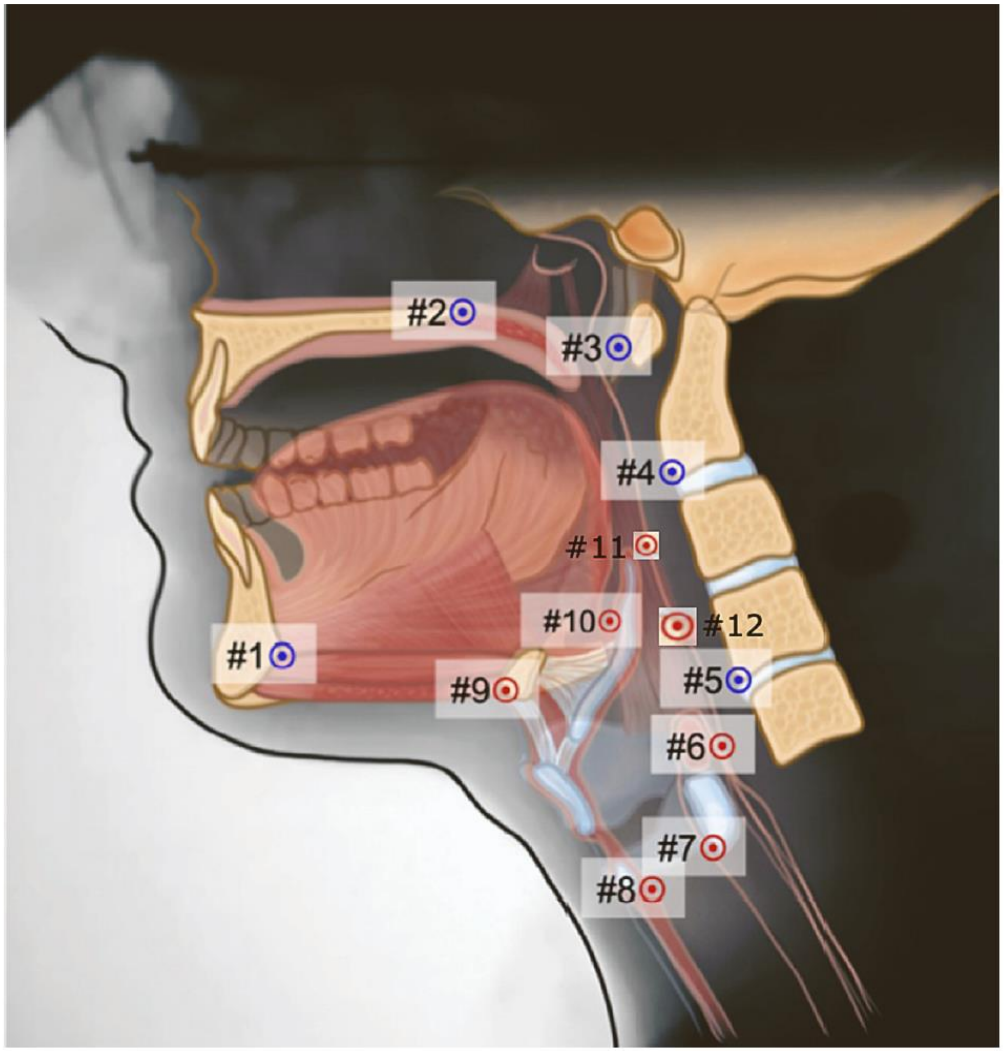
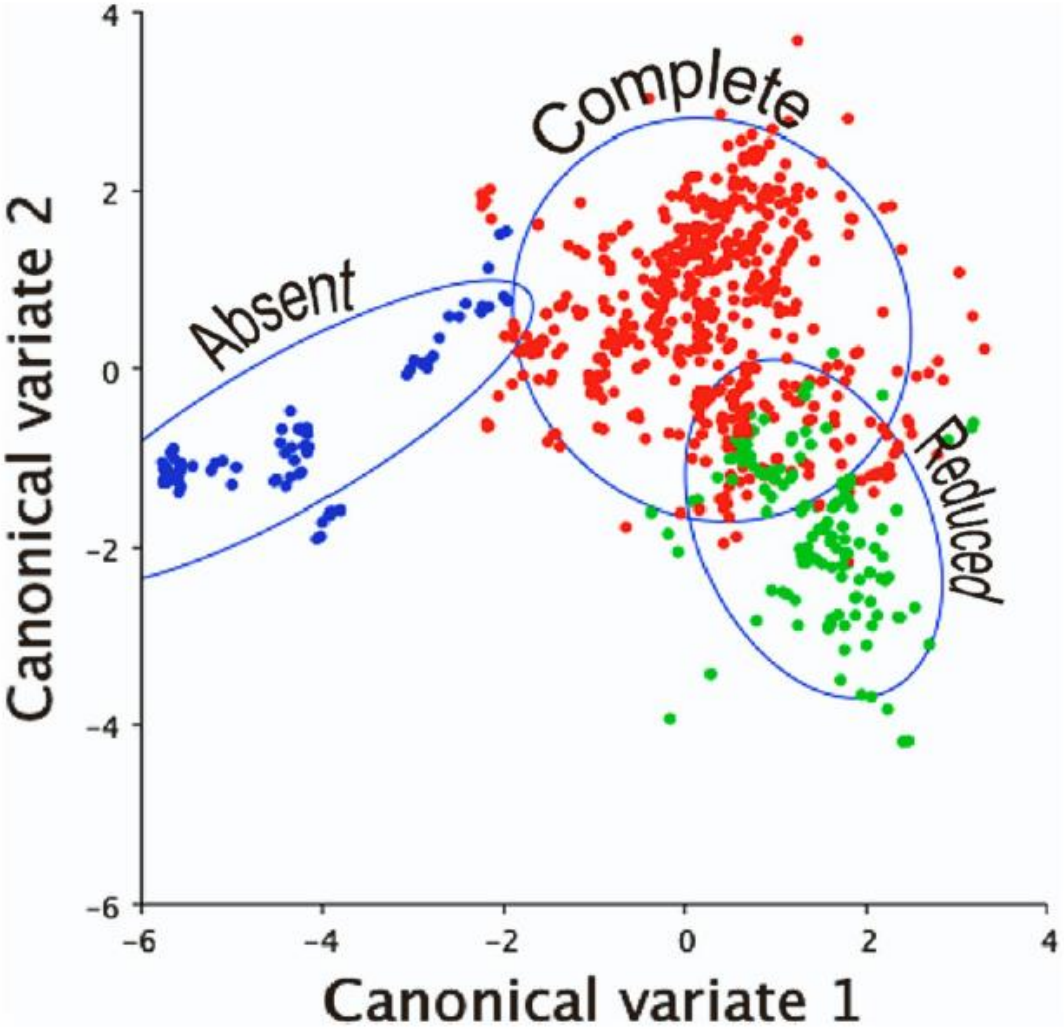


Fig. 3. The twelve swallowing landmarks on MBS.


Absent
Complete
Reduced
Canonical variate 2
Canonical variate 1
4
2
0
−2
−4
−6
−6
−4
−2
0
2
4

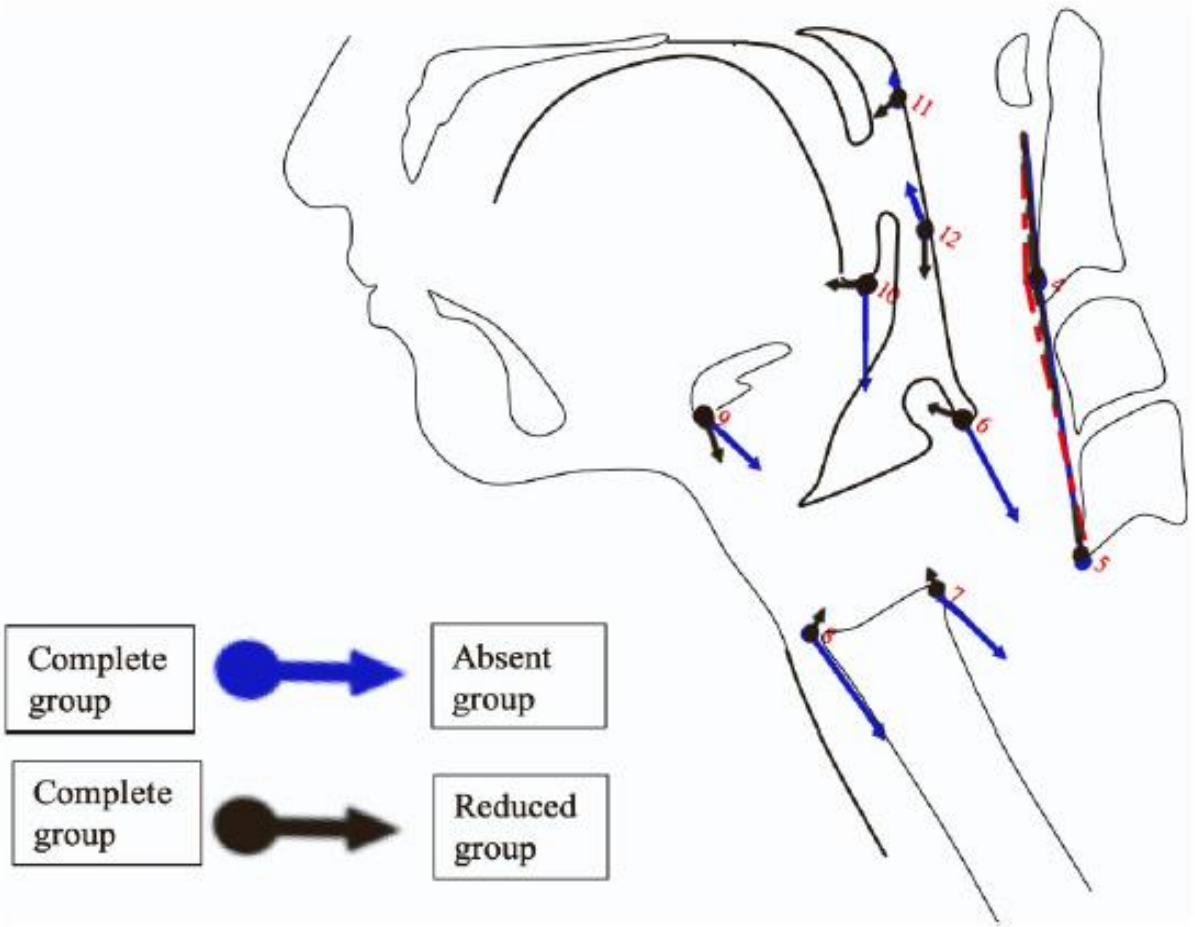

Complete group
Absent group
Complete group
Reduced group

Table 2

Mean hyoid movement by group type.

		Mean (cm) ± SD	
Epiglottic inversion	N	Hyoid movement	Laryngeal elevation
Absent	2	2.22 ± 0.91	1.95 ± 0.96
Reduced	4	1.24 ± 0.12	1.74 ± 0.32
Complete	18	1.65 ± 0.39	2.24 ± 0.49

Hyoid and Laryngeal movements are in centimeters (cm); SD = Standard Deviation.

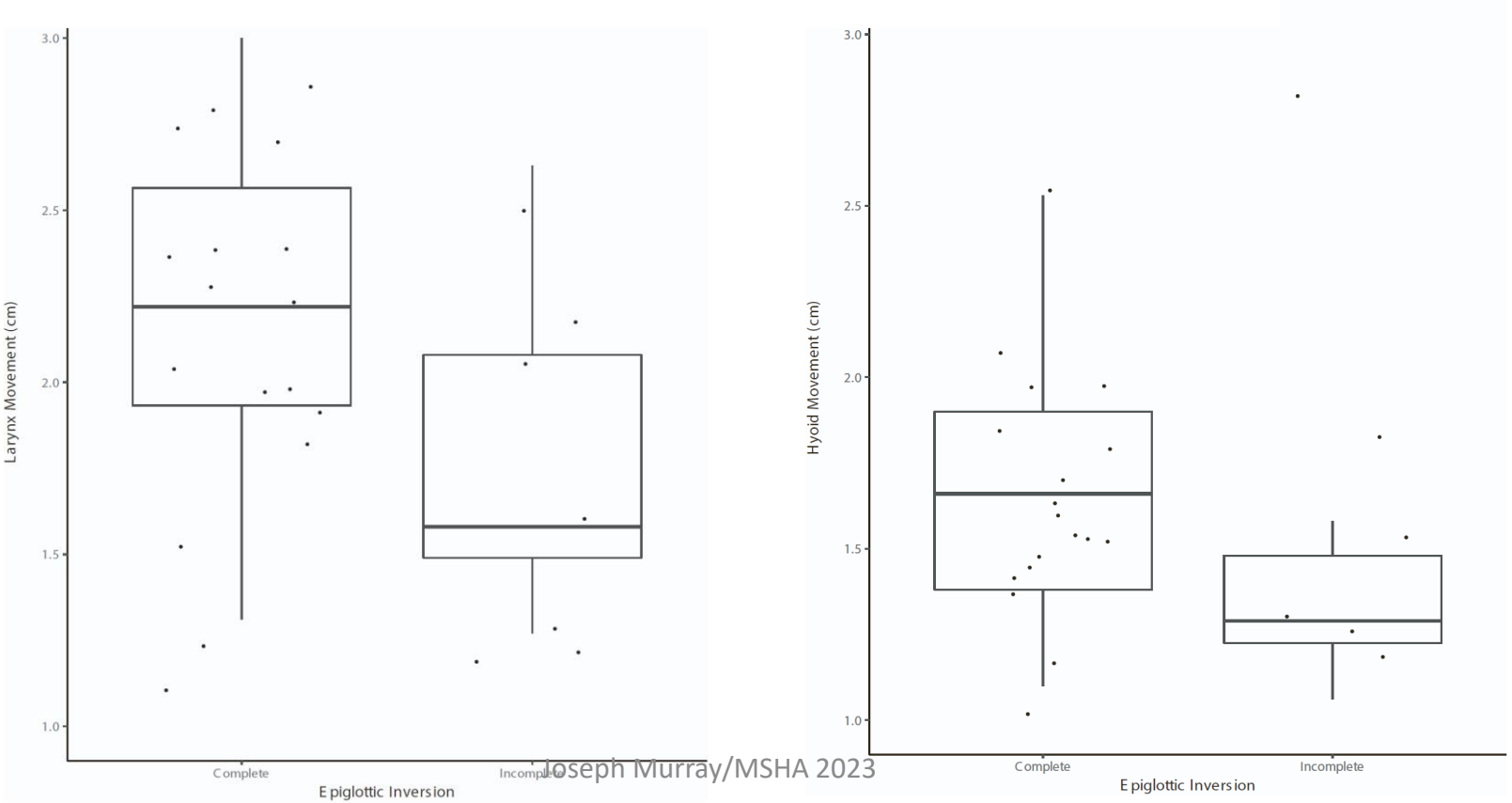


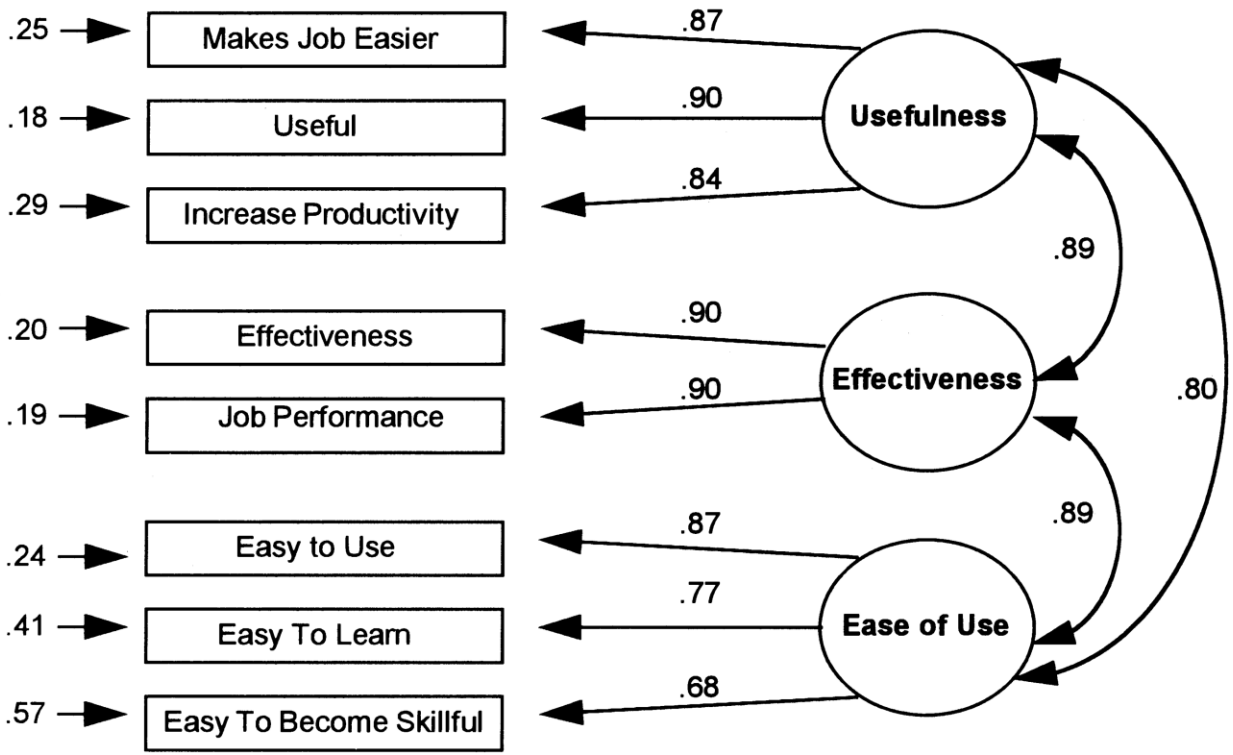
Fig. 6. Boxplot showing mean hyoid excursion in the *complete* vs *incomplete* epiglottic inversion groups.

Imaging the Abnormal Swallow

Scaling and Scaling Issues

A Word About Scaling

- Requirements
  - Construct validity
  - Useful
  - Effective
  - Easy to use
  - Repeatable



http://www.jstor.org/stable/249590

Reliability and Accuracy

High Reliability High Accuracy	High Reliability Low Accuracy
Low Reliability High Accuracy	Low Reliability Low Accuracy

A Word About Protocols

- The **GOOD**:
  - Predictable and consistent data set
  - Uniformity in delivery of care
  - Check lists keep you on track

- The **BAD:**
  - Predictable and consistent data set
    - Tempting to believe “one size fits all”
    - Suppresses innovation
  - Uniformity in delivery of care
    - May not reveal idiosyncrasies of the individual
    - Personalization more powerful than generalization
    - All patients are an N=1

Ann Arbor FEES Protocol

The examination is broken into two loose sections:

- Part One
- Observation:
  - Occurs during the initial passage of the endoscope and is reserved for:
    - The survey of anatomy
    - Elicitation of anatomic movements
    - Observation of secretion management
    - Monitoring of spontaneous swallows

Ann Arbor FEES Protocol

- **Part Two**
- Presentation of food and liquid:
  - Various consistencies of food are presented
  - Interventions are attempted

children

MDPI

Review

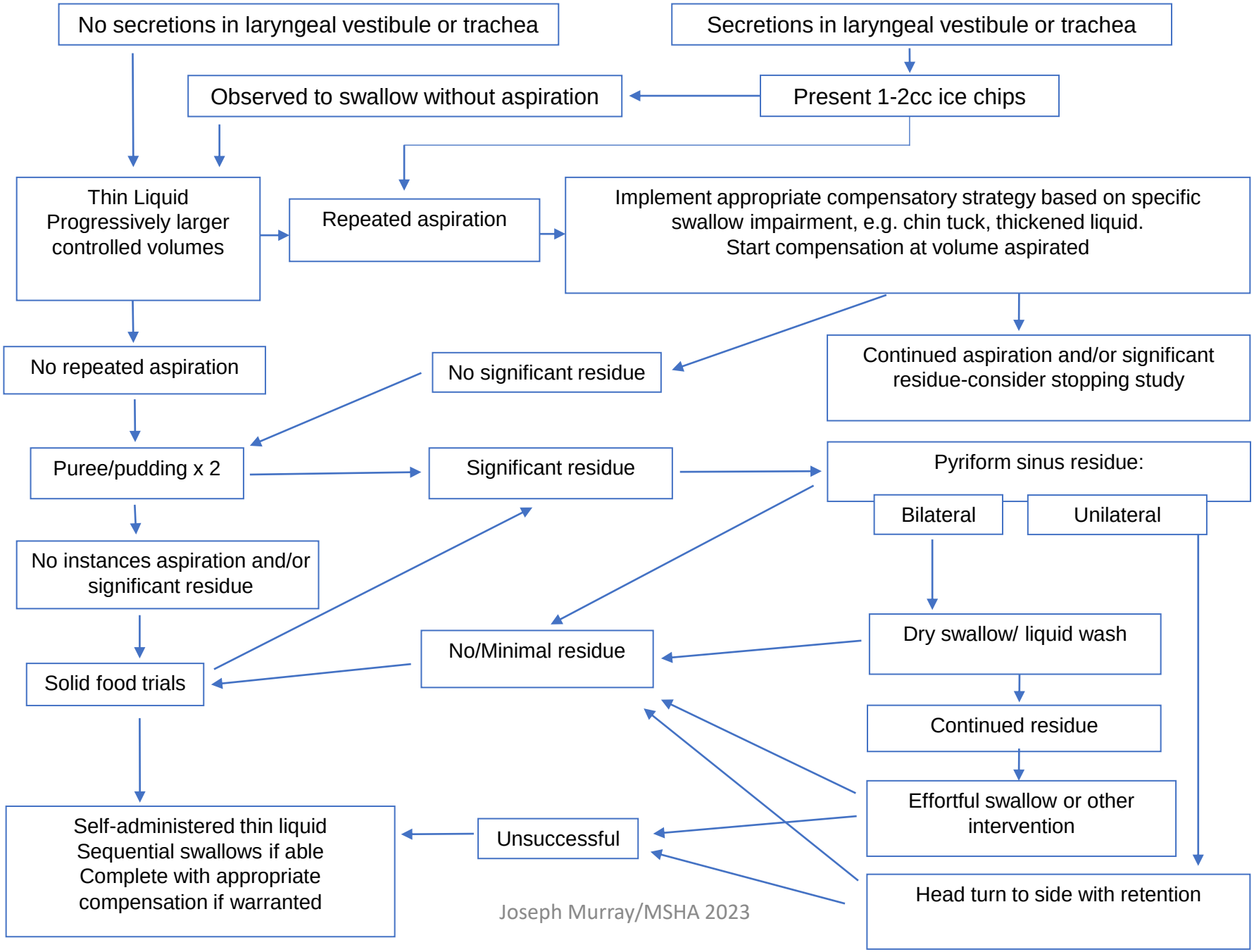
Dysphagia Management in Children: Implementation and Perspectives of Flexible Endoscopic Evaluation of Swallowing (FEES)

Athanasia Printza *, Katerina Sdravou and Stefanos Triaridis

Table 1. A pediatric FEES protocol.

Preprocedure preparation
History
Reason for referral
Current feeding status/difficulties
Diagnoses
Education of the family about the procedure
Oral sensorimotor skills
Level of alertness
Posture and position
Control of oral secretions
Procedure preparation
Nasal decongestion/anesthesia
Positioning
Food and utensils according to the developmental level and the reported usual method of intake

Anatomy and physiology visualization
Nasopharynx: the adequacy of velopharyngeal closure
Oropharynx
Hypopharynx and larynx at rest
Vocal cord mobility (abduction/adduction assessed as the child cries, phonates, coughs, or holds breath)
Pharyngeal squeeze
Secretion management and swallow frequency
Response to aspiration of secretions
Vocal quality (normal/wet)
Sensation
Swallowing assessment: liquids, purees, solids
Assessment of swallowing as the child drinks and eats various bolus consistencies
Swallowing onset time
Timely onset/delay in onset: Initiation of swallow when bolus head in valleculae/
in pyriform/no appreciable swallow initiation
Laryngeal penetration
Inconsistent, consistent, location
Aspiration
Prior to swallow, following swallow
Pharyngeal Residue
Location
Required multiple swallows to clear (spontaneous or at verbal cue)
Compensatory and adaptive treatments
Positioning
Rate of intake
Postural maneuvers
Alternating solids/liquids to clear pharyngeal residue
Effortful swallow


No secretions in laryngeal vestibule or trachea
Secretions in laryngeal vestibule or trachea
Observed to swallow without aspiration
Present 1-2cc ice chips
Thin Liquid
Progressively larger
controlled volumes
Repeated aspiration
Implement appropriate compensatory strategy based on specific swallow impairment, e.g. chin tuck, thickened liquid.
Start compensation at volume aspirated
No repeated aspiration
No significant residue
Continued aspiration and/or significant residue-consider stopping study
Puree/pudding x 2
Significant residue
Pyriform sinus residue:
Bilateral
Unilateral
No instances aspiration and/or significant residue
Dry swallow/ liquid wash
No/Minimal residue
Solid food trials
Continued residue
Effortful swallow or other intervention
Self-administered thin liquid
Sequential swallows if able
Complete with appropriate compensation if warranted
Unsuccessful
Head turn to side with retention
Joseph Murray/MSHA 2023

Penetration-Aspiration Conventions

- Penetration- The passage of material into the laryngeal inlet without passing below the level of the true vocal folds.
- Aspiration- The passage of material below the level of the true vocal folds

Table 1. Eight-Point Penetration Aspiration Scale.15.

Table 1. Eight-Point Penetration Aspiration Scale.[15]

1. Material does not enter airway
2. Material enters the airway, remains above the vocal folds, and is ejected from the airway
3. Material enters the airway, remains above the vocal folds, and is not ejected from the airway
4. Material enters the airway, contacts the vocal folds, and is ejected from the airway
5. Material enters the airway, contacts the vocal folds, and is not ejected from the airway
6. Material enters the airway, passes below the vocal folds, and is ejected into the larynx or out of the airway
7. Material enters the airway, passes below the vocal folds, and is not ejected from the trachea despite effort
8. Material enters the airway, passes below the vocal folds, and no effort is made to eject

Meredith B. O'Dea et al. Ann Otol Rhinol Laryngol 2015;0003489415570935

PAS Scaling
Good and Less Good

- Good!
  - The PAS is ubiquitous
  - Striates events of aspiration and penetration
  - Further striates sequalae to aspiration or penetration
- Less Good
  - The scale is purported to be an interval scale
  - Combines two domains
    - Depth of bolus travel
    - Clearance of the airway
  - Likely categorical rather than ordinal or interval
    - Data manipulation issues

McCullough, G. H., Rosenbek, J. C., Robbins, J. A., Coyle, J. L., & Wood, J. L. (1998). Ordinality and intervality of a penetration-aspiration scale. Journal of Medical Speech Language Pathology, 6, 65-72.

- “The present study reveals two violations of ordinality. A high proportion of judges through that the material remaining in the airway, regardless of the level to which it descended, was more severe than if material, regardless of depth, was expelled.”
- 3 and 4 were reversed
- 5 and 6 were reversed

McCullough et al. 1998

- “Judges believed that where material ends up is more critical to severity than is the level to which the material descends.”
- Intervality is questioned
  - Distances between scores were not equal

Dysphagia (2017) 32:601–616
DOI 10.1007/s00455-017-9809-z

REVIEW ARTICLE

Reflections on Clinical and Statistical Use of the Penetration-Aspiration Scale

Catriona M. Steele[1,2] · Karen Grace-Martin[3]

- Construct validity intact:
  - Scale does what it said it does
    - Describes depth and expulsion
- Rare Scores:
  - 4&6 appear much less common than other scores
    - Poses challenges for score distribution
- Ordinality:
  - Not ordinal, should be a categorical scale
  - Described well by McCullough
- Intervality:
  - See Ordinality
    - Data is not continuous
      - Often see means reported with decimal places
      - At least one study with means of 4.9 and 5.1 that were described as “statistically significant”

Steele: PAS Reflections (cont)

- Reduce the number of “levels”
  - FEES unlikely to reveal level 2
- More appropriate to use frequency measures
  - Report “typical” or “most common”
- Use Quantiles
  - Crude but easy to interpret as categories
  - Look for shifts between categories
    - “healthy” (low on the scale)
    - “unhealthy” (high on the scale)
- Use logistic regression
  - Does not require continuous parameters

Proposed Reorganization of Scale

Table 2 Proposed reorganization of the 8-point Penetration-Aspiration Scale into a 4-level Categorical Penetration-Aspiration Scale

Categorical PAS level	Original PAS scores	Description
A	1, 2, and 4	PAS levels 1 and 2 reflect normal function. Similarly, PAS level 4 reflects an effective response to the slightly deeper penetration of material into the supraglottic space, resulting in the absence of any material in the airway at the end of the swallow
B	3, 5, and 6	PAS Levels 3, 5, and 6 all capture abnormal situations in which material remains in the laryngeal vestibule at the end of the swallow, extending as deep as (but not below) the level of the true vocal folds. These levels reflect failure of supraglottic levels of airway protection. Furthermore, unless timely attempts to initiate secondary clearing swallows are seen, these levels on the PAS may also reflect some degree of iSLN impairment
C	7	PAS Level 7 reflects failure of supraglottic, glottal and tracheal airway protection mechanisms in the presence of some residual recurrent laryngeal nerve sensory integrity
D	8	PAS Level 8 reflects impairment both of effective cough responses to aspiration and also of the sensory circuits that are typically expected to trigger protective cough reflexes

Kim, YJ., Koh, ES., Kim. HR., et al. The Diagnostic Usefulness of the Fiberoptic Endoscopic Evaluation of Swallowing J Korean Acad Rehab Med 2011; 35: 14-22

- 69 Subjects
  - Simultaneous VFSS and FEES
  - Blinded
  - Modified PAS Scale
- Significantly greater detection of aspiration using FEES

Table 2. The Penetration-Aspiration Scale and Modified Penetration-Aspiration Scale

Penetration-aspiration scale	Modified penetration-aspiration scale
1. Material does not enter the airway	1. Material does not enter the airway
2. Material enters the airway, remains above the vocal folds, and is ejected from the airway	2. Material enters the airway, remains above the vocal folds
3. Material enters the airway, remains above the vocal folds, and is not ejected from the airway	
4. Material enters the airway, contacts the vocal folds, and is ejected from the airway	3. Material enters the airway, contacts the vocal folds
5. Material enters the airway, contacts the vocal folds, and is not ejected from the airway	
6. Material enters the airway, passes below the vocal folds, and is ejected into the larynx or out of the airway	4. Material enters the airway, passes below the vocal folds, and effort is made to eject
7. Material enters the airway, passes below the vocal folds, and is not ejected from the trachea despite effort	
8. Material enters the airway, passes below the vocal folds, and no effort is made to eject	5. Material enters the airway, passes below the vocal folds, and no effort is made to eject

- Kim et al. 2011

Table 4. Detection Rates of Penetration, Aspiration and Pharyngeal Residues by Videofluoroscopic Swallowing Study and Fiberoptic Endoscopic Evaluation of Swallowing

	Penetration or aspiration			Aspiration			Vallecular residue			Pyriform sinus residue		
	VFSS alone	VFSS +FEES	p-value	VFSS alone	VFSS +FEES	p-value	VFSS alone	VFSS +FEES	p-value	VFSS alone	VFSS +FEES	p-value
SF	0.43	0.50	0.008	0.21	0.27	0.031	0.40	0.66	<0.001	0.43	0.54	<0.001
LF	0.69	0.80	0.008	0.39	0.49	0.016	0.70	0.86	0.001	0.61	0.75	0.002
SBD	0.11	0.27	<0.001	0.07	0.08	0.500	0.40	0.69	<0.001	0.22	0.40	<0.001
YOP	0.07	0.27	<0.001	0.04	0.08	0.063	0.44	0.79	<0.001	0.31	0.57	<0.001
NRD	0.10	0.27	<0.001	0.03	0.05	0.250	0.60	0.76	<0.001	0.24	0.46	<0.001

VFSS: Videofluoroscopic swallowing study, FEES: Fiberoptic endoscopic evaluation of swallowing, SF: Small amount of fluid, LF: Large amount of fluid, SBD: Semi-blended diet, YOP: Yogurt, NRD: Boiled rice

- **Kim et al. 2011**

Retention

- Disordered propulsive components
- Bolus Clearance and Driving Forces
  - Tongue Driving Force
  - Pharyngeal Contraction
  - Pharyngeal shortening/Laryngeal Elevation

Parameters of Instrumental Swallowing Evaluations: Describing a Diagnostic Dilemma

Jessica M. Pisegna[1,2,3] · Susan E. Langmore[1,2]

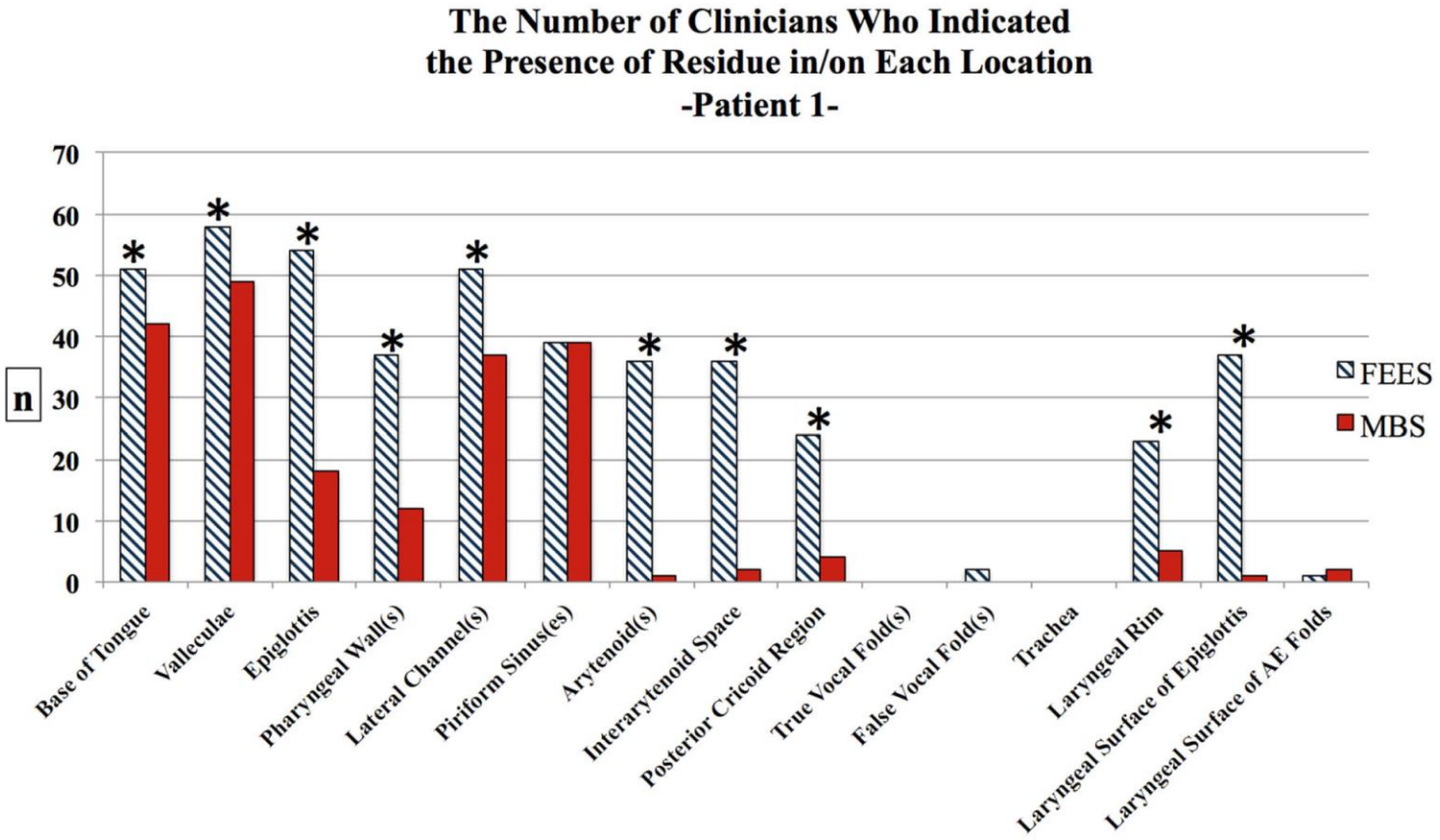


Fig. 2 The number of clinicians who indicated the presence of residue in Patient 1's FEES and MBS videos in 15 given locations. *Significant at $p < 0.05$

Dysphagia (2016) 31:462–472

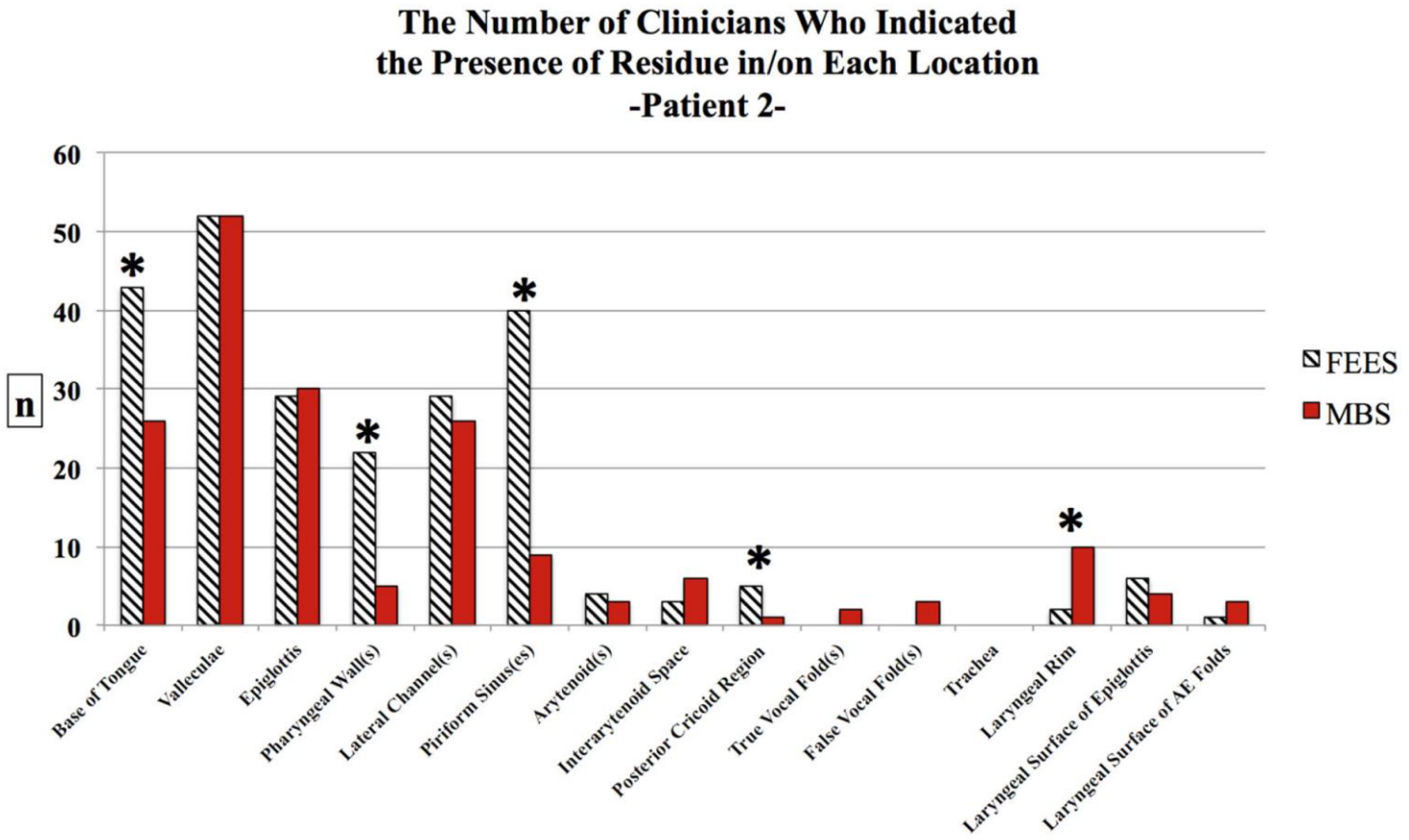
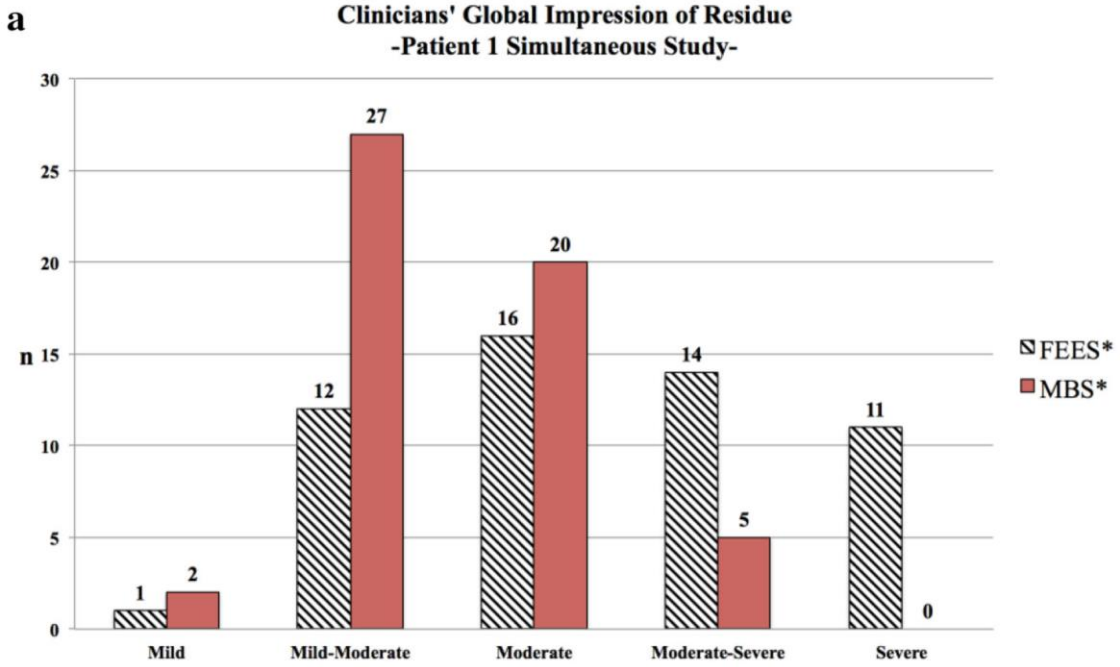
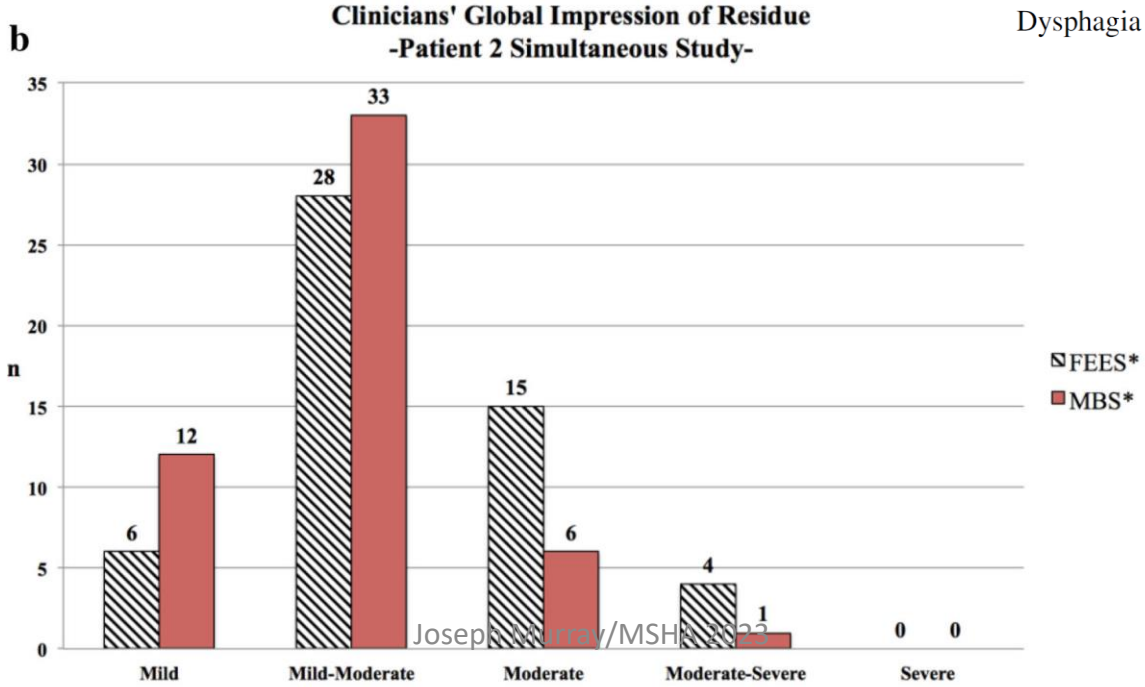


Fig. 3 The number of clinicians who indicated the presence of residue in Patient 2's FEES and MBS videos in 15 given locations. *Significant at $p < 0.05$

Dysphagia (2016) 31:462–472





Dysphagia (2016) 31:462–472

Table 3 Themes from open-ended responses to "*What do you find challenging about viewing FEES studies?*"

FEES challenges	Number of responses	Relative frequency (%)
White out (no visualization at the height of the swallow)/viewing aspiration during the swallow	18	31.0
Poor visualization of other structures and movements (oral phase, hyoid, UES opening)	8	13.8
Interpretation of the exam	5	8.6
Scope movement/positioning	4	6.9
Lack of experience	4	6.9
Narrow view	4	6.9
Identifying penetration/aspiration	4	6.9
Identifying structures	3	5.2
Knowing how to rate the amount of residue	3	5.2
Visualization after the swallow	2	3.4
No limitations	2	3.4
Patient cooperation/discomfort	1	1.7
Not answered	18	31.0
Total	76	100

Table 4 Themes from open-ended responses to "*What do you find challenging about viewing MBS studies?*"

MBS challenges	Number of responses	Relative frequency (%)
Poor visual quality (hazy)/black and white image	11	13.3
Viewing laryngeal structures and surface anatomy	9	10.8
Identifying and differentiating structures	8	9.6
Identifying residue location and amount	8	9.6
Limitations of a lateral and/or anterior-posterior view	7	8.4
Positioning and view limitations	7	8.4
Limited time, fluoro on/off, radiation concerns, not enough time to assess strategies	6	7.2
Difficulty viewing penetration or aspiration	4	4.8
Describing what is seen/subjectivity of results	4	4.8
Not representative of a realistic situation (i.e., eating a meal)	1	1.2
Not answered	18	21.7
Total	83	100

Pharyngeal Residue Severity Rating Scales Based on Fiberoptic Endoscopic Evaluation of Swallowing: A Systematic Review

Paul D. Neubauer[1] · Denise P. Hersey[2] · Steven B. Leder[1]

Dysphagia (2016) 31:352–359

Table 2 Definitions for severity of valleculla residue [44]

I	None	0 %	No residue
II	Trace	1–5 %	Trace coating of the mucosa
III	Mild	5–25 %	Epiglottic ligament visible
IV	Moderate	25–50 %	Epiglottic ligament covered
V	Severe	>50 %	Filled to epiglottic rim

Table 3 Definitions for severity of pyriform sinus residue [44]

I	None	0 %	No residue
II	Trace	1–5 %	Trace coating of mucosa
III	Mild	5–25 %	Up wall to quarter full
IV	Moderate	25–50 %	Up wall to half full
V	Severe	>50 %	Filled to aryepiglottic fold

Observers' Agreement on Measurements in Fiberoptic Endoscopic Evaluation of Swallowing

Walmari Pilz[1] · Sophie Vanbelle[2] · Bernd Kremer[1] · Michel R. van Hooren[1] · Tine van Becelaere[1] · Nel Roodenburg[3] · Laura W. J. Baijens[1]

Dysphagia (2016) 31:180–187

Table 1 Description of the ordinal rating scales of the four visuoperceptual FEES variables

FEES variable	Definition	Rating scale
Piecemeal deglutition	Sequential swallowing on the same bolus	0 = one swallow 1 = two swallows 2 = three swallows 3 = four swallows 4 = five or more swallows
Postswallow vallecular pooling	Bolus retention in the valleculae after swallowing	0 = no pooling 1 = filling of less than 50 % of the valleculae 2 = filling of more than 50 % of the valleculae
Postswallow pyriform sinus pooling	Bolus retention in the pyriform sinuses after swallowing	0 = no pooling 1 = trace to moderate pooling 2 = severe pooling up to complete filling of the sinus
Laryngeal penetration/tracheal aspiration	Bolus in the laryngeal vestibule above or on the level of the vocal folds (laryngeal penetration) or bolus passes below the vocal folds (tracheal aspiration)	0 = no laryngeal penetration 1 = laryngeal penetration 2 = tracheal aspiration

Table 2 Frequency distribution of patients per category of the different FEES variables, given as absolute numbers *N* and percentages (%) according to the etiological group

FEES variables	Rating scale	Etiology	
		Oncological	Neurological
Vallecular pooling	0	78 (54)	92 (63)
	1	47 (32)	39 (27)
	2	20 (14)	15 (10)
Pyriform sinus pooling	0	128 (75)	131 (74)
	1	32 (19)	45 (25)
	2	10 (5.9)	1 (0.6)
Piecemeal deglutition	0	26 (15)	39 (22)
	1	59 (34)	74 (43)
	2	36 (21)	32 (18)
	3	14 (8.1)	10 (5.7)
	4	37 (22)	19 (11)
Penetration/aspiration	0	79 (48)	126 (75)
	1	59 (36)	35 (21)
	2	27 (16)	7 (4.2)

The scores of the observer with the highest intraobserver agreement level were used for the analysis

Table 3 Linear weighted kappa coefficient (SE) of agreement for all rating tasks

FEES variables	Intraobserver agreement		Interobserver agreement			Intrapanel agreement
	Observer 1	Observer 2	Thin liquid	Thick liquid	Total	Total
Piecemeal deglutition	0.86 (0.041)	0.90 (0.026)	0.84 (0.033)	0.93 (0.019)	0.88 (0.020)	0.95 (0.029)
Postswallow vallecular pooling	0.93 (0.041)	0.79 (0.068)	0.30 (0.075)	0.76 (0.040)	0.65 (0.037)	0.85 (0.071)
Postswallow pyriform sinus pooling	0.79 (0.054)	0.76 (0.084)	0.55 (0.071)	0.67 (0.069)	0.61 (0.059)	0.91 (0.068)
Laryngeal penetration/tracheal aspiration	0.79 (0.064)	0.79 (0.066)	0.82 (0.037)	0.58 (0.070)	0.73 (0.035)	0.93 (0.049)

SE standard error

The Yale Pharyngeal Residue Severity Rating Scale: An Anatomically Defined and Image-Based Tool

Paul D. Neubauer[1] · Alfred W. Rademaker[2] · Steven B. Leder[1]

Dysphagia (2015) 30:521–528

Table 6 Definitions for severity of vallecula residue

I	None	0 %	No residue
II	Trace	1–5 %	Trace coating of the mucosa
III	Mild	5–25 %	Epiglottic ligament visible
IV	Moderate	25–50 %	Epiglottic ligament covered
V	Severe	>50 %	Filled to epiglottic rim

Table 7 Definitions for severity of pyriform sinus residue

I	None	0 %	No residue
II	Trace	1–5 %	Trace coating of mucosa
III	Mild	5–25 %	Up wall to quarter full
IV	Moderate	25–50 %	Up wall to half full
V	Severe	>50 %	Filled to aryepiglottic fold

The Yale Pharyngeal Residue Severity Rating Scale: An Anatomically Defined and Image-Based Tool

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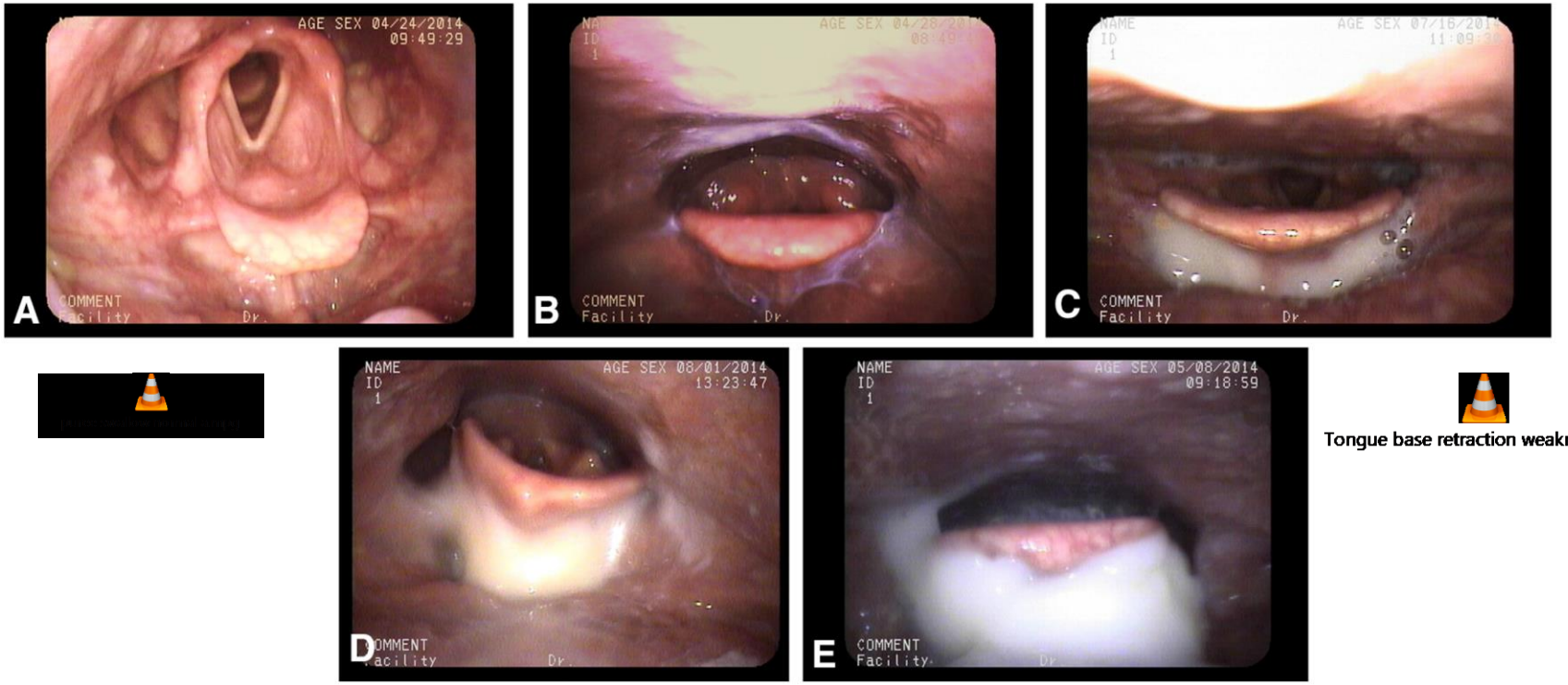

Tongue base retraction weakness.mpg

Fig. 1 The vallecula images with the greatest inter-rater agreement for each residue level: **a** none; **b** trace; **c** mild; **d** moderate; and **e** severe

The Yale Pharyngeal Residue Severity Rating Scale: An Anatomically Defined and Image-Based Tool

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Dysphagia (2015) 30:521–528

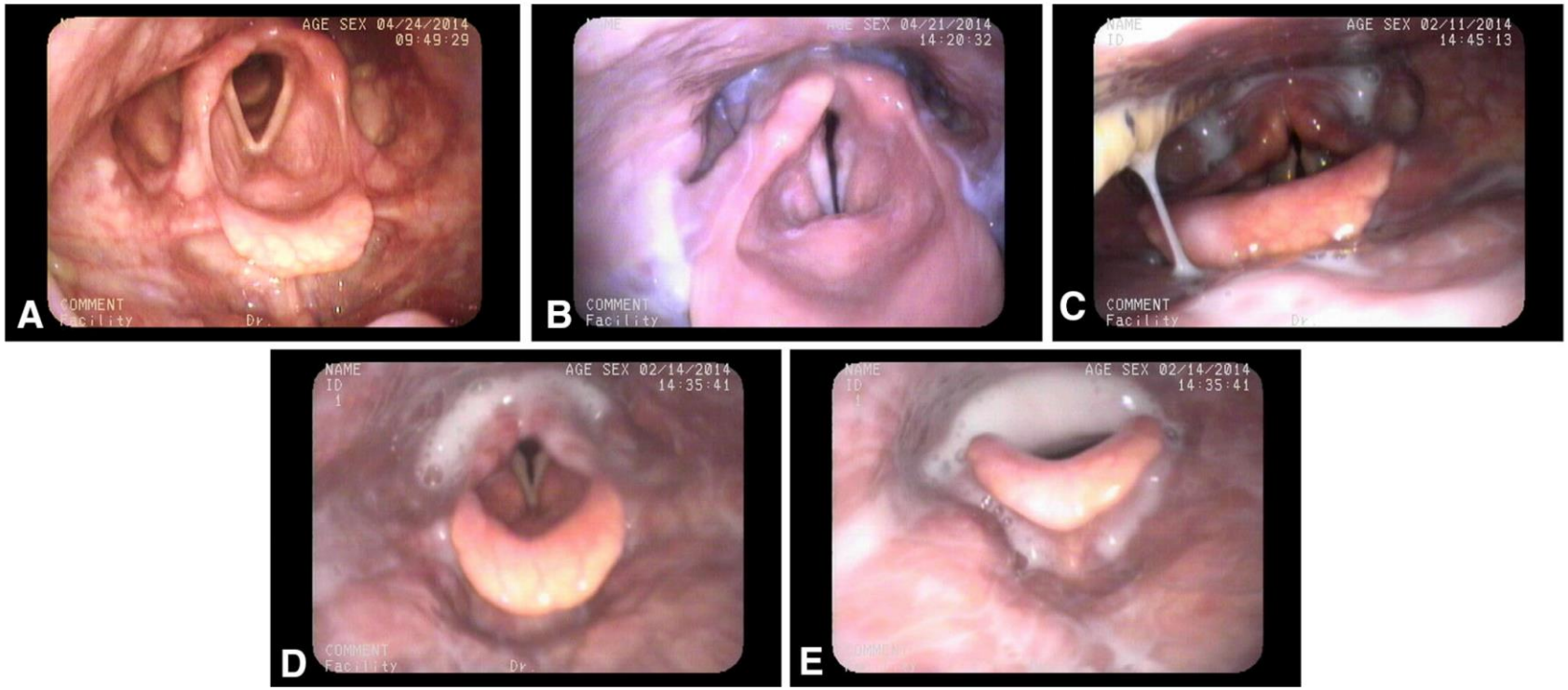


Fig. 2 The pyriform sinus images with the greatest inter-rater agreement for each residue level: **a** none; **b** trace; **c** mild; **d** moderate; and **e** severe

Dziewas R,Warnecke T, Ritter M,Dittrich R, Schilling M, Schäbitz WR, Ringelstein EB,Nabavi DG (2006) Fatigable Swallowing in Myasthenia Gravis – Proposal of a Standardized Test and Report of a Case. J Clin Neuromusc Dis 8:12–15

- Attempt to quantify and monitor fatigue during mealtime in myasthenia gravis patients
- Patients were given up to 30 consecutive pieces of bread (3cmx3cmx0.5 cm)
- If > 50% of bolus is retained the procedure was stopped
- The number of successfully swallowed bread pieces at that point (1 to 30) quantified the degree of fatigable swallowing

Warnecke, T. Teismann, I. Zimmermann, J. Oelenberg, S. Ringelstein, E. B. Dziewas, R.J Fiberoptic endoscopic evaluation of swallowing with simultaneous tensilon application in diagnosis and therapy of myasthenia gravisNeurology (2008) 255:224–230

- Case series
  - Subjects: Four severely affected patients with dysphagia as their leading symptom were examined
  - Monitored for normalization or improvement of swallowing function shortly after Tensilon administration
  - *Results*
    - Three/four FEES-Tensilon Test positive for MG-related dysphagia.
    - FEES-Tensilon Test was useful in the differentiation between myasthenic and cholinergic crisis and in guiding treatment decisions.
  - *Conclusion* The FEES-Tensilon Test is a suitable tool in the diagnosis and therapy of myasthenia gravis with pharyngeal muscles weakness.

JSLHR

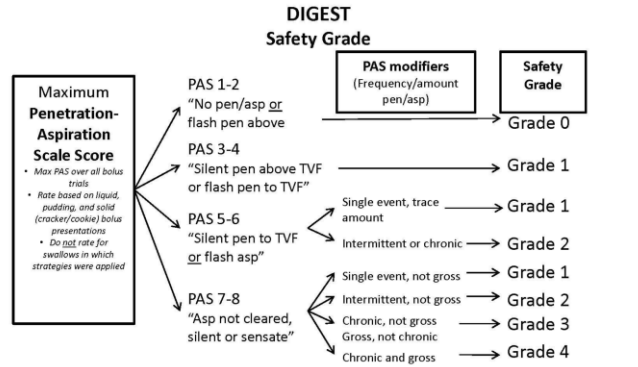
Research Article

Adaptation and Validation of the Dynamic Imaging Grade of Swallowing Toxicity for Flexible Endoscopic Evaluation of Swallowing: DIGEST-FEES

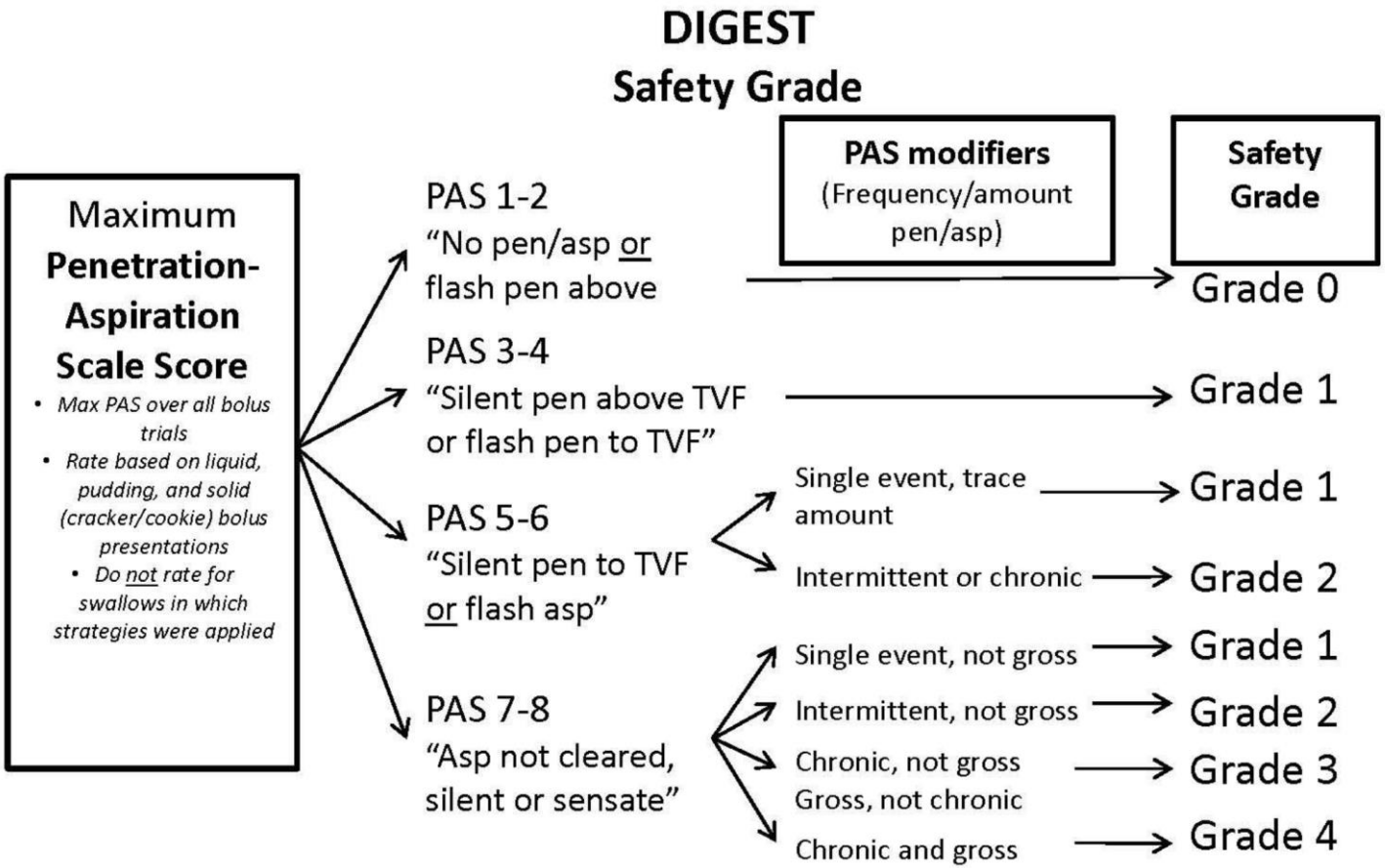
Heather M. Starmer,[a] Loni Arrese,[b] Susan Langmore,[c] Yifei Ma,[a] Joseph Murray,[d] Joanne Patterson,[e] Jessica Pisegna,[c] Justin Roe,[f] Lauren Tabor-Gray,[g] and Katherine Hutcheson[h]

2021 Journal of Speech, Language, and Hearing Research, *64*(6), 1802-1810.

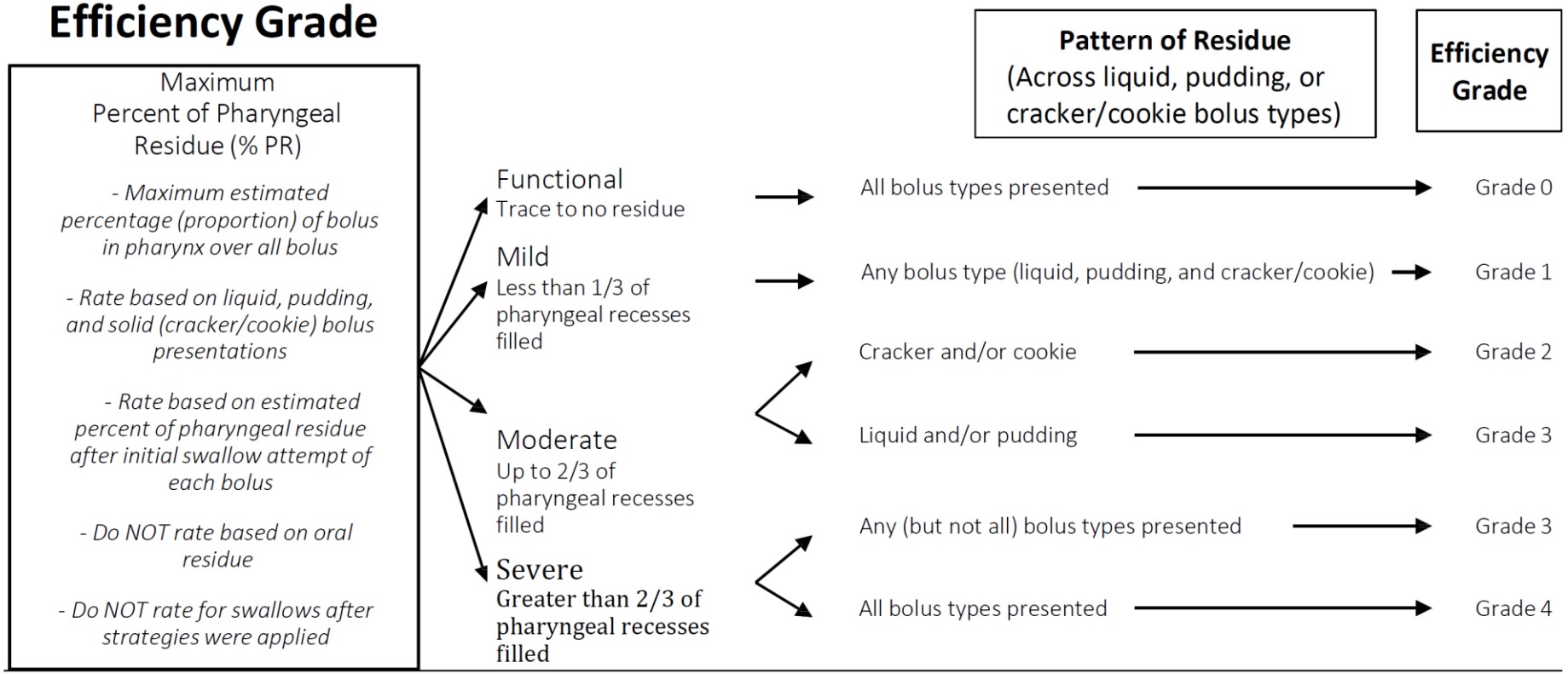
Hutcheson, K. A., Barrow, M. P., Barringer, D. A., Knott, J. K., Lin, H. Y., Weber, R. S., ... & Lazarus, C. L. (2017). Dynamic imaging grade of swallowing toxicity (DIGEST): scale development and validation. *Cancer*, *123*(1), 62-70.



	S0	S1	S2	S3	S4
E0	0	1	2	3	3
E1	1	1	2	3	3
E2	1	2	2	3	3
E3	2	2	3	3	4
E4	3	3	3	4	4


DIGEST
Safety Grade
Maximum
Penetration-Aspiration Scale Score
• Max PAS over all bolus trials
• Rate based on liquid, pudding, and solid (cracker/cookie) bolus presentations
• Do not rate for swallows in which strategies were applied
PAS 1-2
"No pen/asp or flash pen above
PAS 3-4
"Silent pen above TVF or flash pen to TVF"
PAS 5-6
"Silent pen to TVF or flash asp"
PAS 7-8
"Asp not cleared, silent or sensate"
PAS modifiers
(Frequency/amount pen/asp)
Safety Grade
Grade 0
Grade 1
Single event, trace amount
Grade 1
Intermittent or chronic
Grade 2
Single event, not gross
Grade 1
Intermittent, not gross
Grade 2
Chronic, not gross
Gross, not chronic
Grade 3
Chronic and gross
Grade 4

Efficiency Grade



Digest Score

- Interaction of Safety and Efficiency Scores

	S0	S1	S2	S3	S4
E0	0	1	2	3	3
E1	1	1	2	3	3
E2	1	2	2	3	3
E3	2	2	3	3	4
E4	3	3	3	4	4

1 = Mild 2 = Moderate 3 = Severe 4 = Life threatening

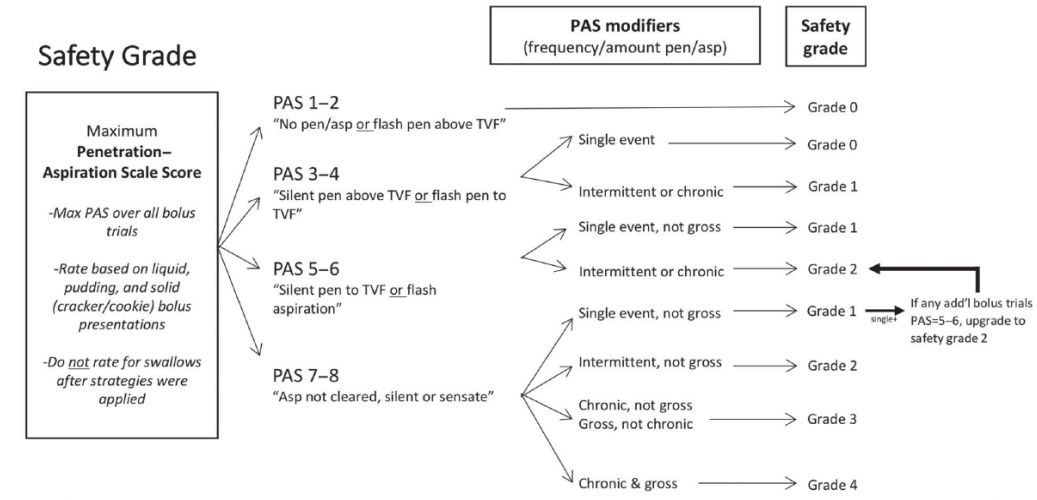
JSLHR

Research Article

Adaptation and Validation of the Dynamic Imaging Grade of Swallowing Toxicity for Flexible Endoscopic Evaluation of Swallowing: DIGEST-FEES

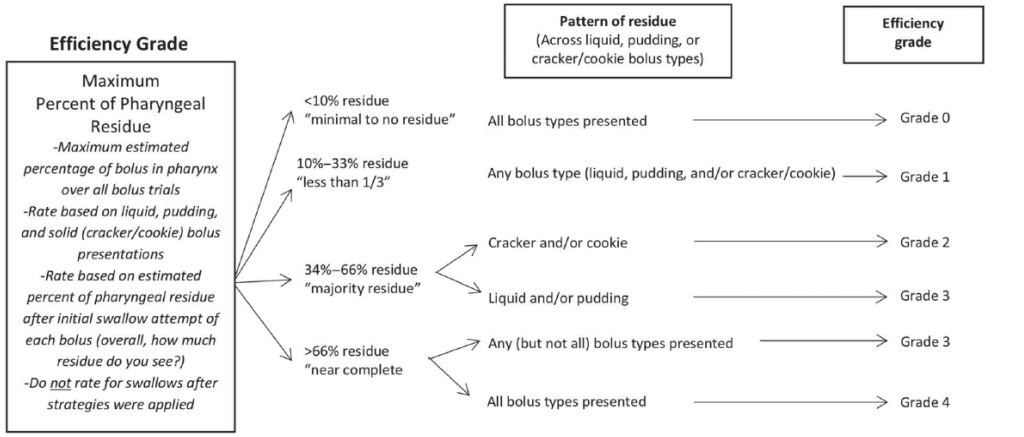
Heather M. Starmer,[a] Loni Arrese,[b] Susan Langmore,[c] Yifei Ma,[a] Joseph Murray,[d] Joanne Patterson,[e] Jessica Pisegna,[c] Justin Roe,[f] Lauren Tabor-Gray,[g] and Katherine Hutcheson[h]

DIGEST-FEES



Frequency/pattern of PAS If **max PAS ≥3**, PAS 3–4, 5–6 or PAS 7–8 occurred:	Amount of PAS **If max PAS ≥5**, amount of bolus on or below TVF based on worst performance on any single bolus:
☐ Single event ☐ Single+ (max PAS 7–8 only) ☐ Intermittent (on multiple but <50% of trials on a single consistency) ☐ Chronic (majority [≥50%] of thin liquid trials and/or on >1 consistency	☐ Trace (resembles faint coating, droplets or trickle of bolus on/below TVF) ☐ Neither trace nor gross ☐ Gross (> 25% of bolus volume)

1 = mild 2 = moderate 3 = severe 4 = profound/life threatening



DIGEST Score (Interaction of Assigned Safety and Efficiency Grades)					
	S0	S1	S2	S3	S4
E0	0	1	2	3	3
E1	1	1	2	3	3
E2	1	2	2	3	3
E3	2	2	3	3	4
E4	3	3	3	4	4

1 = Mild 2 = Moderate 3 = Severe 4 = Life threatening

Table 3. Spearman correlation coefficients for DIGEST-FEES by criterion measures.

Measures	Safety	Efficiency	DIGEST
MDADI	−.388	−.422	−.434
	< .0001	*< .0001*	*< .0001*
MDADI (emotional)	−.371	−.372	−.395
	.0001	*.0001*	*< .0001*
MDADI (functional)	−.307	−.310	−.315
	.002	*.002*	*.001*
MDADI (physical)	−.392	−.472	−.468
	< .0001	*< .0001*	*< .0001*
Functional Oral Intake score	−.390	−.434	−.433
	< .0001	*< .0001*	*< .0001*
Secretion Severity score	.419	.503	.469
	< .0001	*< .0001*	*< .0001*
Yale Vallecula	.630	.846	.733
	< .0001	*< .0001*	*< .0001*
Yale Pyriform Sinus	.611	.664	.652
	< .0001	*< .0001*	*< .0001*

Note. Italicized values represent statistical significance. DIGEST = Dynamic Imaging Grade of Swallowing Toxicity; FEES = flexible endoscopic evaluation of swallowing; MDADI = MD Anderson Dysphagia Inventory.

European Archives of Oto-Rhino-Laryngology
https://doi.org/10.1007/s00405-023-07840-1

LARYNGOLOGY

Intra and interobserver agreement of the Dynamic Imaging Grade of Swallowing Toxicity Scale (DIGEST) in fiberoptic endoscopic evaluation of swallowing (FEES): the importance of observer-tailored training

Sorina R. Simon[1,2,3] · Monse W. M. Wieland[1] · Charlotte Hendriks[1] · Walmari Pilz[1,3,4] · Antonio Schindler[5] · Bjorn Winkens[6,7] · Laura W. J. Baijens[1,3]

Received: 21 September 2022 / Accepted: 15 January 2023

Table 2 Linearly weighted kappa coefficient and percentage of agreement on the PAS and PPR when considering all bolus consistencies together ('total') and per bolus consistency during the first measurement attempt[a]

FEES variable and bolus consistency	Intraobserver agreement					Interobserver agreement		
	N (%)	Observer 1		Observer 2		*N* (%)	Kappa (SE)	% of agreement
		Kappa (SE)	% of agreement	Kappa (SE)	% of agreement			
First measurement attempt								
PAS								
Total	78	0.90 (0.04)	87.2	0.87 (0.04)	82.9	78	0.77 (0.08)	71.8
Thin liquid	33 (42)	0.91 (0.04)	82.4	0.86 (0.05)	69.7	33 (42)	0.72 (0.20)	60.6
Thick liquid	32 (41)	0.88 (0.07)	90.9	0.84 (0.07)	90.3	32 (41)	0.78 (0.09)	74.2
Bite-sized cracker	13 (17)	[b]	90.9	1.00 (0.00)	100	13 (17)	1.00 (0.00)	100
PPR								
Total	78	0.85 (0.06)	92.3	0.59 (0.09)	77	78	0.62 (0.09)	78.7
Thin liquid	33 (42)	0.88 (0.12)	96.3	0.67 (0.13)	80	33 (42)	0.38 (0.15)	62.5
Thick liquid	32 (41)	0.82 (0.09)	89.3	0.50 (0.15)	73.1	32 (41)	0.87 (0.09)	96.3
Bite-sized cracker	13 (17)	0.74 (0.24)	90	0.54 (0.26)	80	13 (17)	0.58 (0.26)	80

PAS Penetration-Aspiration Scale [8]; *PPR* percentage of pharyngeal residue; *FEES* fiberoptic endoscopic evaluation of swallowing; *N* number of bolus swallows; *SE* standard error

Table 4 Linearly weighted kappa coefficient and percentage of agreement on the PAS and PPR when considering all bolus consistencies together ('total') and per bolus consistency during the second measurement attempt

FEES variable and bolus consistency	Intraobserver agreement					Interobserver agreement		
	N (%)	Observer 1		Observer 2		*N* (%)	Kappa (SE)	% of agreement
		Kappa (SE)	% of agreement	Kappa (SE)	% of agreement			
Second measurement attempt								
PAS								
Total	59	0.88 (0.05)	86.4	0.86 (0.07)	91.5	184	0.78 (0.04)	78.7
Thin liquid	26 (44)	0.83 (0.08)	76.9	0.77 (0.12)	84.6	79 (43)	0.82 (0.05)	76.3
Thick liquid	24 (41)	0.92 (0.06)	91.7	0.97 (0.03)	95.8	77 (42)	0.80 (0.05)	79.7
Bite-sized cracker	9 (15)	[a]	100	1.00 (0.00)	100	28 (15)	0.44 (0.13)	82.1
PPR								
Total	59	0.84 (0.08)	91.7	0.86 (0.07)	92.3	184	0.82 (0.04)	88.1
Thin liquid	26 (44)	0.78 (0.14)	89.5	0.92 (0.08)	95.7	79 (43)	0.84 (0.07)	91.9
Thick liquid	24 (41)	0.84 (0.11)	90.5	0.84 (0.11)	90.5	77 (42)	0.82 (0.06)	83.9
Bite-sized cracker	9 (15)	[a]	100	[a]	87.5	28 (15)	0.55 (0.18)	88.9

PAS Penetration-Aspiration Scale [8], *PPR* percentage of pharyngeal residue, *FEES* fiberoptic endoscopic evaluation of swallowing, *N* number of bolus swallows, *SE* standard error

[a]Linearly weighted kappa could not be carried out for all measurements due to a limited number of measurements for some bolus consistencies, such as for bite-sized cracker, or a lack of variation of the scores across the PAS or PPR scales

Table 5 Interobserver agreement on the safety, efficiency, and summary DIGEST grade

Grade	Interobserver agreement	
	Linearly weighted kappa (SE)	% of agreement
Safety grade	0.65 (0.12)	74.1
Efficiency grade	0.85 (0.09)	88.9
Summary DIGEST grade	0.71 (0.09)	25.9

DIGEST Dynamic Imaging Grade of Swallowing Toxicity, *SE* standard error

Dysphagia (2019) 34:852–861
https://doi.org/10.1007/s00455-019-09979-8

ORIGINAL ARTICLE

Simultaneous Radiological and Fiberendoscopic Evaluation of Swallowing ("SIRFES") in Patients After Surgery of Oropharyngeal/Laryngeal Cancer and Postoperative Dysphagia

M. Scharitzer[1] · I. Roesner[2] · P. Pokieser[3] · M. Weber[1] · D. M. Denk-Linnert[2]

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Table 2 Interrater agreement for variables assessed by VFSS and FEES

Modality	Weighted kappa	95% CI
VFSS		
PA-score	0.979	0.963–0.994
Retentions valleculae	0.819	0.748–0.890
Retentions piriform sinus	0.857	0.784–0.930
Time of triggering	0.771	0.689–0.853
FEES		
PA-score	0.911	0.864–0.959
Retentions valleculae	0.613	0.528–0.697
Retentions piriform sinus	0.762	0.686–0.837
Time of triggerung	0.828	0.750–0.906

PA score penetration aspiration score, *CI* confidence interval

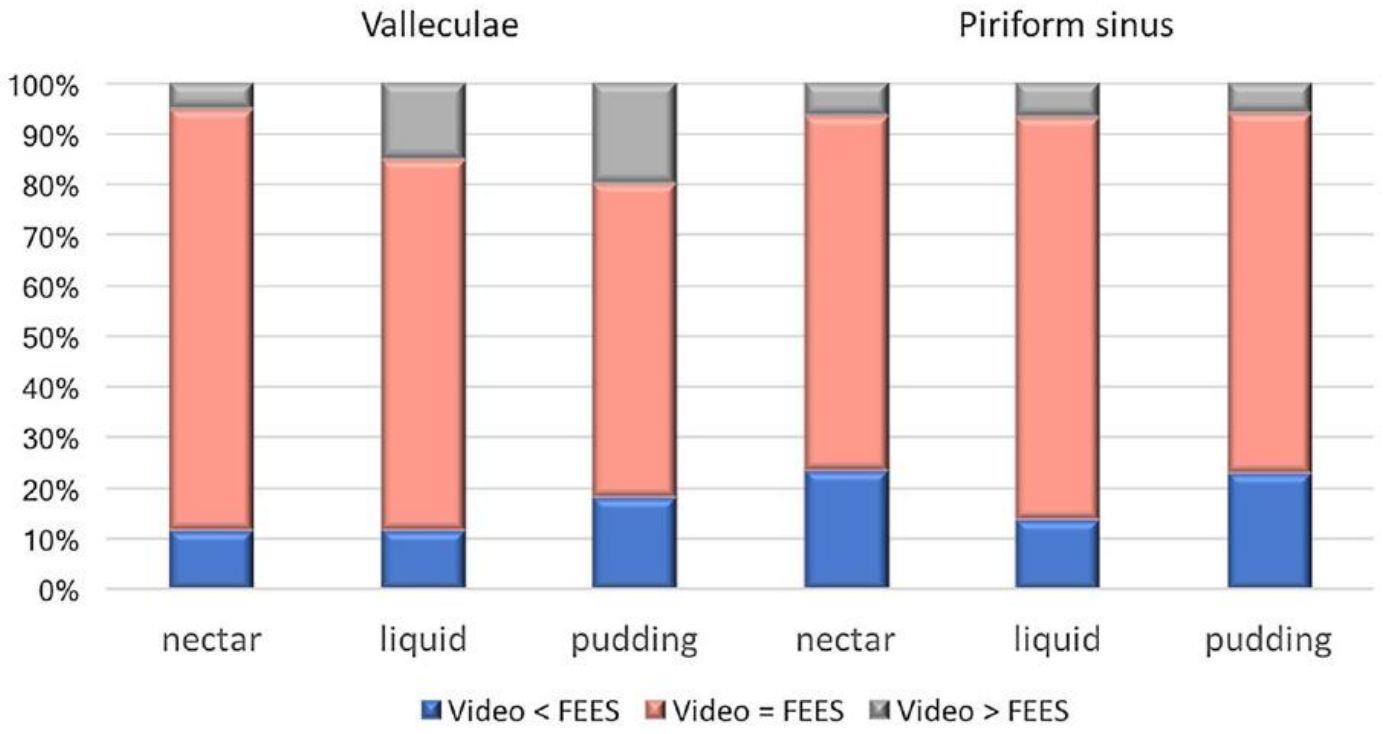


Fig. 4 Different evaluation results of pharyngeal residues in the valleculae and the piriform sinus between VFSS and FEES of the first rater each at the entire number of evaluations per consistency and localization

Dysphagia (2022) 37:417–435
https://doi.org/10.1007/s00455-021-10293-5

ORIGINAL ARTICLE

Visual Analysis of Swallowing Efficiency and Safety (VASES): A Standardized Approach to Rating Pharyngeal Residue, Penetration, and Aspiration During FEES

James A. Curtis[1] · James C. Borders[1] · Sarah E. Perry[1,2,3,4] · Avery E. Dakin[1] · Zeina N. Seikaly[1] · Michelle S. Troche[1]

- Standardized approach for rating pharyngeal residue, penetration, and aspiration during FEES
- Consensus panel (N=6) of experienced FEES users
  - Rated swallowing performance on 55 swallow sequences

Oropharynx	0–100% filled, expressed relative to the vallecular space
Hypopharynx	0–100% filled, expressed relative to the piriform sinuses and lateral channels
Epiglottis	0–100% covered, expressed relative to the laryngeal surface of the epiglottis
Laryngeal vestibule	0–100% covered, expressed relative to the laryngeal vestibule surface area
Vocal folds	0–100% covered, expressed relative to the vocal folds surface area
Subglottis	0–100% covered, expressed relative to the subglottic shelf surface area

  - PAS

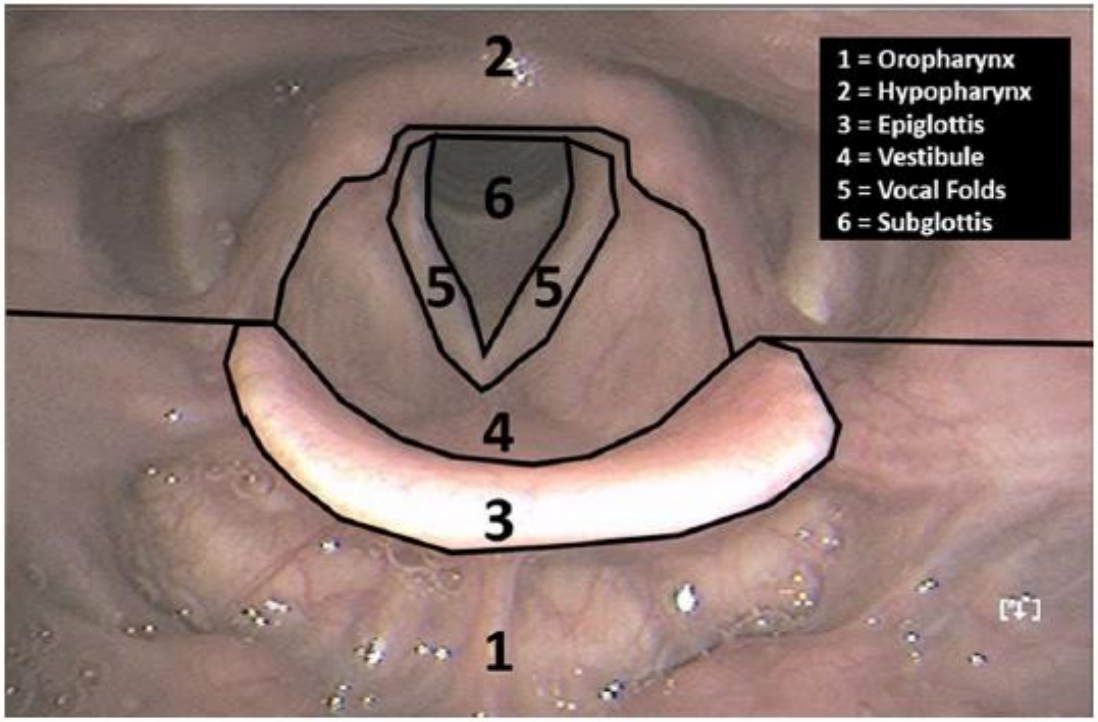


Fig. 1 Picture of the anatomic landmarks provided during pre- and post-training

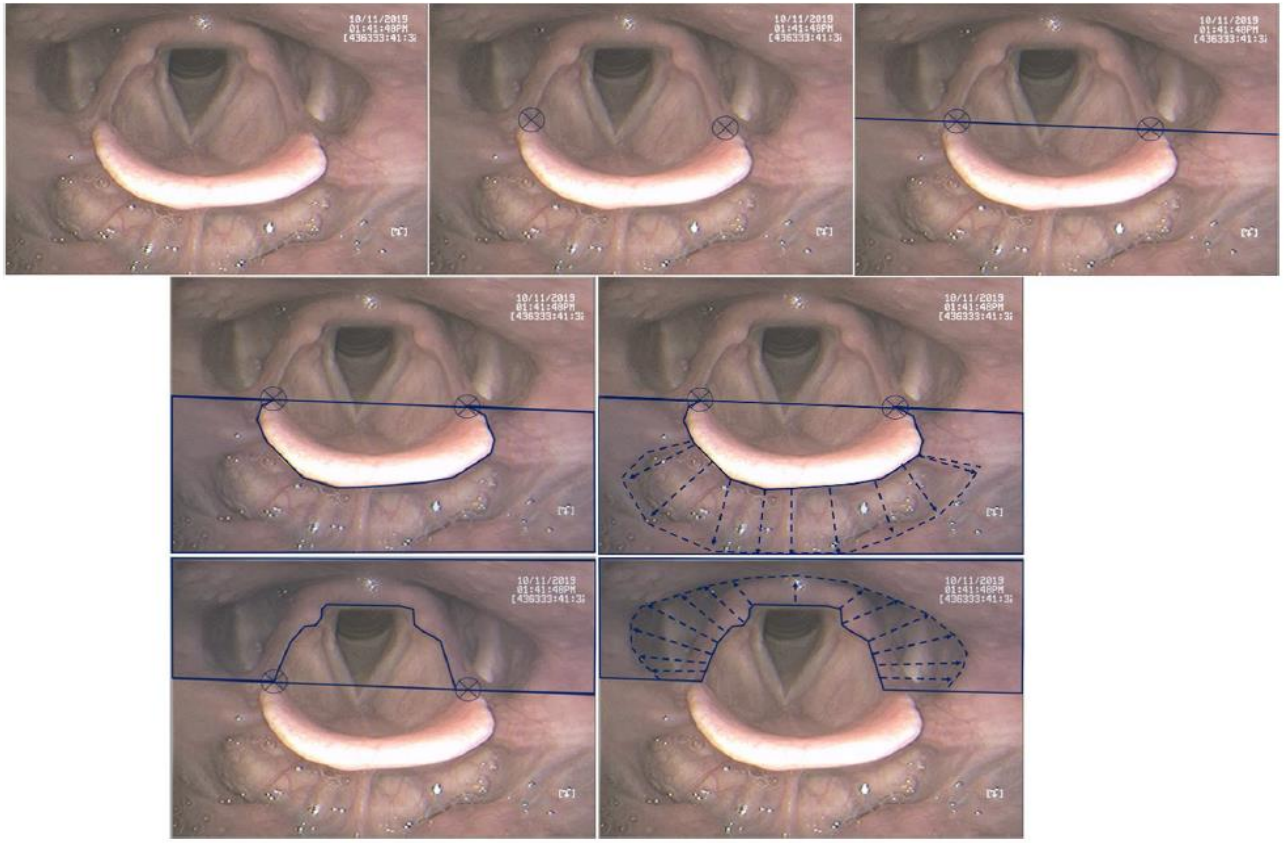


Fig. 2 Anatomic boundary for the oropharynx and hypopharynx

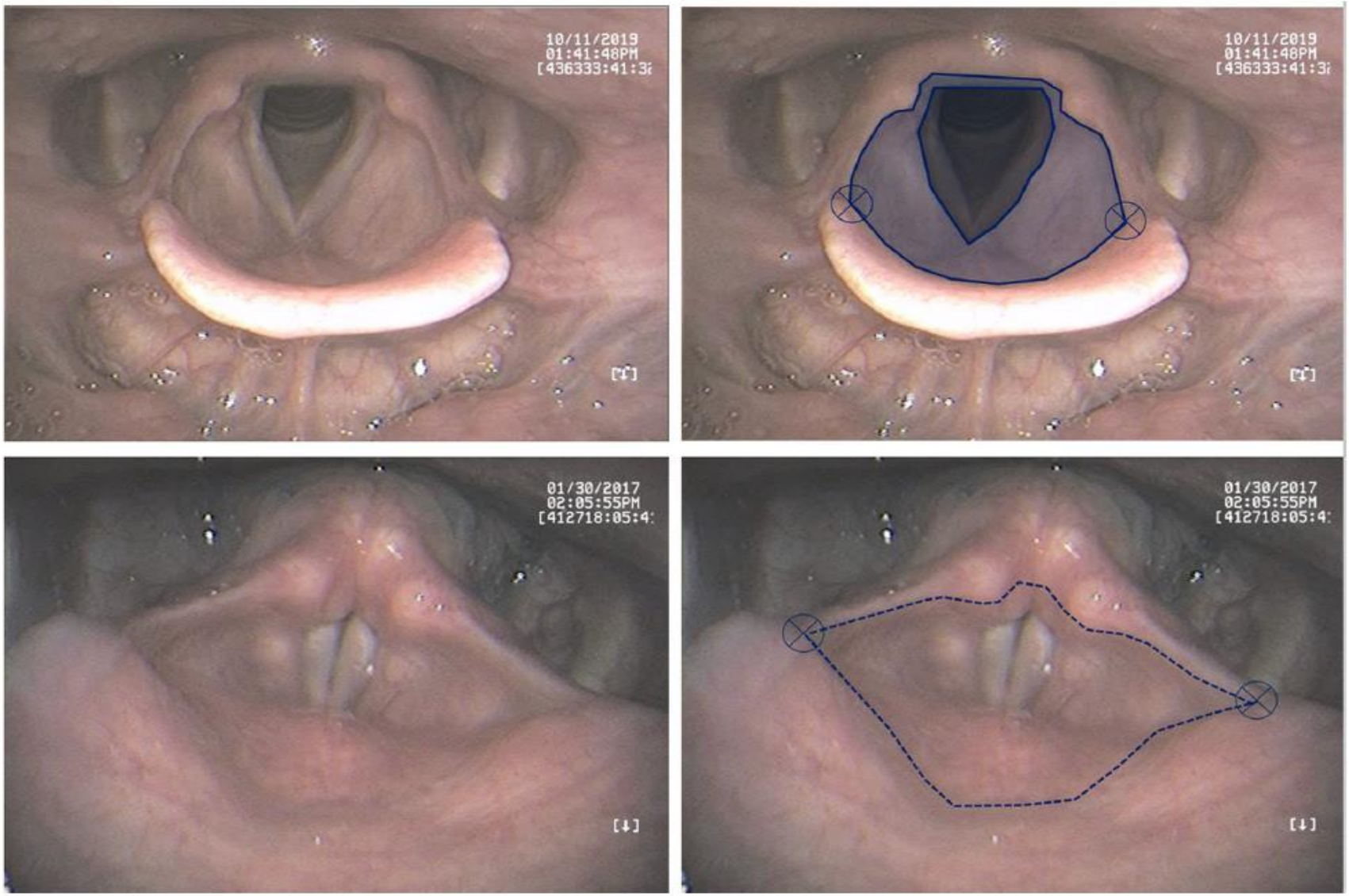


Fig. 4 Anatomic boundary for the laryngeal vestibule

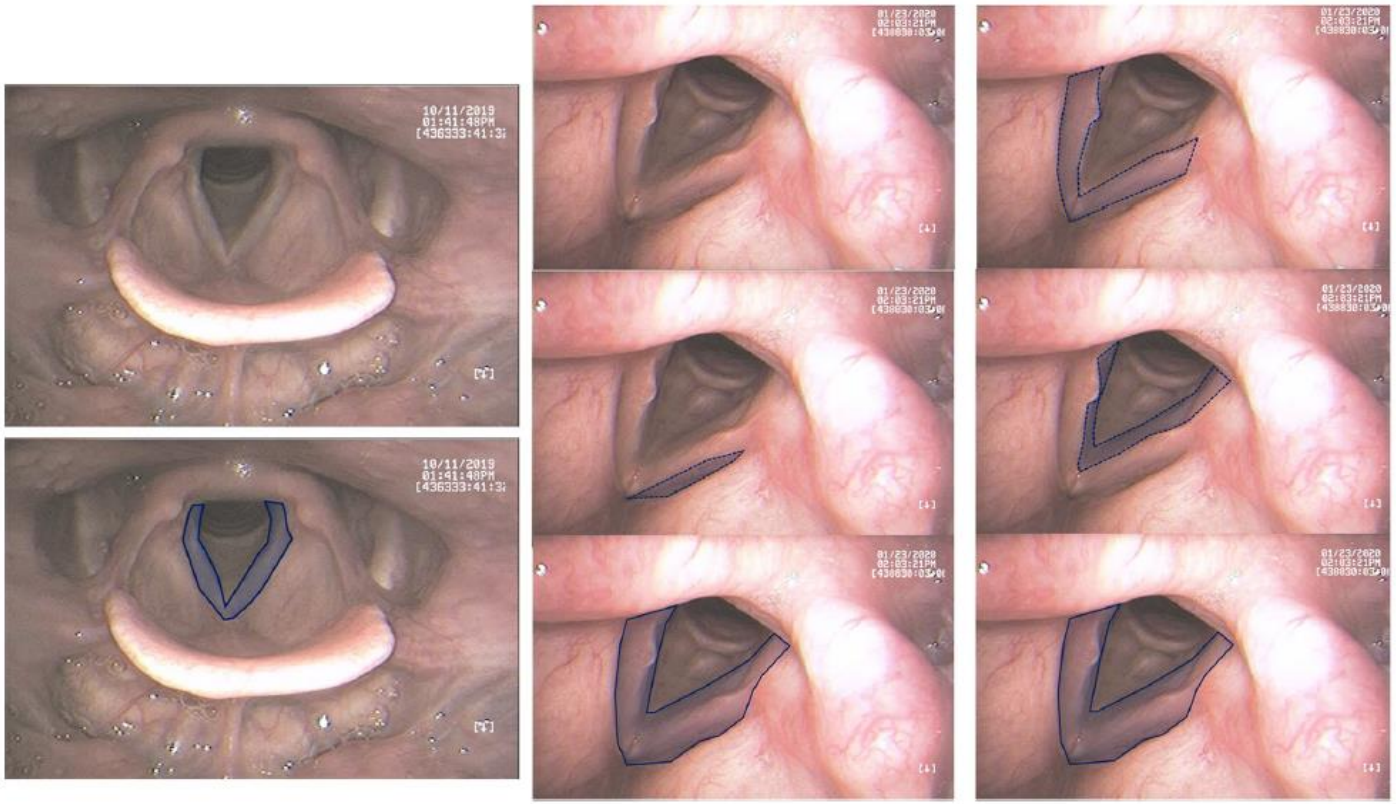


Fig. 5 Anatomic boundary for the vocal folds including the laryngeal ventricles, superior surface of the vocal folds, and medial edge/lower lip of the vocal folds

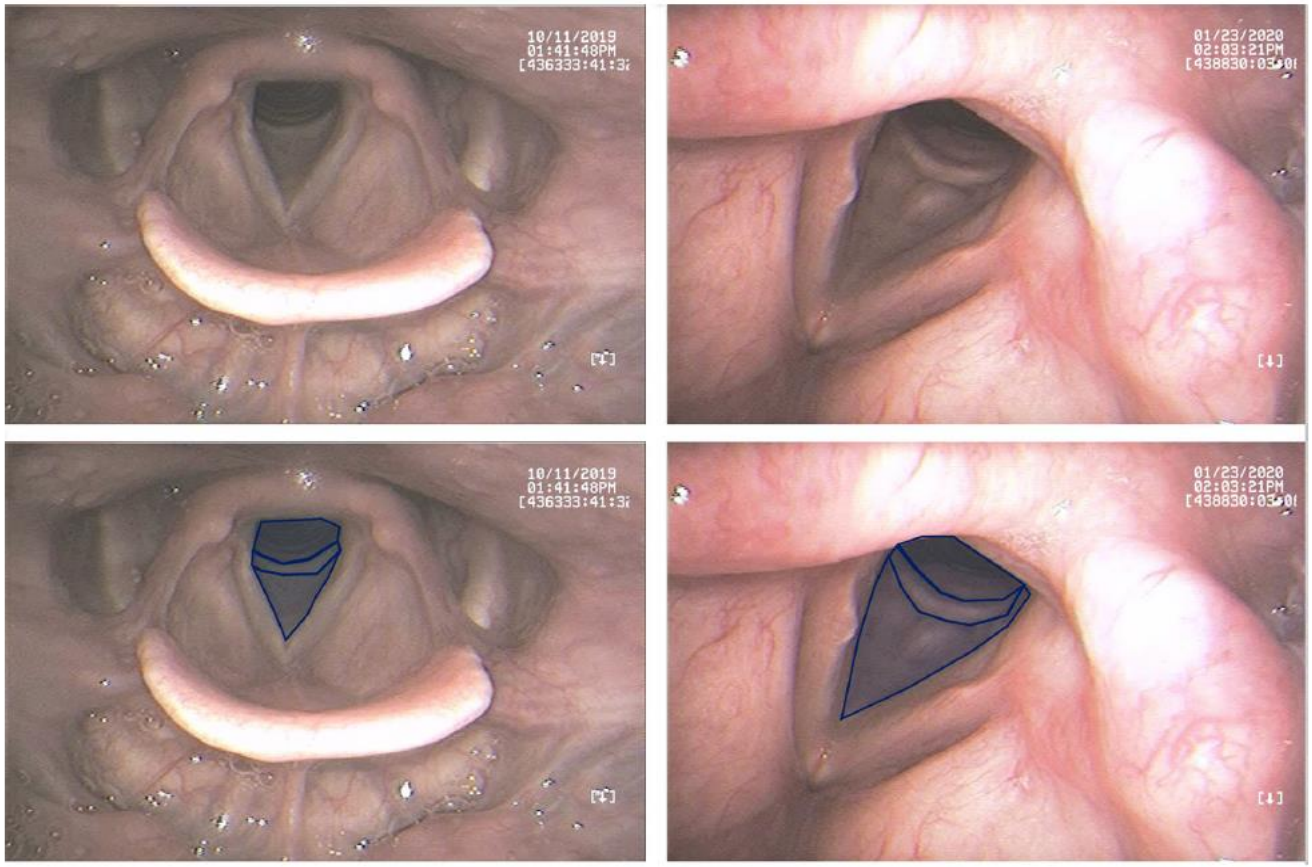


Fig. 6 Anatomic boundary for the subglottis including the subglottic shelf, cricoid ring, and trachea

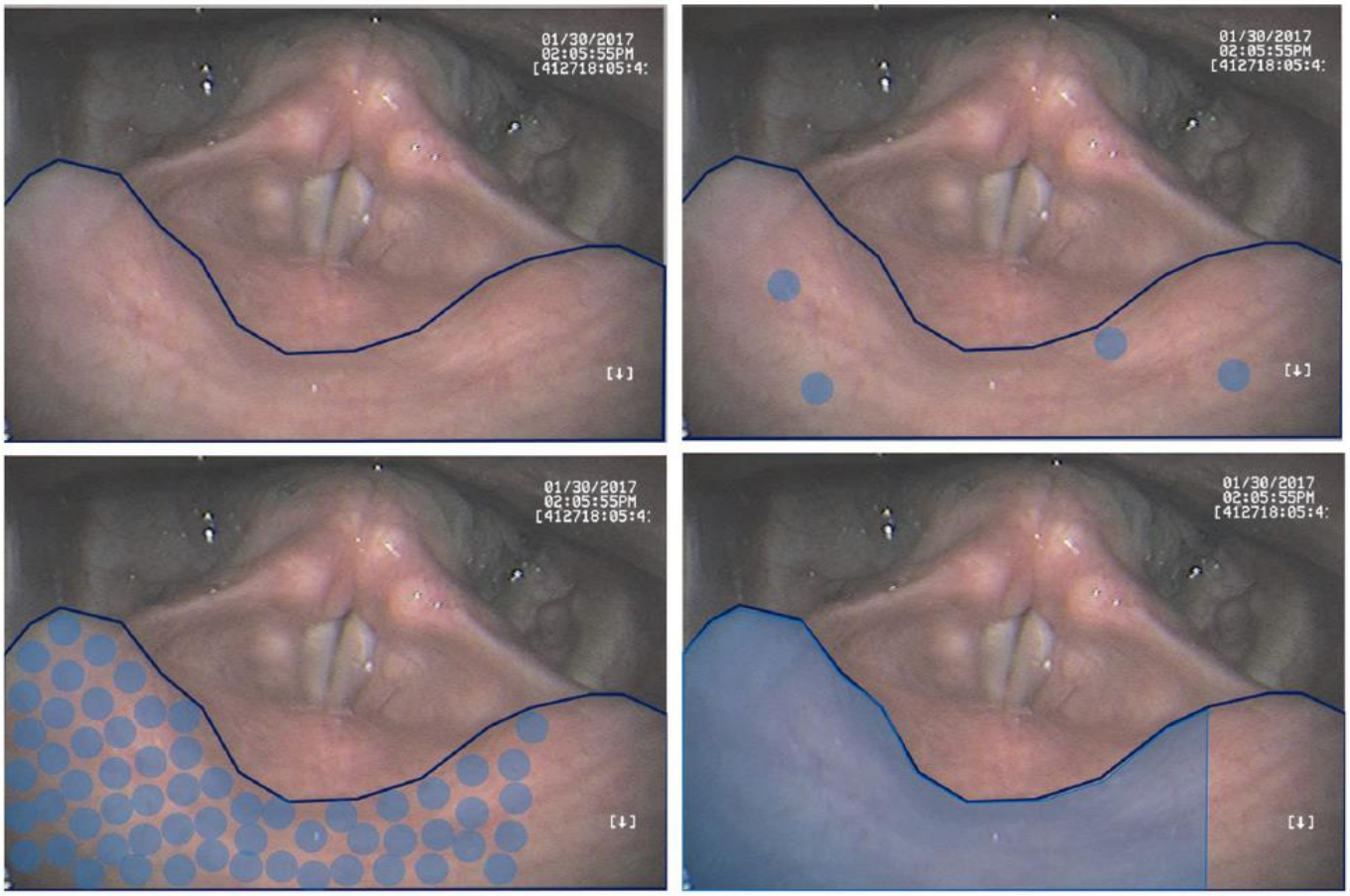
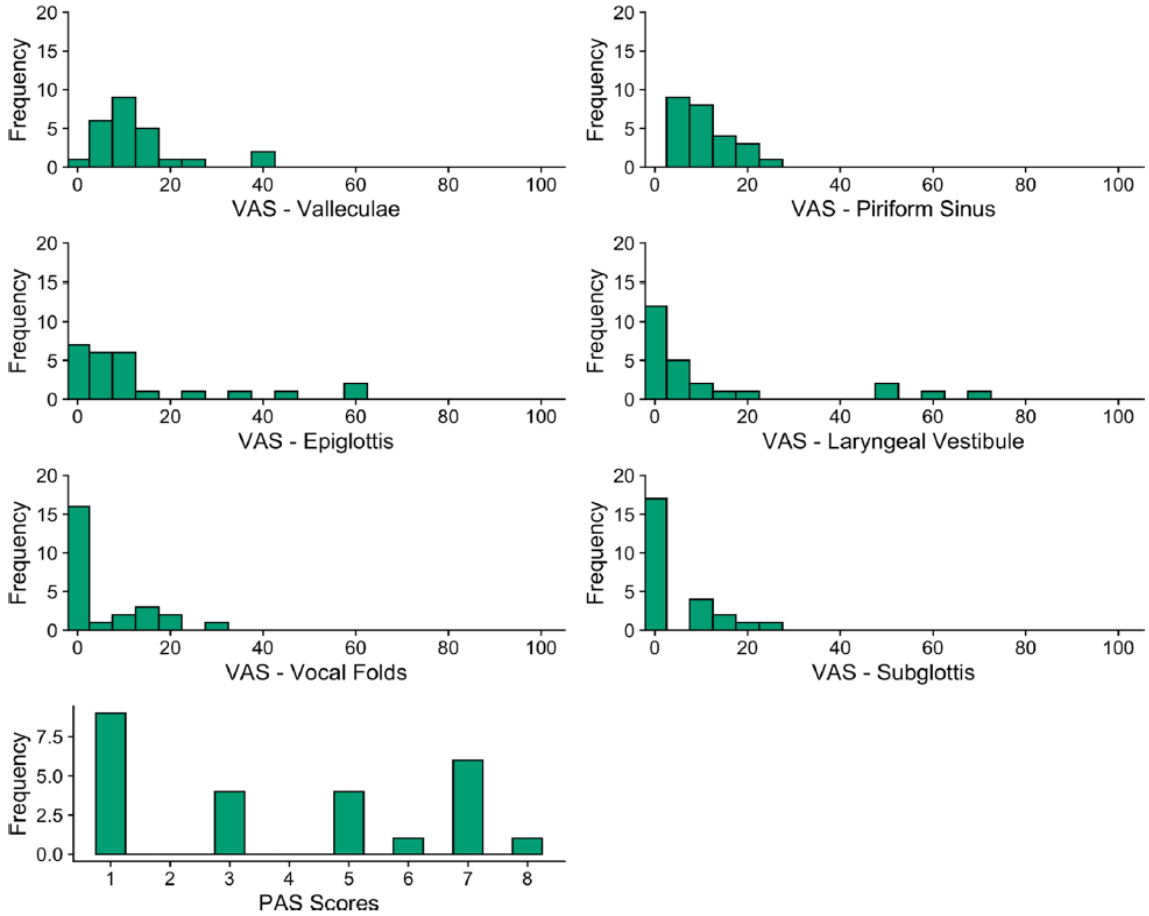
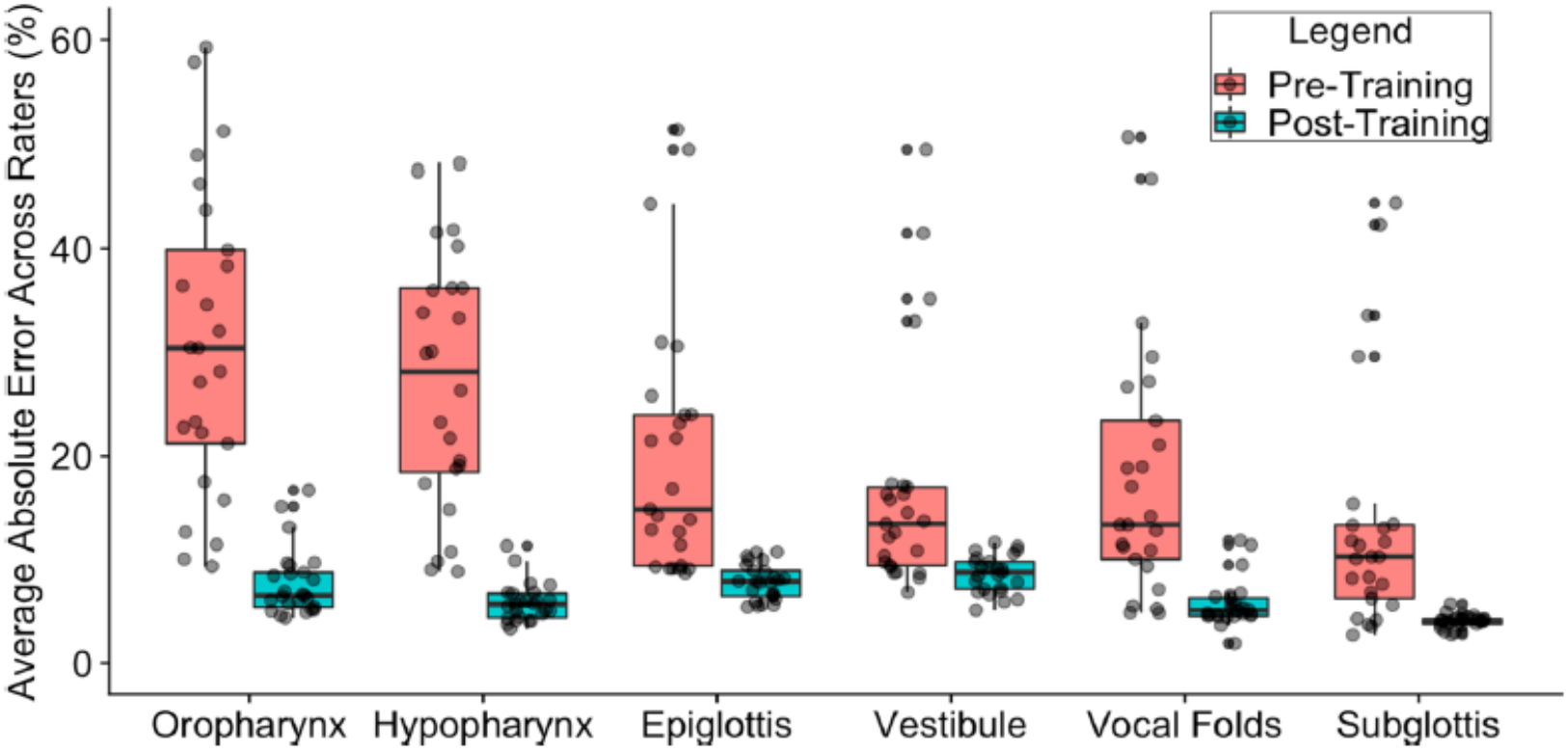


Fig. 8 Illustrated examples of blue residue covering the laryngeal surface of the epiglottis, with residue covering 0% (top left), 3% (top right) 45% (bottom left), and 76% (bottom right)

VASES Consensus Scores



25 Novice VASES Users



Curtis, J. A., Borders, J. C., Dakin, A., & Troche, M. S. (2023). Normative Reference Values for FEES and VASES: A Prospective, Observational Study of Non-dysphagic, Community-dwelling Adults.

- 38 normal subject
  - 15 Swallow trials (all uncued)
  - 584 Swallow trials analyzed

Table 1: Standardized FEES Protocol

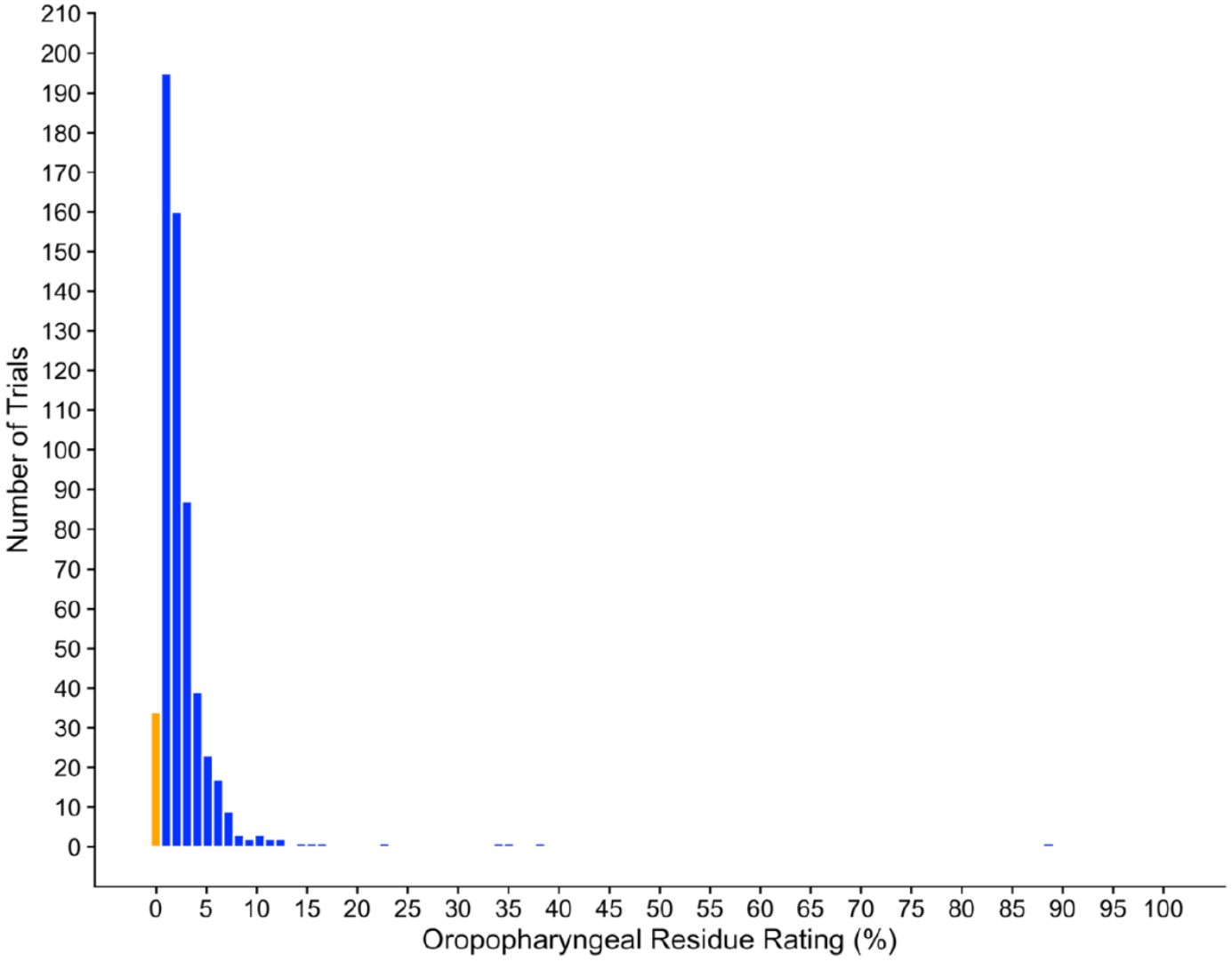
Order of Presentation	Swallow Condition	Verbal Instruction	Number of Trials
1	Self-selected volume of water, via 8-ounce cup, natural swallow	"Take one normal size sip, whatever is normal for you, and drink it like you normally would."	2
2	5 mL of water, via 30 mL medicine cup, single swallow	"Put all of this in your mouth and try to swallow it in just one swallow."	2
3	10 mL of water, via 30 mL medicine cup, single swallow	"Put all of this in your mouth and try to swallow it in just one swallow."	2
4	20 mL of water, via 30 mL medicine cup, single swallow	"Put all of this in your mouth and try to swallow it in just one swallow."	2
5	Self-selected volume of water, via 8-ounce cup, single swallow	"Take one normal size sip, whatever is normal for you, and swallow it in just one swallow."	2
6	90 mL of water, via 8-ounce cup, uninterrupted	"Take this cup and drink the whole thing slow and study but without stopping."	1
7	5 mL of vanilla pudding, via spoon, single swallow	"Put all of this in your mouth and try to swallow it in just one swallow."	2
8	Self-selected volume of cracker, hand delivered, single swallow	"Take one normal size bite, whatever is normal for you, chew it, and swallow it in just one swallow whenever you're ready."	2

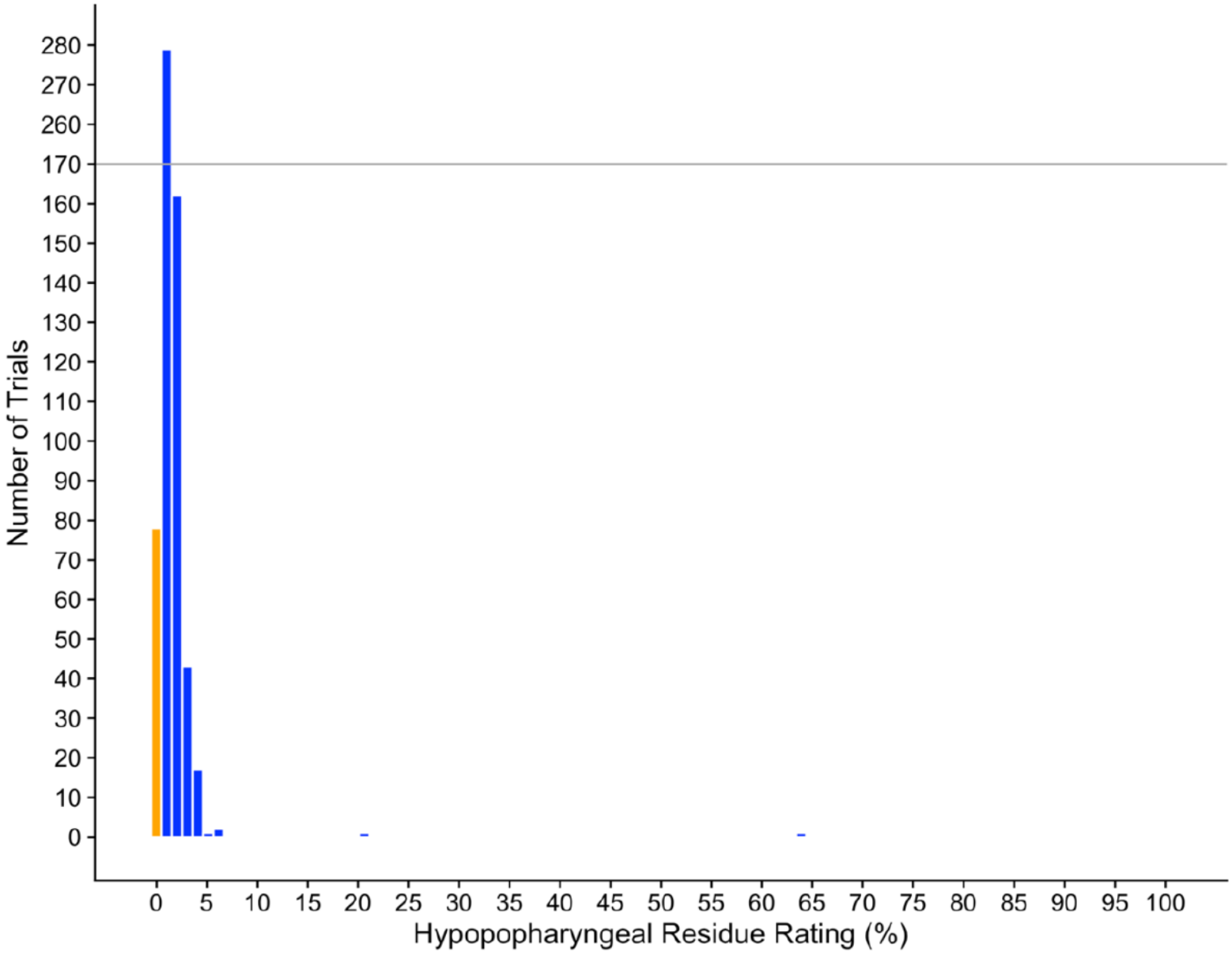
VASES Normative Data

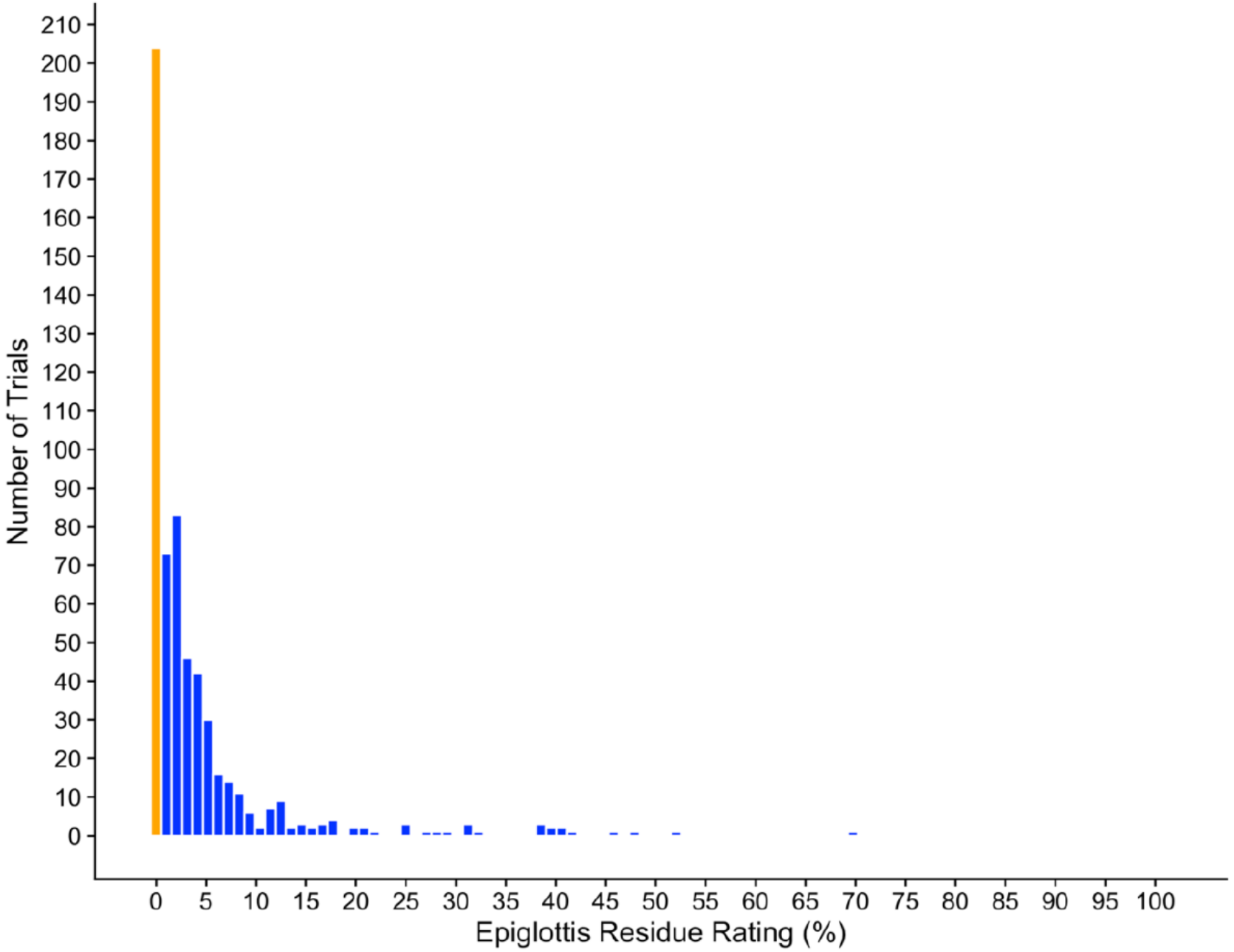
- Primary outcome measures:
  - Bolus location at swallow onset
  - Penetration-Aspiration Scale (PAS) scores
  - Percentage based residue ratings for six anatomic landmarks
- Secondary outcome measures:
  - Sip size
  - Bite size
  - Number of swallows/bolus

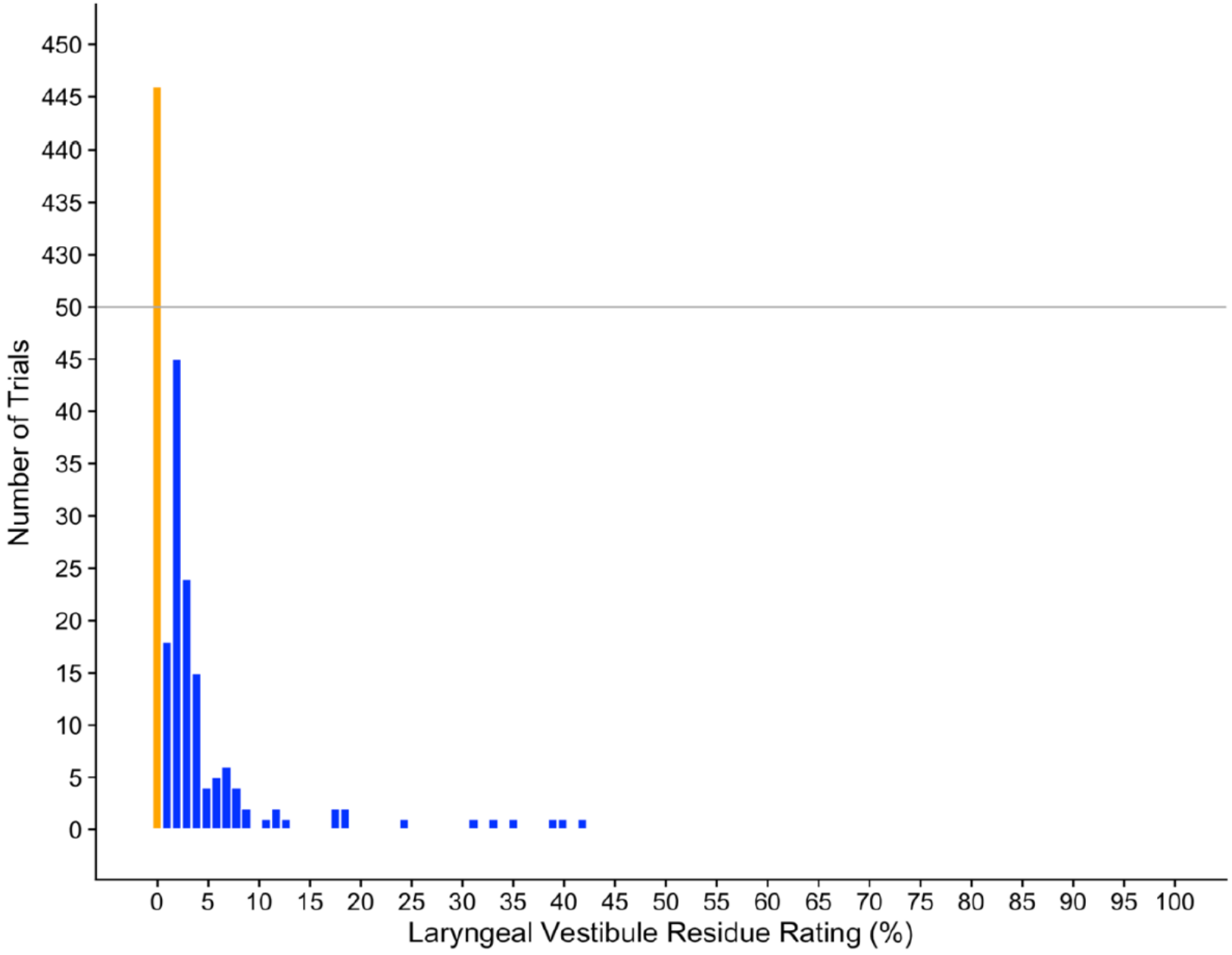
Table 3: Rater Reliability

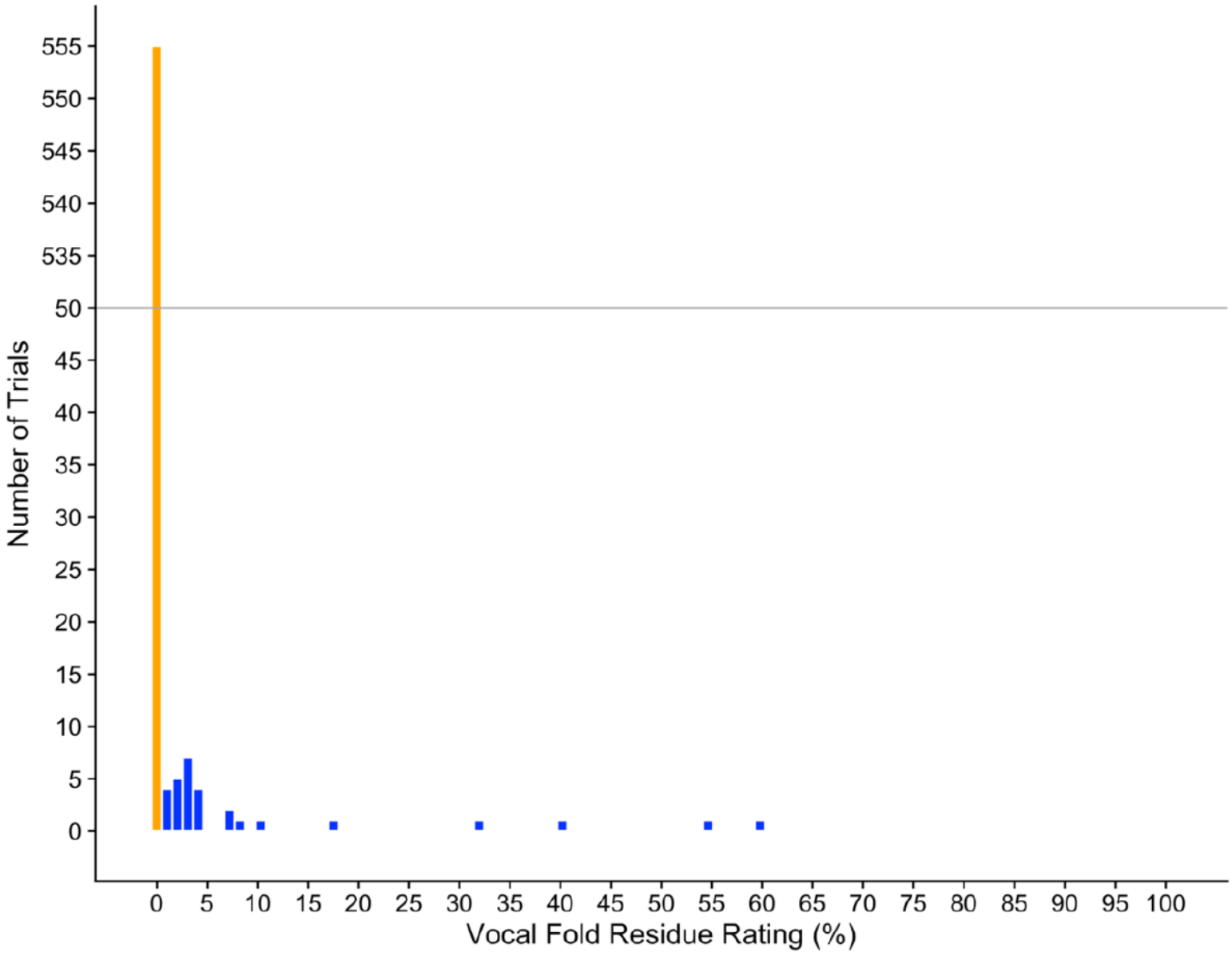
	Intra-Rater Reliability			Inter-Rater Reliability		
	Estimate	**P-value**	**Descriptive**	**Estimate**	**P-value**	**Descriptive**
Number of Swallows	0.710	<0.0005	90.0%	0.624	<0.0005	83.6%
Oropharyngeal Residue	0.931	<0.0005	0.7%	0.938	<0.0005	0.8%
Hypopharyngeal Residue	0.698	<0.0005	0.3%	0.696	<0.0005	0.6%
Epiglottic Residue	0.955	<0.0005	0.8%	0.760	<0.0005	1.9%
Laryngeal Vestibule Residue	0.968	<0.0005	0.4%	0.960	<0.0005	0.8%
Vocal Fold Residue	0.979%	<0.0005	0.1%	0.946	<0.0005	0.05%
Subglottic Residue	N/A	<0.0005	N/A	1.0	<0.0005	0%
PAS	1.0	<0.0005	100%	0.839	<0.0005	93.2%
Bolus Location at Swallow Onset	0.738	<0.0005	96.7%	0.44	<0.0005	76.7%

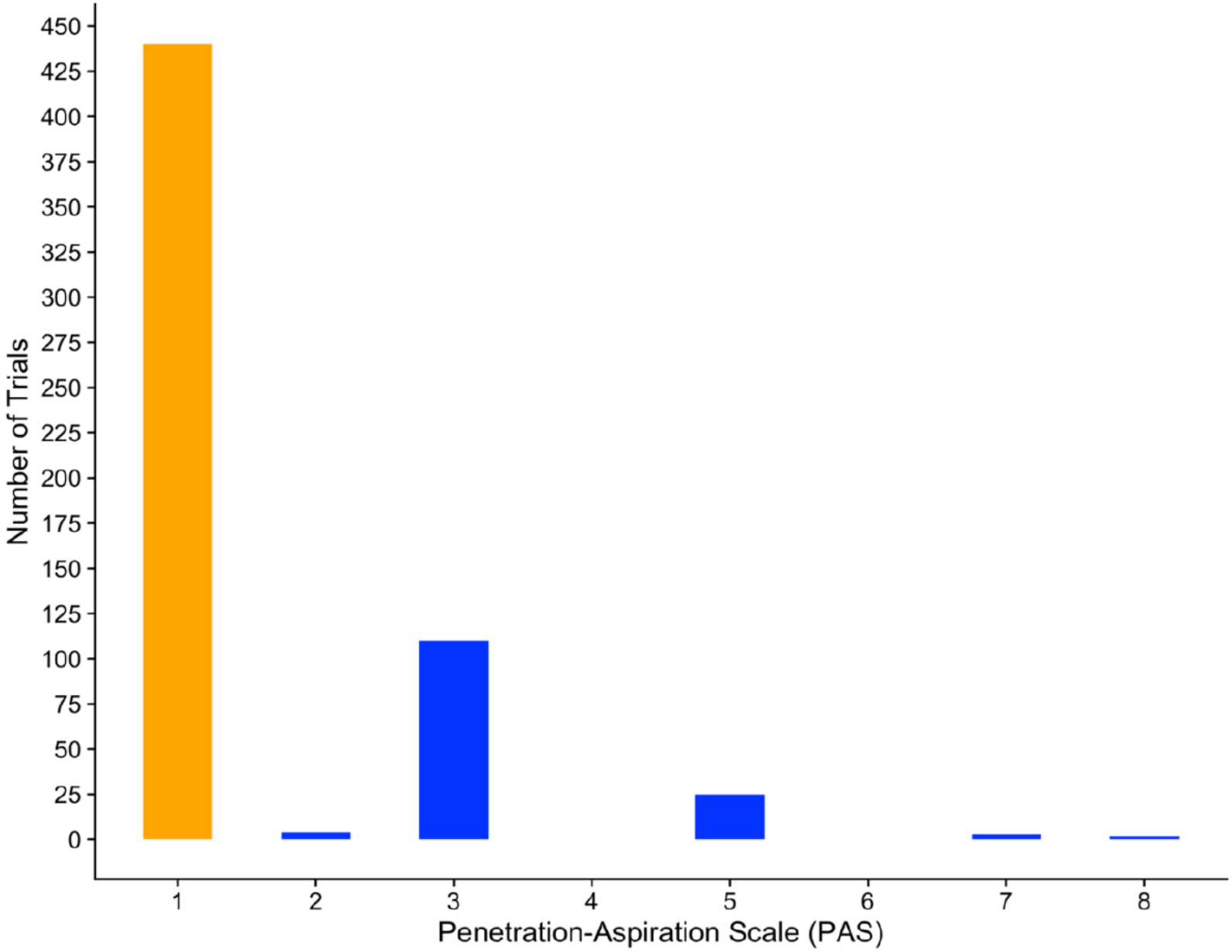

Number of Trials
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100
Oropopharyngeal Residue Rating (%)

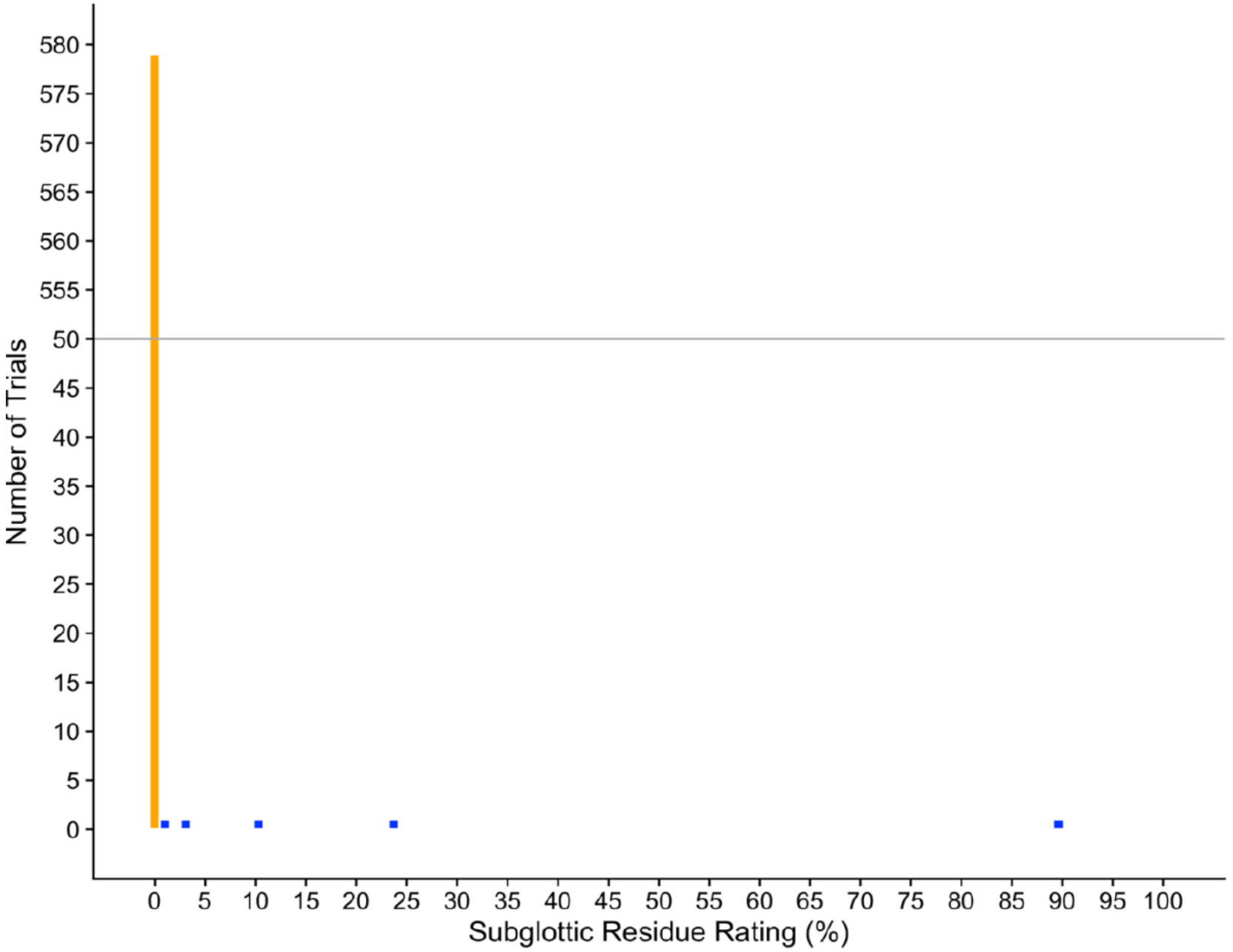

Number of Trials
280
270
260
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100
Hypopopharyngeal Residue Rating (%)


Number of Trials
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100
Epiglottis Residue Rating (%)


Number of Trials
450
445
440
435
430
50
45
40
35
30
25
20
15
10
5
0
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100
Laryngeal Vestibule Residue Rating (%)


Number of Trials
555
550
545
540
535
50
45
40
35
30
25
20
15
10
5
0
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100
Vocal Fold Residue Rating (%)


Number of Trials
450
425
400
375
350
325
300
275
250
225
200
175
150
125
100
75
50
25
0
1
2
3
4
5
6
7
8
Penetration-Aspiration Scale (PAS)


Number of Trials
580
575
570
565
560
555
50
45
40
35
30
25
20
15
10
5
0
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100
Subglottic Residue Rating (%)

Reflection

- Technology continues to advance
  - High Resolution Manometry
  - Improved Ultrasound techniques
  - Fast MRI
- Expect change in technology
- Expect associated change in practice
- Embrace change!