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MEDICAL UNIVERSITY of SOUTH CAROLINA

The Charleston Pharyngoesophageal Manometry Program • April 7-8, 2023 • Charleston, SC

Normal Manometric Pharyngeal Swallowing

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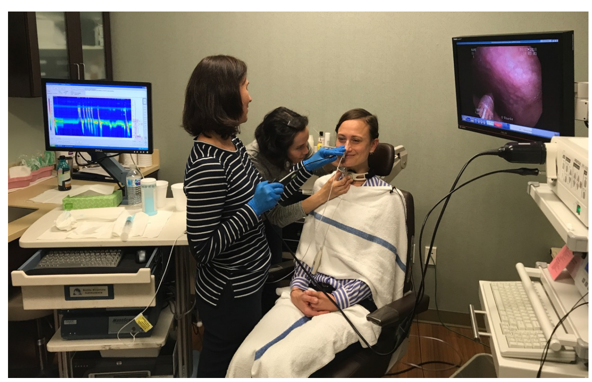
Endoscopic View of the Procedure



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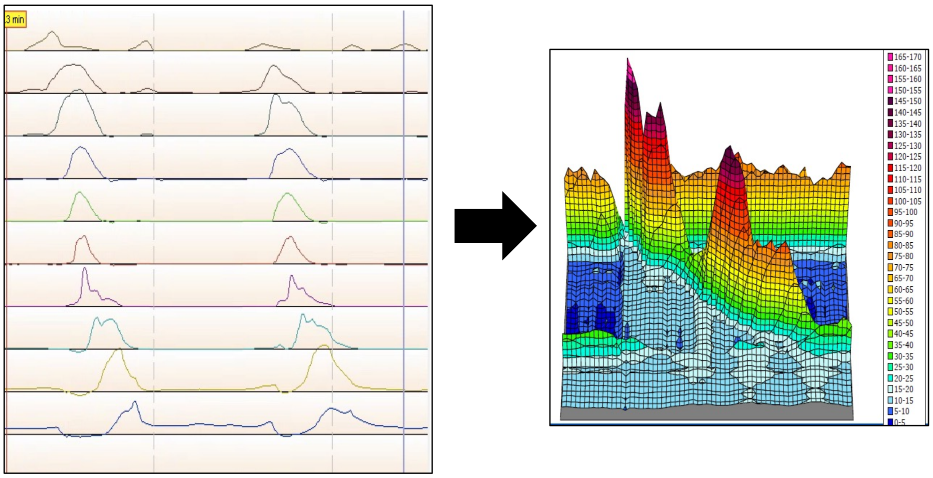
Topographical Pressure Plots

Clouse et al AJP 1996



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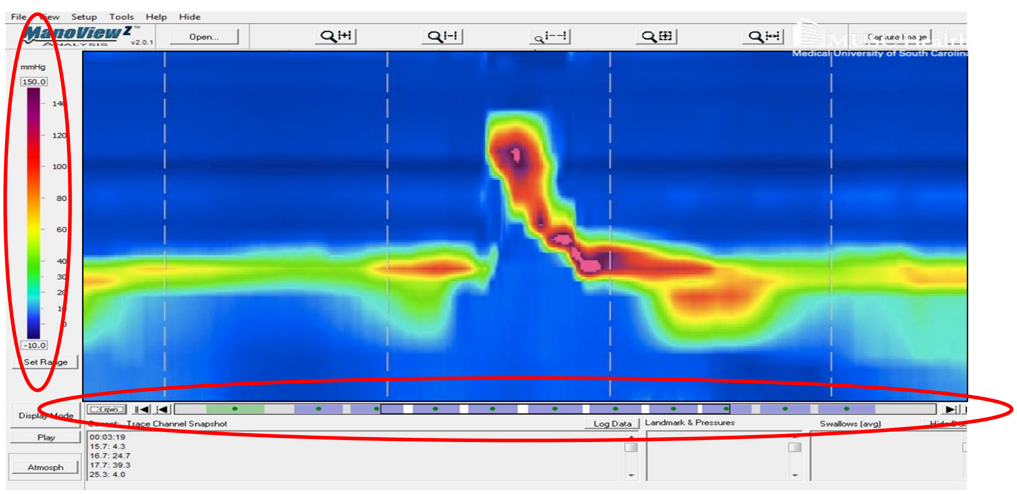
High Resolution Pharyngeal Manometry



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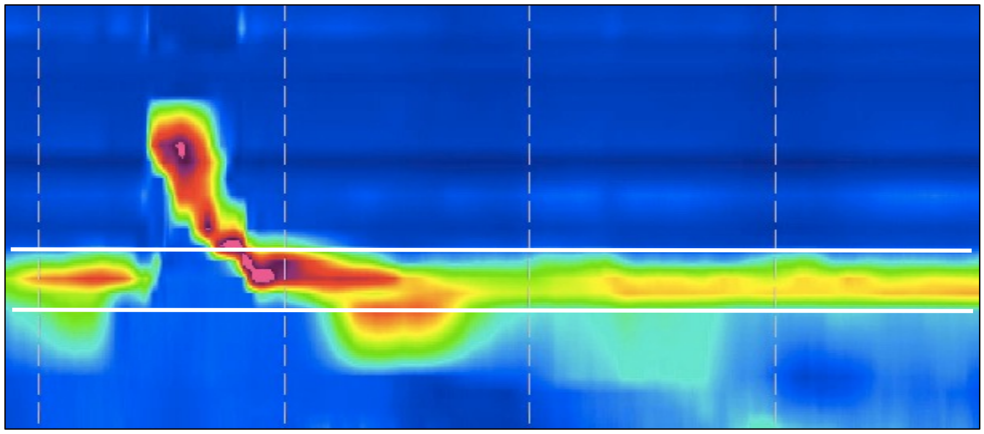
High Resolution Pharyngeal Manometry

Upper Esophageal Sphincter pressure band



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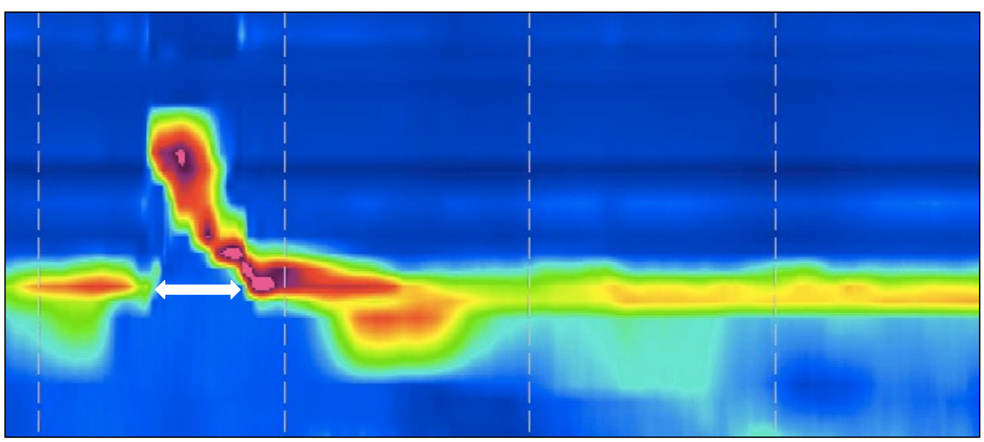
High Resolution Pharyngeal Manometry

Opening of the UES



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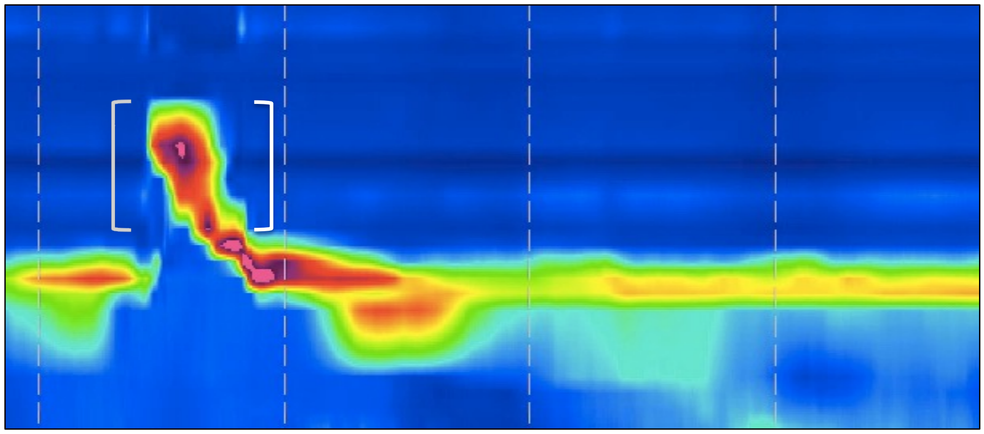
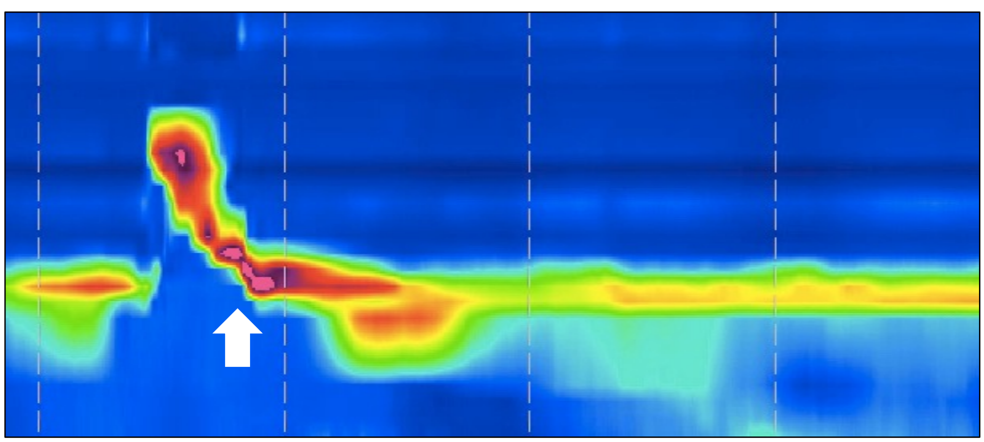
High Resolution Pharyngeal Manometry

Pharyngeal Pressures



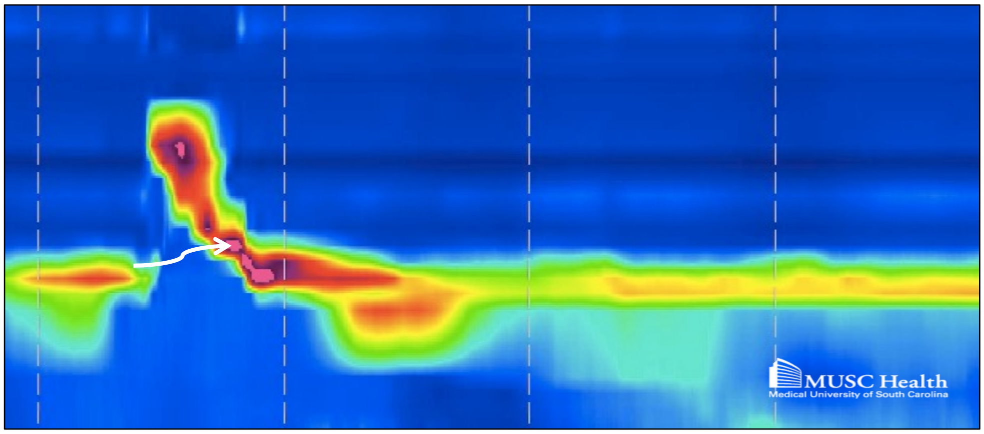
High Resolution Pharyngeal Manometry

Post-closure UES pressure spike

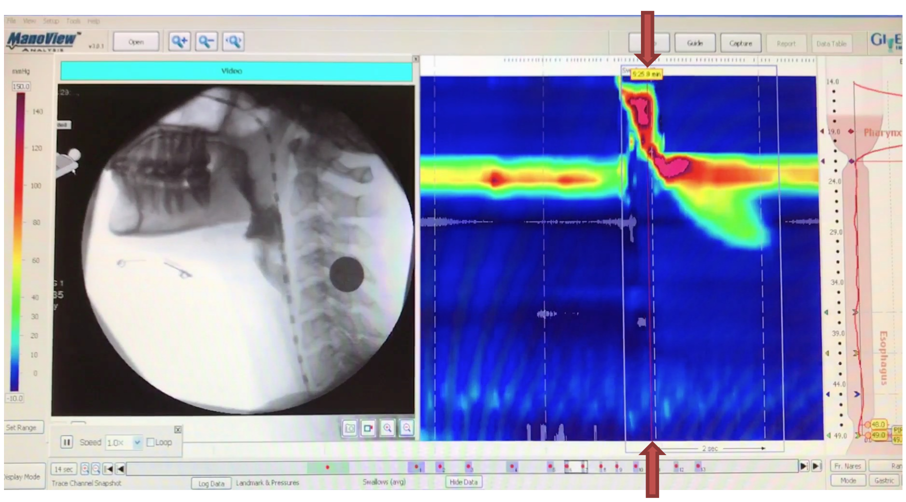


High Resolution Pharyngeal Manometry

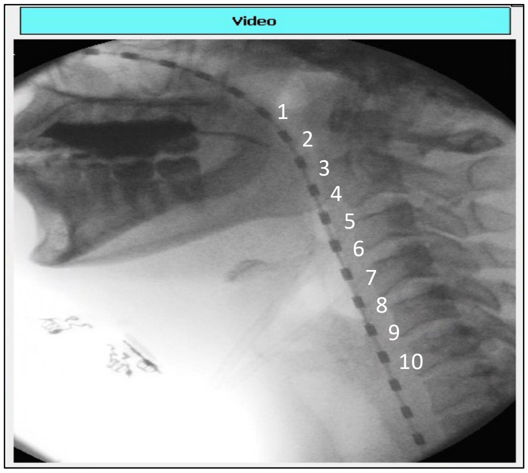
Upward movement of pharynx during swallowing

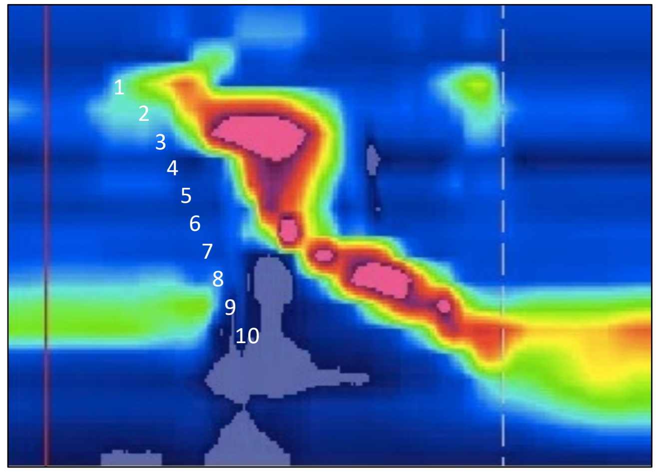


Simultaneous Manometry & Fluoroscopy



High Resolution Pharyngeal Manometry





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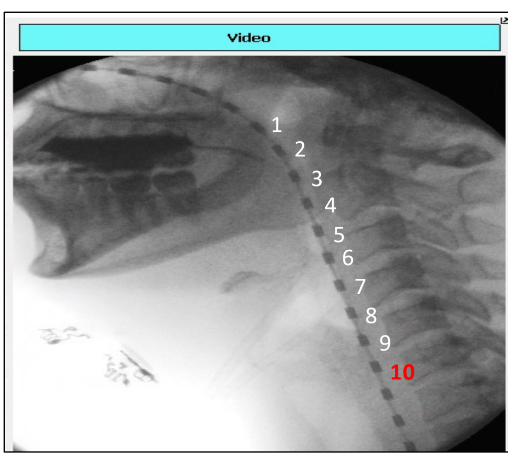
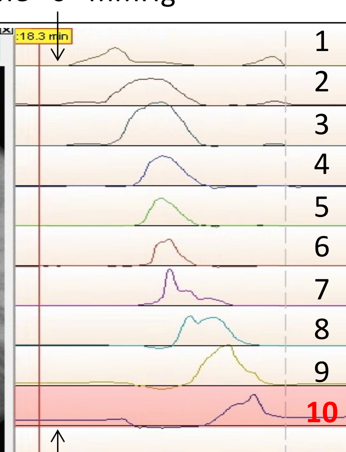
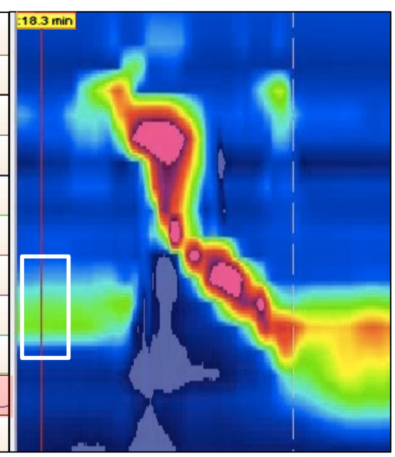
Resting Position

Baseline "0" mmHg







UES at ~ 30 mmHg

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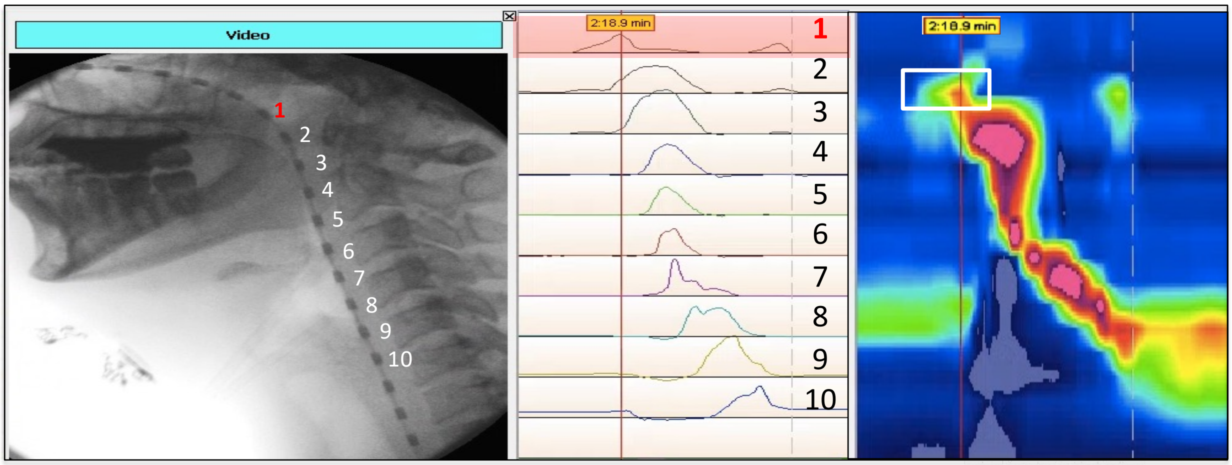
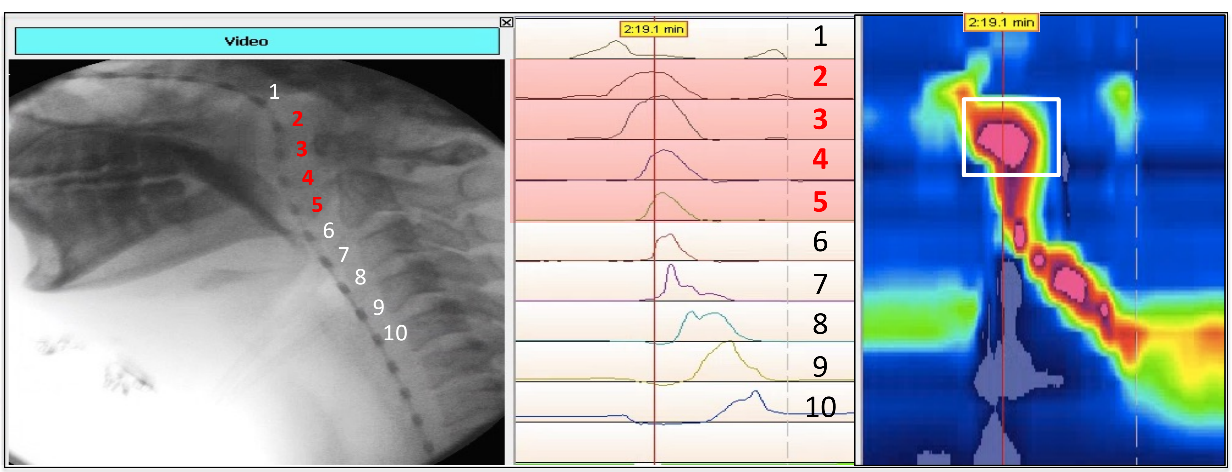
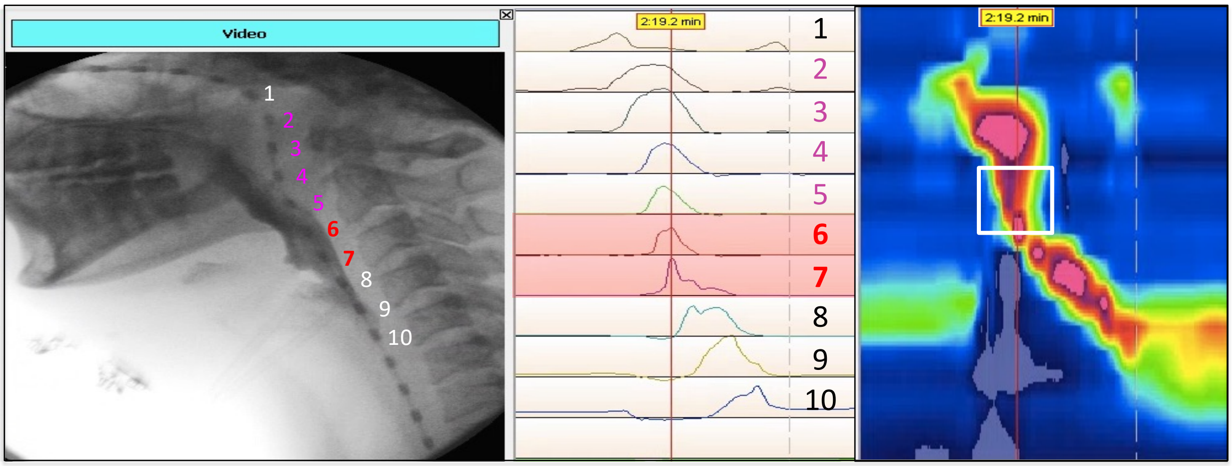
Velopharyngeal Contraction



Tongue Base – Superior Pharyngeal Constrictors



Hypopharynx – Middle Pharyngeal Constrictors



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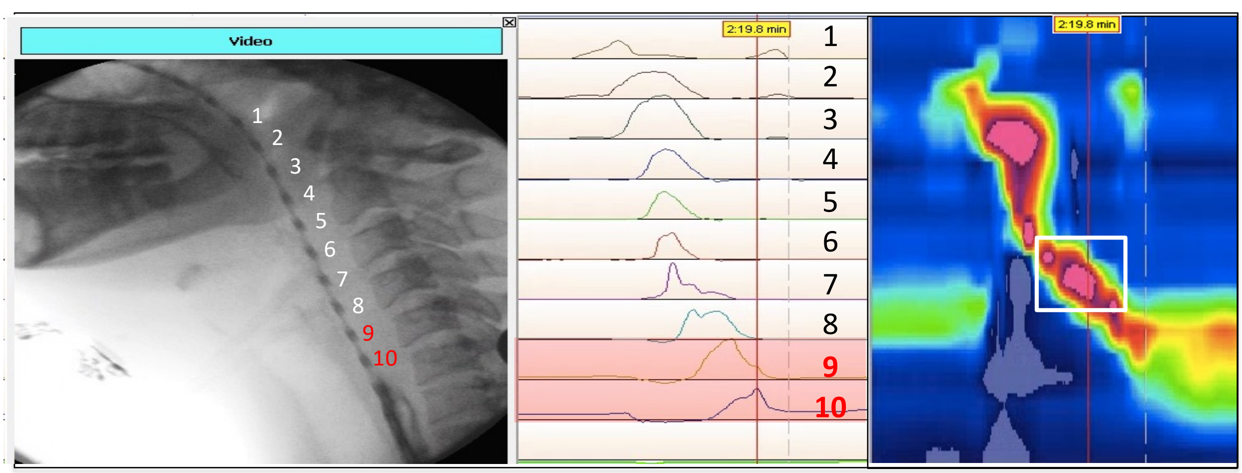
UES Post Closure Elevated Pressures



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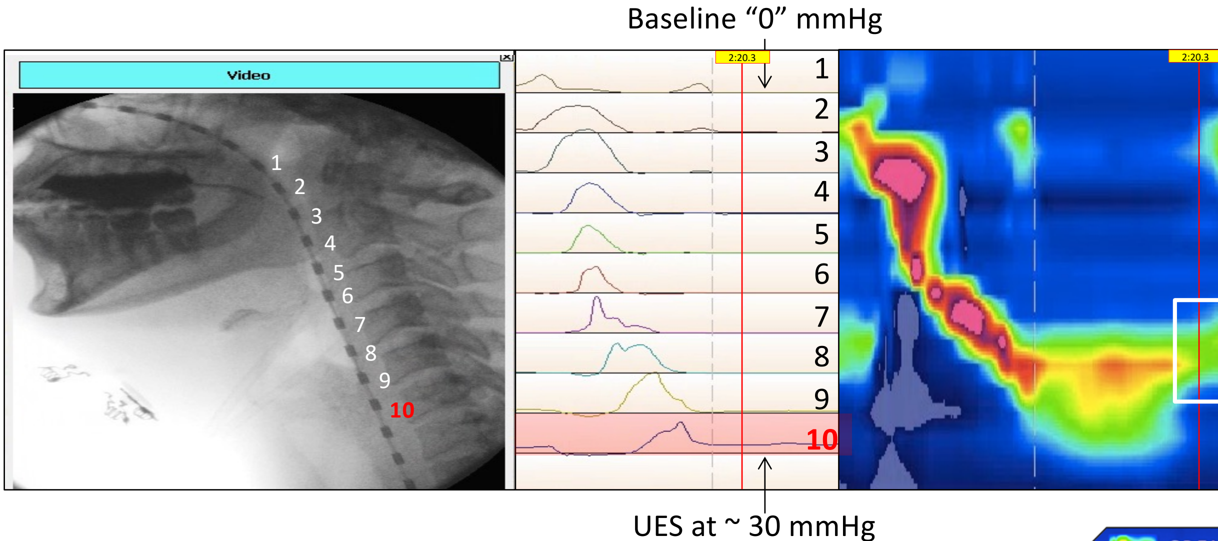
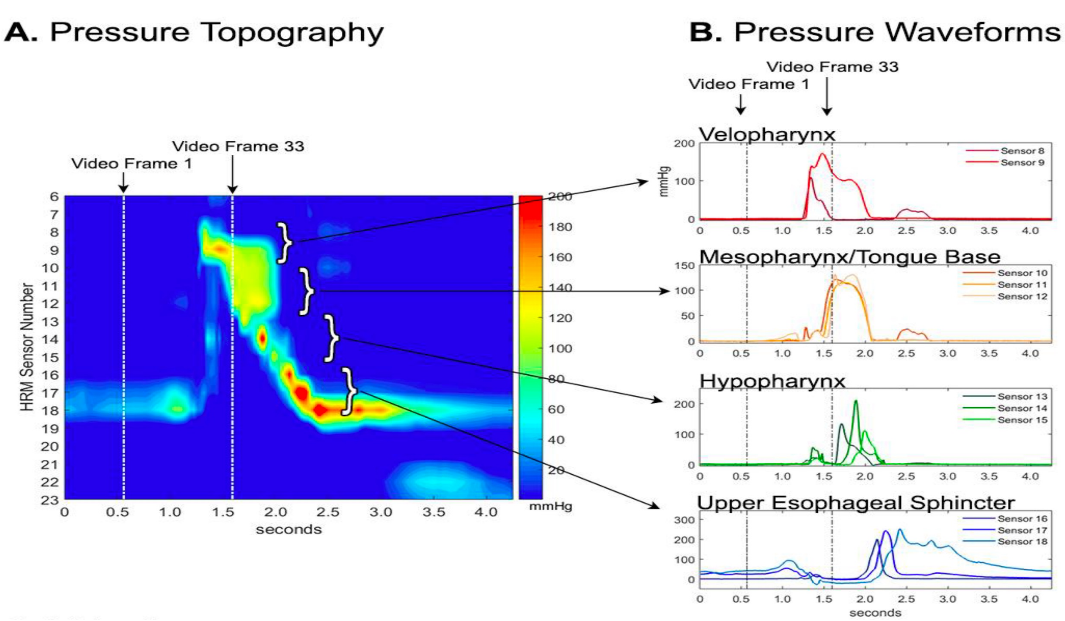
Back to Resting Position





International HRPM Working Group

VISION

"To improve the quality of dysphagia care through the clinical implementation of high-resolution pharyngeal manometry."

MISSION

"To create a standardization of high-resolution pharyngeal manometry acquisition, measurement, reporting, education and training as well as advocate with payers and healthcare systems."

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Omari et al...O'Rourke AK. Dysphagia 2019

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International HRPM Working Group

Methodology Sub-Group	Training & Education Sub-Group	Partnership/Knowledge Dissemination Sub-Group
• **Goal:** Develop a consensus on the standard methodology for HRPM including equipment, acquisition protocol, instrumentation and measurements.	• **Goal:** Establish education and training protocols.	• **Goal:** Align the HRPM Working Group with a larger entity to gain support and aid in information dissemination.

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Dysphagia
https://doi.org/10.1007/s00455-019-10023-y

ORIGINAL ARTICLE

Check for updates

High-Resolution Pharyngeal Manometry and Impedance: Protocols and Metrics—Recommendations of a High-Resolution Pharyngeal Manometry International Working Group

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Received: 24 July 2018 / Revised: 28 March 2019 / Accepted: 25 May 2019

Abstract

High-resolution manometry has traditionally been utilized in gastroenterology diagnostic clinical and research applications. Recently, it is also finding new and important applications in speech pathology and laryngology practices. A High-Resolution Pharyngeal Manometry International Working Group was formed as a grass roots effort to establish a consensus on methodology, protocol, and outcome metrics for high-resolution pharyngeal manometry (HRPM) with consideration of impedance as an adjunct modality. The Working Group undertook three tasks (1) survey what experts were currently doing in their clinical and/or research practice; (2) perform a review of the literature underpinning the value of particular HRPM metrics for understanding swallowing physiology and pathophysiology; and (3) establish a core outcomes set of HRPM metrics via a Delphi consensus process. Expert survey results were used to create a recommended HRPM protocol addressing system configuration, catheter insertion, and bolus administration. Ninety two articles were included in the final literature review resulting in categorization of 22 HRPM-impedance metrics into three classes: pharyngeal lumen occlusive pressures, hypopharyngeal intrabolus pressures, and upper esophageal sphincter (UES) function. A stable Delphi consensus was achieved for 8 HRPM-Impedance metrics: pharyngeal contractile integral (CI), velopharyngeal CI, hypopharyngeal CI, hypopharyngeal pressure at nadir impedance, UES integrated relaxation pressure, relaxation time, and maximum admittance. While some important unanswered questions remain, our work represents the first step in standardization of high-resolution pharyngeal manometry acquisition, measurement, and reporting. This could potentially inform future proposals for an HRPM-based classification system specifically for pharyngeal swallowing disorders.

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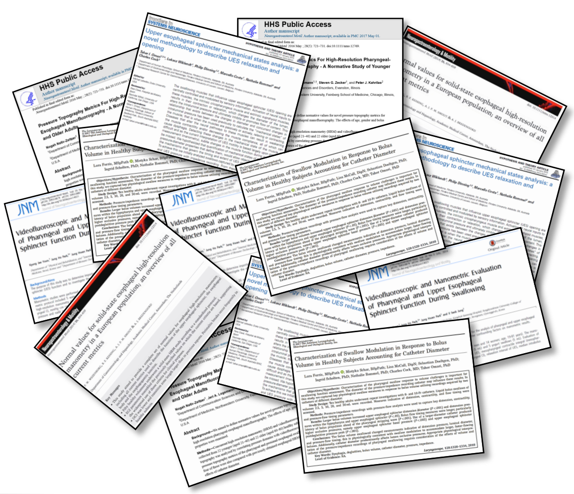
Delphi Consensus

92 Articles



22 HRPM-Impedance Metrics

16 Pharyngeal Lumen Occlusive Pressures

2 Hypopharyngeal Intrabolus Pressures

4 Upper Esophageal Sphincter Function

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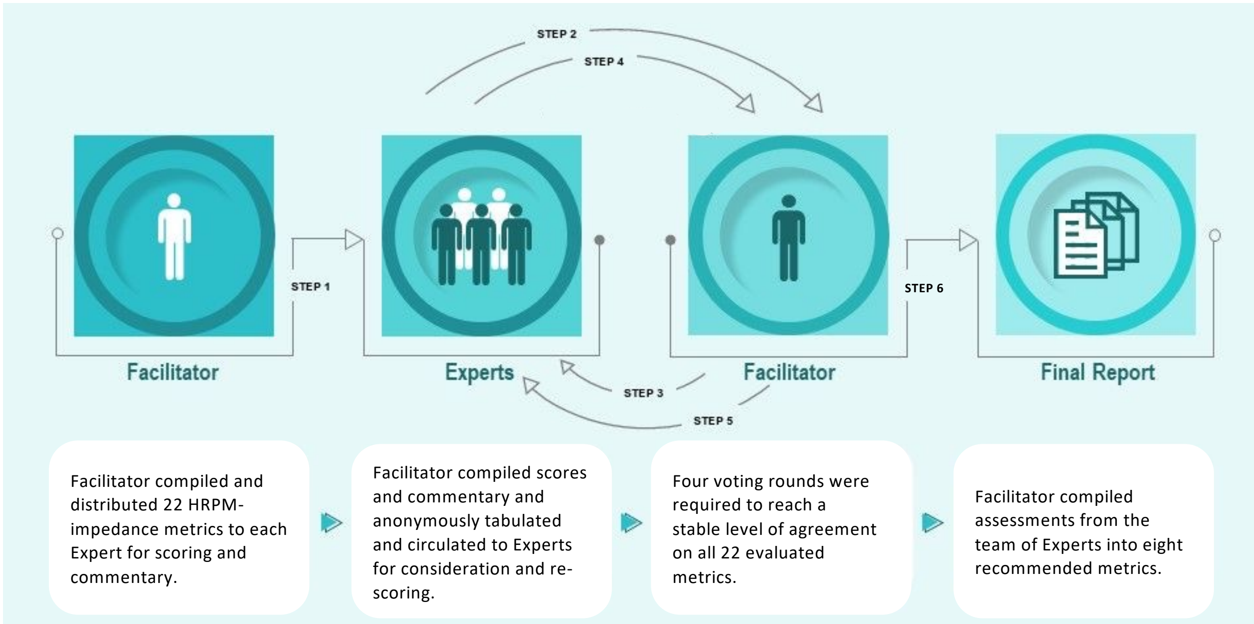

Recommended HRPM Protocol

- Expert survey responses served as the basis for protocol development
- Consistent themes were:
  - Judicious use of topical anesthesia (86%)
  - Minimum 5-min accommodation period (57%)
  - Bolus delivery via syringe (100%)
  - Consistency of test boluses (71%) (e.g. IDDSI)

System to use	Any solid-state HRM system including a catheter configured with at least 10 pressure sensors at 1 cm spacing If adjacent impedance is included then electrode segments at 2 cm spacing
Catheter placement	Requires education and training Apply lubricant gel to catheter Apply topical anesthesia to nasal passage Liquid sips via straw during placement Wait 5 min for catheter accommodation
Test boluses	Position-seated with head neural Delivery-syringe preferred Volumes-5 ml, 10 ml & sometimes 20 ml (case by case) Minimum 3 repeats (case by case)

Pharyngeal Lumen Occlusive Pressures

Region	Metric	Number of Assigned Final 4th Round Scores									Consensus Reached?
		Disagree			Equivocal			Agree			
		1	2	3	4	5	6	7	8	9	
Composite Measures	Pharyngeal Contractile Integral	0	0	0	0	0	0	0	0	10	YES
	Velo+Mesopharyngeal Contractile Integral	2	3	2	0	0	0	1	1	1	NO
	Meso+Hypopharyngeal Contractile Integral	4	2	2	0	0	1	1	0	0	NO
Velopharynx	Velopharyngeal Contractile Integral	0	0	0	0	0	1	0	0	9	YES
	Velopharyngeal Mean Peak Pressure	1	4	4	0	0	0	0	1	0	NO
	Velopharyngeal Maximum Pressure	3	2	3	0	0	1	1	0	0	NO
Mesopharynx	Mesopharyngeal Contractile Integral	0	1	0	0	0	1	0	0	8	YES
	Mesopharyngeal Mean Peak Pressure	1	4	5	0	0	0	0	0	0	NO
	Mesopharyngeal Maximum Pressure	2	4	3	0	0	1	0	0	0	NO
Hypopharynx	Hypopharyngeal Contractile Integral	0	1	0	0	0	1	0	2	6	YES
	Hypopharyngeal Mean Peak Pressure	1	3	3	0	1	0	0	1	1	NO
	Hypopharyngeal Maximum Pressure	3	1	3	0	1	1	1	0	0	NO
UES pre-deglutitive	UES Mean Basal Pressure	1	2	0	0	0	1	1	1	4	NO
	UES Maximum Basal Pressure	1	3	3	0	2	0	0	1	0	NO
UES post-deglutitive	UES Contractile Integral	1	1	2	1	2	2	0	1	0	NO
	UES Maximum Pressure	1	0	3	1	1	0	0	2	2	NO

Hypopharyngeal Intrabolus Pressure

Region	Metric	Number of Assigned Final 4th Round Scores									Consensus Reached?
		Disagree			Equivocal			Agree			
		1	2	3	4	5	6	7	8	9	
Hypopharynx	Hypopharyngeal Pressure Increment	0	1	3	0	2	0	0	2	2	NO
	Hypopharyngeal Pressure at Nadir Impedance	0	0	1	0	1	0	**0**	**2**	**6**	**YES**

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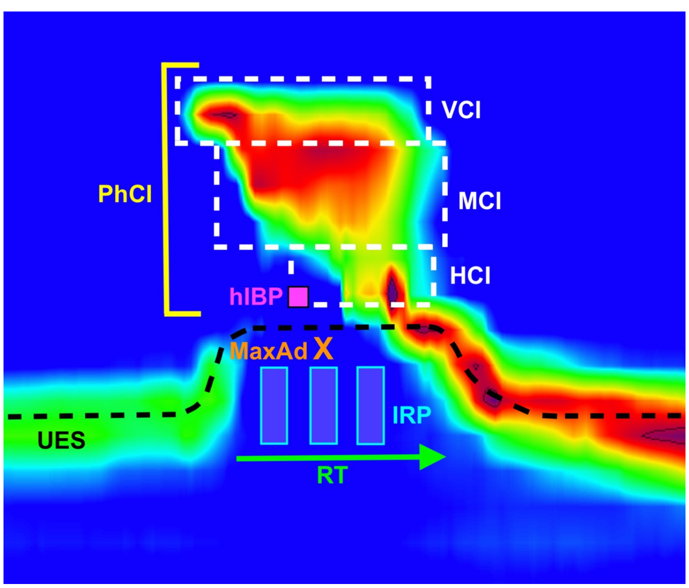
UES Relaxation & Opening

Region	Metric	Number of Assigned Final 4th Round Scores									Consensus Reached?
		Disagree			Equivocal			Agree			
		1	2	3	4	5	6	7	8	9	
UES Relaxation	Nadir UES Relaxation Pressure	1	1	1	1	0	1	2	2	1	NO
	UES Integrated Relaxation Pressure	0	0	0	0	0	0	0	0	10	YES
	UES Relaxation Time	0	1	0	0	0	1	0	0	8	YES
UES Opening	UES Maximum Admittance	0	0	0	0	2	0	0	1	7	YES



Representative Figure of the Diagnostic Metrics Evaluated on High-Resolution Pharyngeal Manometry

Contractile Integrals of the Pharynx (PhCI), Velopharynx (VCI), Mesopharynx (MCI), and Hypopharynx (HCI), the Upper Esophageal Sphincter (UES) Integrated Relaxation Pressure (IRP), UES Relaxation Time (RT), UES Maximum Admittance (MaxAd), and Hypopharyngeal Intrabolus Pressure (hIBP).

HRPM Core Outcomes

Metric class	Metric [Delphi group agreement level]	Acronym	Definition
Pharyngeal lumen occlusive pressure	Pharyngeal contractile integral [Agree 100%, Neutral 0%, Disagree 0%]	PhCI	PhCI is a global measure of pharyngeal contractile vigor within a space–time box on the pressure topography plot spanning from the velopharynx superiorly to the upper margin of the UES. The PhCI is the mean pressure within this domain multiplied by duration (s) and length (cm) in units of mmHg s cm
	Velopharyngeal contractile integral [Agree 100%, Neutral 0%, Disagree 0%]	VCI	VCI is a measure of contractile vigor within a space–time box on the pressure topography plot spanning the velopharyngeal region only. VCI is the mean pressure within this domain multiplied by duration (s) and length (cm) in units of mmHg s cm
	Mesopharyngeal contractile integral [Agree 90%, Neutral 0%, Disagree 10%]	MCI	MCI is a measure of contractile vigor within a space–time box on the pressure topography plot spanning the mesopharyngeal region only. MCI is the mean pressure within this domain multiplied by duration (s) and length (cm) in units of mmHg s cm
	Hypopharyngeal contractile integral [Agree 90%, Neutral 0%, Disagree 10%]	HCI	HCI is a measure of contractile vigor within a space-time box on the pressure topography plot spanning the hypopharyngeal region only. HCI is the mean pressure within this domain multiplied by duration (s) and length (cm) in units of mmHg s cm
UES relaxation & opening	UES integrated relaxation pressure [Agree 100%, Neutral 0%, Disagree 0%]	UES IRP	UES IRP is a measure of the extent of UES relaxation. UES IRP is the median of the lowest non-consecutive 0.20–0.25 s of e-sleeve pressure in units of mmHg
	UES relaxation time [Agree 90%, Neutral 0%, Disagree 10%]	UES RT	UES RT is a measure of the duration of UES relaxation. UES RT is the e-sleeve pressure interval below 50% of baseline or 35 mmHg, whichever is lower, in units of sec
	UES maximum admittance [Agree 80%, Neutral 0%, Disagree 20%]	UES MaxAd	UES MaxAd is a measure of extent of UES opening. UES MaxAd is the highest admittance value recorded during trans-sphincteric bolus flow in units of millisiemens (mS)
Hypopharyngeal intrabolus distension pressure	Hypopharyngeal intrabolus pressure [Agree 80%, Neutral 10%, Disagree 10%]	IBP	IBP is defined by the pressure 1 cm superior of UES apogee position at the time of maximum hypopharyngeal distension deduced from impedance topography in units of mmHg

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HRPM International Working Group, Protocols & Metrics, Omari et al., 2019

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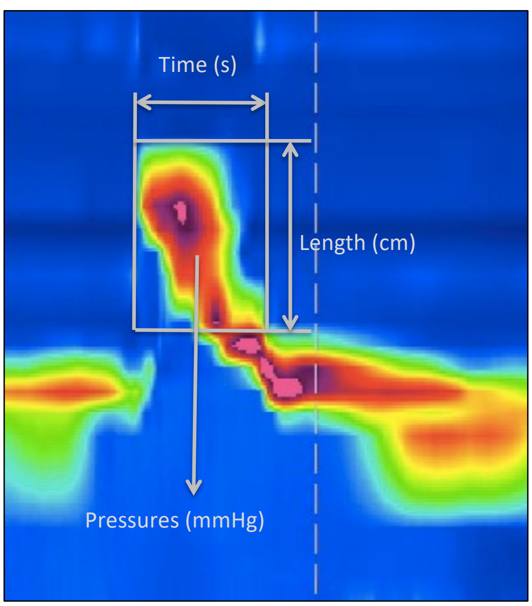

Contractile Integrals

An ***integral*** is a mathematical term that represents an area or a generalization of an area.

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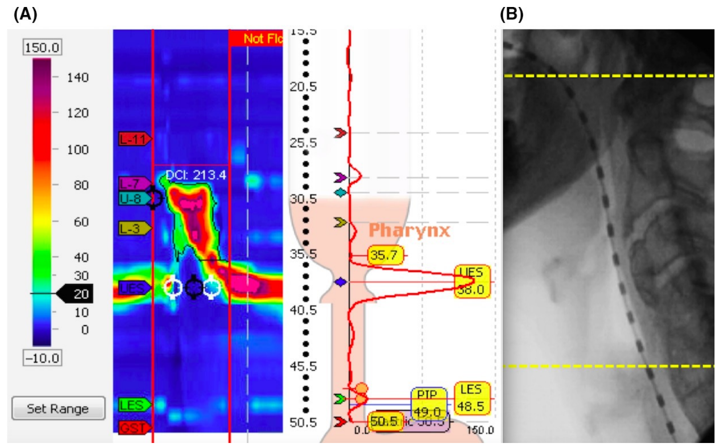
Pharyngeal Contractile Integral (PhCI)

- **PhCI** is a global measure of pharyngeal contractile vigor.
- Measured within a space–time box on the pressure topography plot spanning from the *velopharynx superiorly to the upper margin of the UES*.
- The PhCI is the mean pressure within this domain multiplied by duration (s) and length (cm) in units of mmHg-s-cm.



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Associated Muscles & Innervation

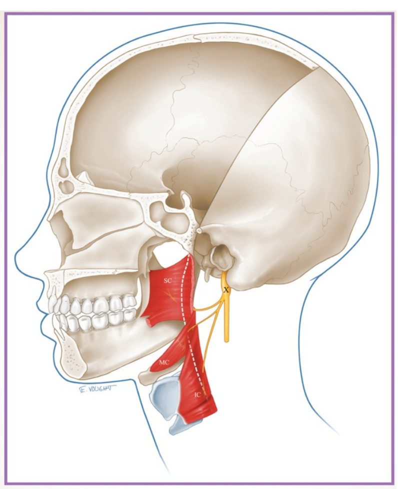

Figure 24 Muscles and innervation of Pharyngeal Stripping Wave (Component 12). IC-Inferior pharyngeal constrictor; MC-Middle pharyngeal constrictor; SC-Superior pharyngeal constrictor. X refers to vagus nerve.

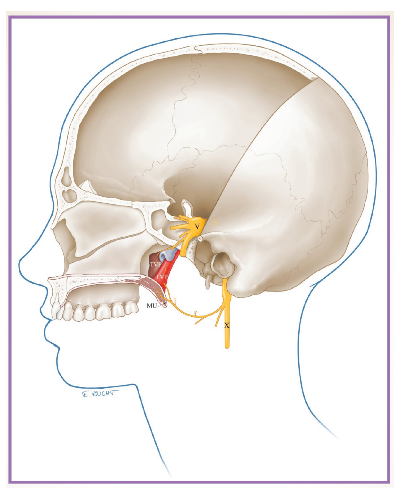

Figure 14 Muscles and innervation of Soft Palate Elevation (Component 7). LVP-Levator veli palatini; MU-Musculus uvulae; TVP-Tensor veli palatini. V and X refer to trigeminal and vagus nerves, respectively.

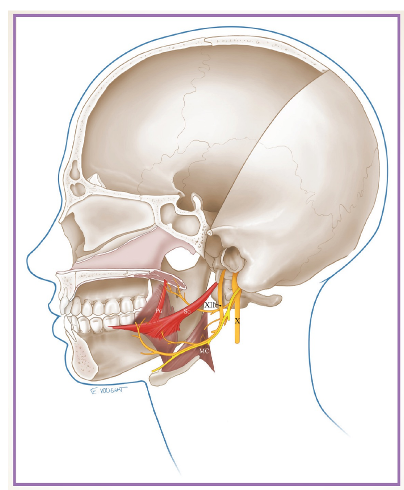

Figure 30 Muscles and innervation of Tongue Base Retraction (Component 15). PG-Palatoglossus; SG-Styloglossus; MC-Middle pharyngeal constrictor. X and XII refer to vagus and hypoglossus nerves, respectively.

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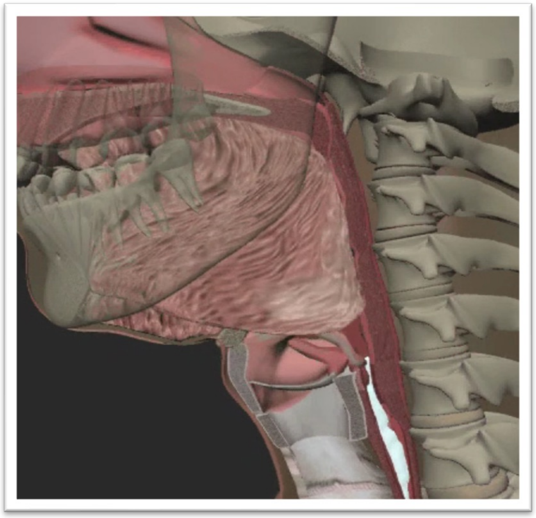
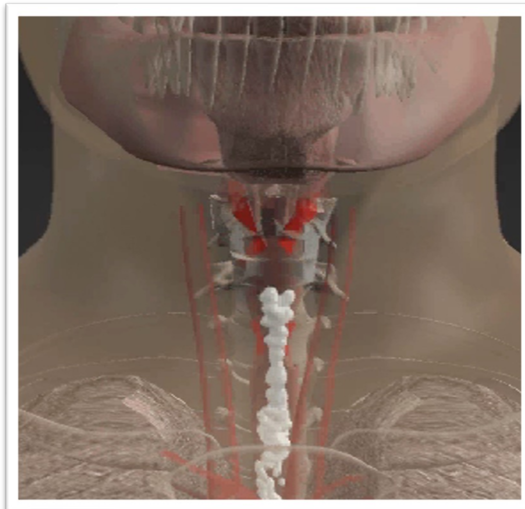
Soft Palate Elevation, Tongue Base Retraction, Pharyngeal Stripping Wave, Pharyngeal Contraction





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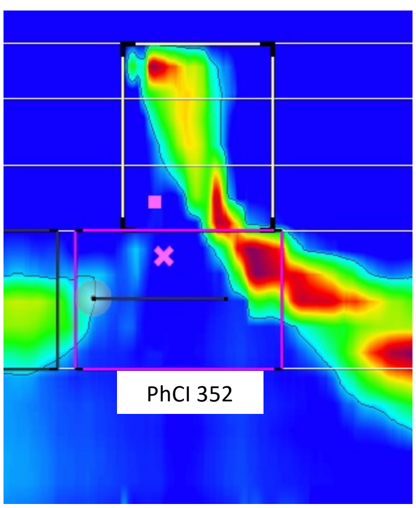
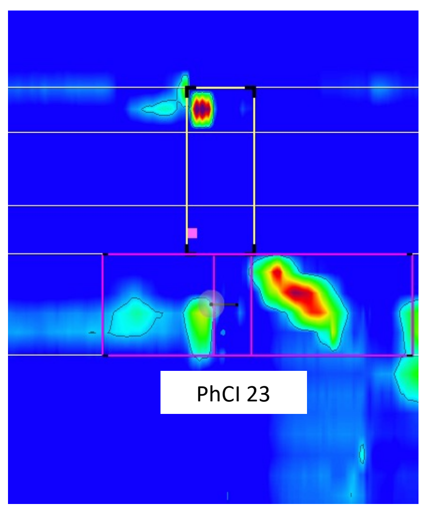
Illustrative Examples of Pharyngeal Contractile Integral (PhCI)





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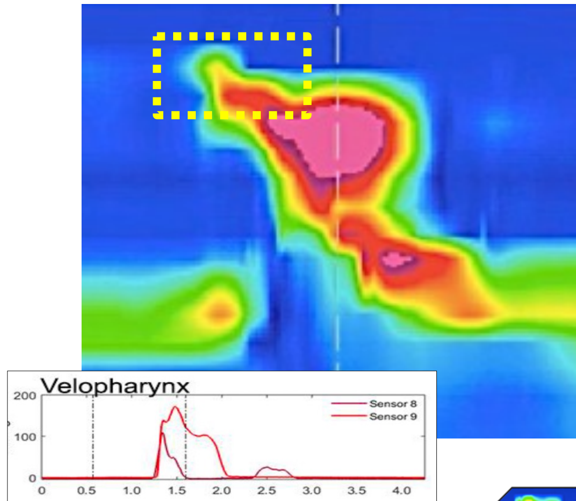
Velopharyngeal Contractile Integral (VCI)

- **VCI** is a measure of contractile vigor.
  - Soft palate to pharyngeal wall contact
- Measured within a space–time box on the pressure topography plot spanning the *velopharyngeal region only*.
- VCI is the mean pressure within this domain multiplied by duration (s) and length (cm) in units of mmHg s cm



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Associated Muscles & Innervation

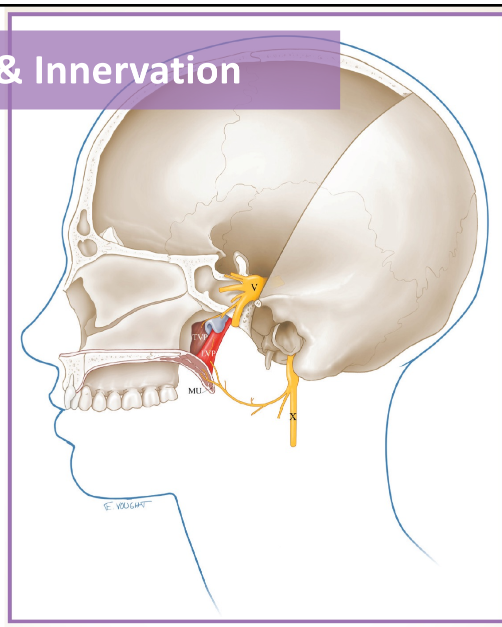

Figure 14 Muscles and innervation of Soft Palate Elevation (Component 7).
LVP-Levator veli palatini; MU-Musculus uvulae; TVP-Tensor veli palatini. V and X refer to trigeminal and vagus nerves, respectively.

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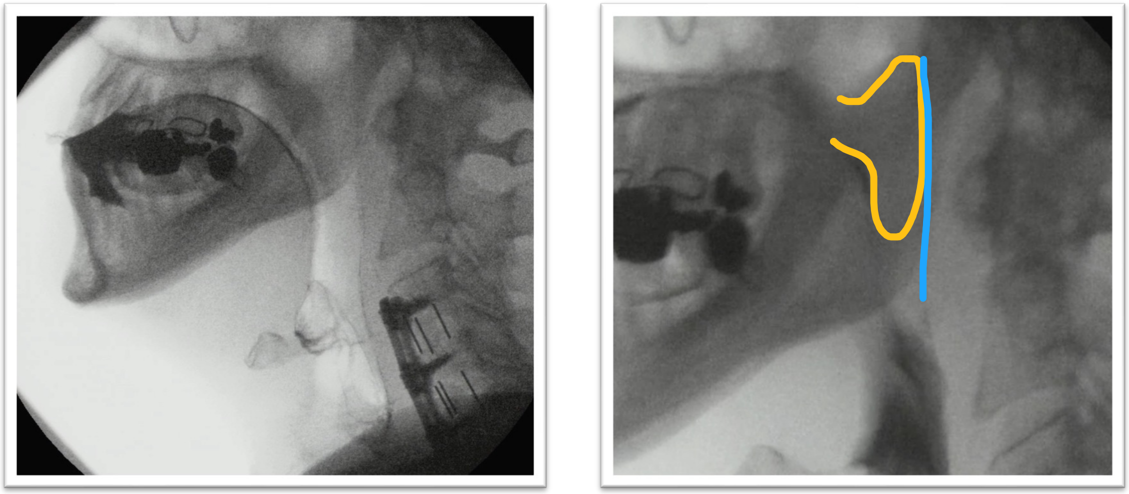
Soft Palate Elevation



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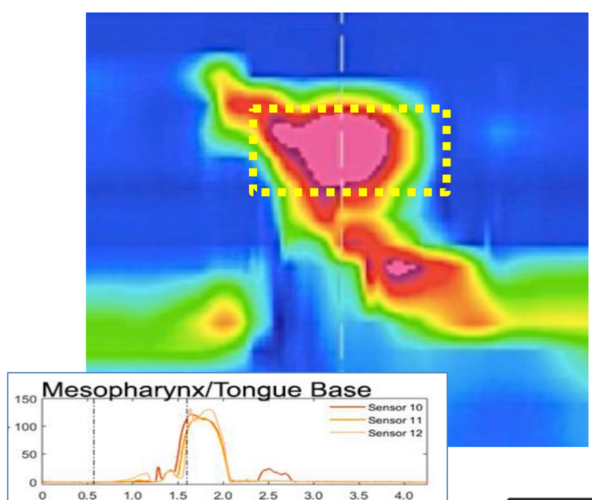
Mesopharyngeal Contractile Integral (MCI)

- **MCI** is a measure of contractile vigor
  - Tongue base to pharyngeal wall contact
- Measured within a space–time box on the pressure topography plot spanning the *mesopharyngeal region only*.
- MCI is the mean pressure within this domain multiplied by duration (s) and length (cm) in units of mmHg s cm



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Associated Muscles & Innervation

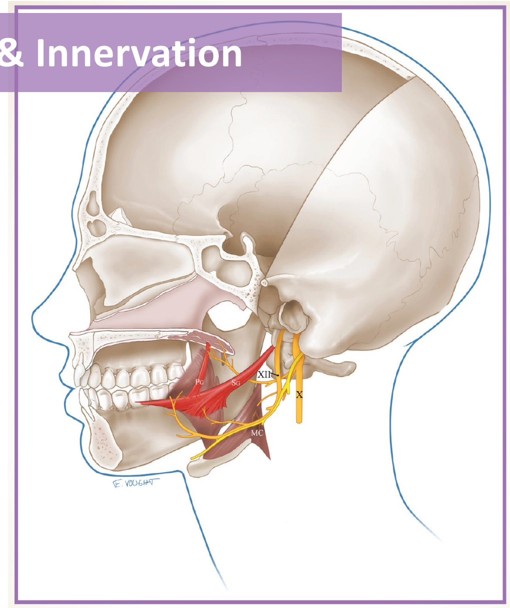

Figure 30 Muscles and innervation of Tongue Base Retraction (Component 15).
PG-Palatoglossus; SG-Styloglossus; MC-Middle pharyngeal constrictor. X and XII refer to vagus and hypoglossus nerves, respectively.

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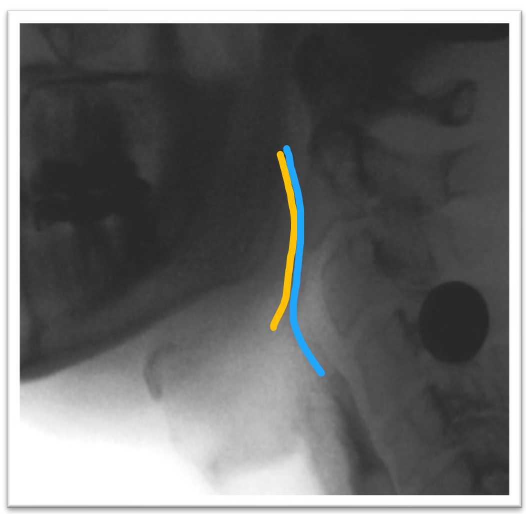
Tongue Base Retraction



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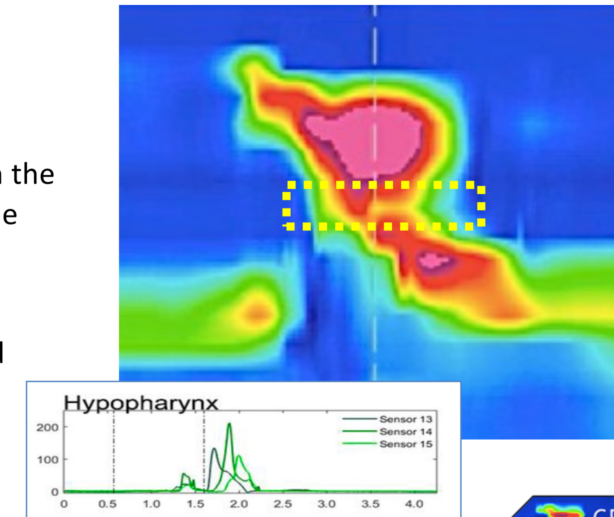
Hypopharyngeal Contractile Integral (HCI)

- **HCI** is a measure of contractile vigor
  - **Epiglottis to pharyngeal wall contact
- Measured within a space-time box on the pressure topography plot spanning the *hypopharyngeal region only*.
- HCI is the mean pressure within this domain multiplied by duration (s) and length (cm) in units of mmHg s cm



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Associated Muscles & Innervation

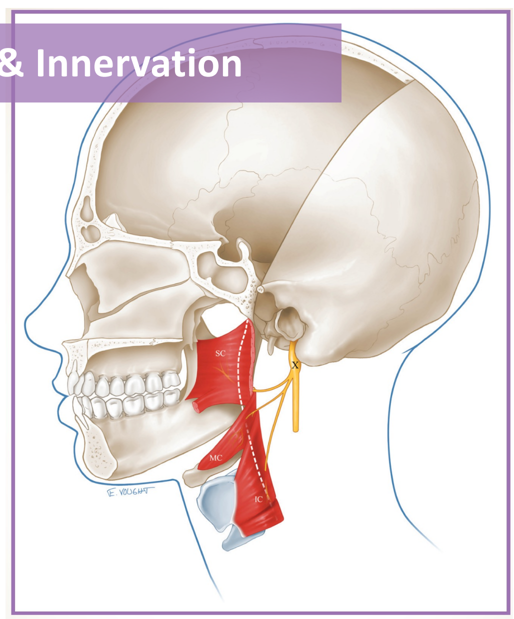

Figure 24 Muscles and innervation of Pharyngeal Stripping Wave (Component 12). IC-Inferior pharyngeal constrictor; MC-Middle pharyngeal constrictor; SC-Superior pharyngeal constrictor. X refers to vagus nerve.

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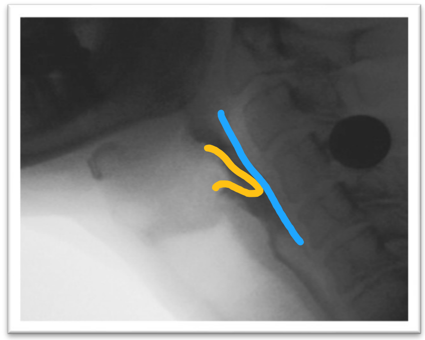
Pressure Transient: Epiglottic Inversion



- potentially erroneous and can influence numerical values generated for IBP
- may reliably predict epiglottic inversion - clinical relevance for some patients.

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HRPM Core Outcomes

Metric class	Metric [Delphi group agreement level]	Acronym	Definition
Pharyngeal lumen occlusive pressure	Pharyngeal contractile integral [Agree 100%, Neutral 0%, Disagree 0%]	PhCI	PhCI is a global measure of pharyngeal contractile vigor within a space–time box on the pressure topography plot spanning from the velopharynx superiorly to the upper margin of the UES. The PhCI is the mean pressure within this domain multiplied by duration (s) and length (cm) in units of mmHg s cm
	Velopharyngeal contractile integral [Agree 100%, Neutral 0%, Disagree 0%]	VCI	VCI is a measure of contractile vigor within a space–time box on the pressure topography plot spanning the velopharyngeal region only. VCI is the mean pressure within this domain multiplied by duration (s) and length (cm) in units of mmHg s cm
	Mesopharyngeal contractile integral [Agree 90%, Neutral 0%, Disagree 10%]	MCI	MCI is a measure of contractile vigor within a space–time box on the pressure topography plot spanning the mesopharyngeal region only. MCI is the mean pressure within this domain multiplied by duration (s) and length (cm) in units of mmHg s cm
	Hypopharyngeal contractile integral [Agree 90%, Neutral 0%, Disagree 10%]	HCI	HCI is a measure of contractile vigor within a space-time box on the pressure topography plot spanning the hypopharyngeal region only. HCI is the mean pressure within this domain multiplied by duration (s) and length (cm) in units of mmHg s cm
UES relaxation & opening	UES integrated relaxation pressure [Agree 100%, Neutral 0%, Disagree 0%]	UES IRP	UES IRP is a measure of the extent of UES relaxation. UES IRP is the median of the lowest non-consecutive 0.20–0.25 s of e-sleeve pressure in units of mmHg
	UES relaxation time [Agree 90%, Neutral 0%, Disagree 10%]	UES RT	UES RT is a measure of the duration of UES relaxation. UES RT is the e-sleeve pressure interval below 50% of baseline or 35 mmHg, whichever is lower, in units of sec
	UES maximum admittance [Agree 80%, Neutral 0%, Disagree 20%]	UES MaxAd	UES MaxAd is a measure of extent of UES opening. UES MaxAd is the highest admittance value recorded during trans-sphincteric bolus flow in units of millisiemens (mS)
Hypopharyngeal intrabolus distension pressure	Hypopharyngeal intrabolus pressure [Agree 80%, Neutral 10%, Disagree 10%]	IBP	IBP is defined by the pressure 1 cm superior of UES apogee position at the time of maximum hypopharyngeal distension deduced from impedance topography in units of mmHg

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HRPM International Working Group, Protocols & Metrics, Omari et al., 2019

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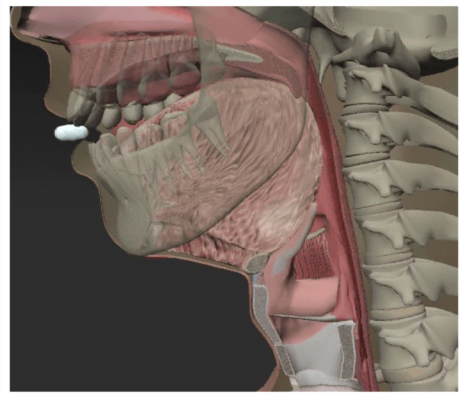
UES Relaxation & Opening

- Why is it important to look at UES parameters?
- The mechanisms that determine UES opening extent include:
  - strength and timing of supra- and infra-hyoid muscle activation (hyolaryngeal movement)
  - distension pressure generated by the swallowed bolus driven by pharyngeal propulsion (tongue base retraction, pharyngeal stripping)
  - neural deactivation and compliance of the cricopharyngeus



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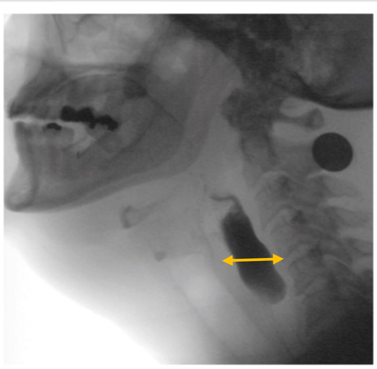
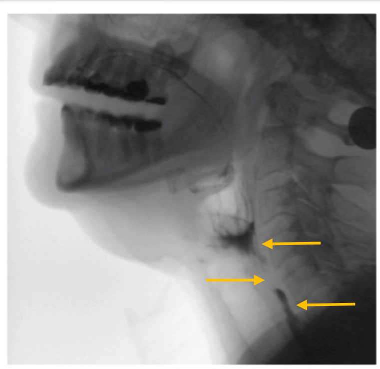
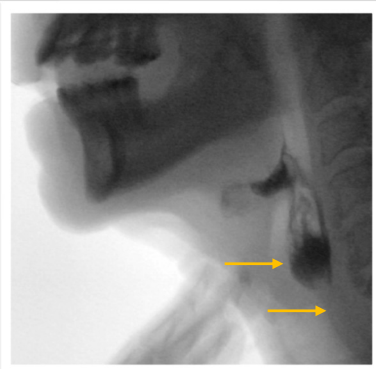
UES Relaxation & Opening



Distension



Duration



Obstruction

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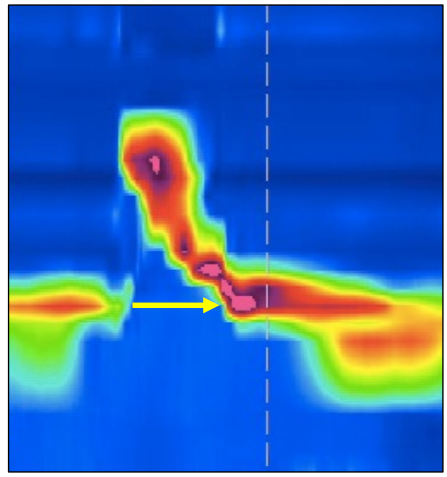
UES Relaxation Time (UES-RT)

- UES-RT describes the duration of UES opening.
- Time in milliseconds from relaxation to contraction of the upper esophageal sphincter.
- Relaxation is defined as a 50% reduction in baseline pressure or less than 35 mmHg



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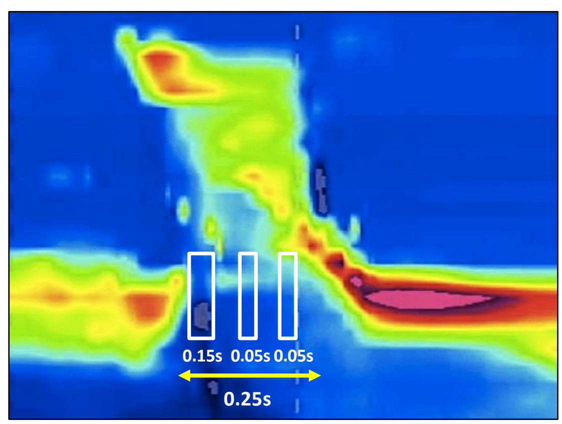
UES Integrated Relaxation Pressure (UES-IRP)

- The lowest non-consecutive 0.20–0.25 s of UES pressure during relaxation
- Analogous to LES IRP
- Reported in mmHg



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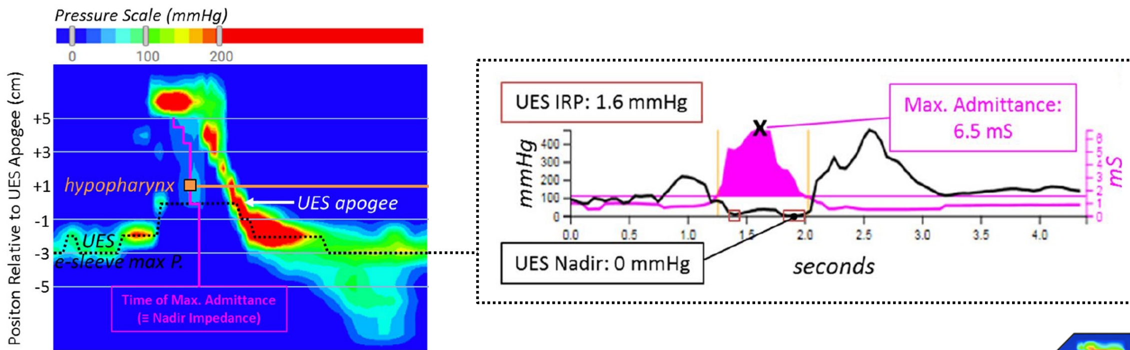
UES Maximum Admittance

- **Measure of extent of UES opening – correlate of luminal diameter**
- UES MaxAd is the highest admittance value recorded during trans-sphincteric bolus flow in units of millisiemens (mS)



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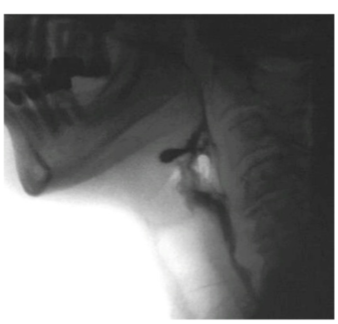

Admittance

- Impedance is the resistance to flow
  - Used to estimate changes in diameter associated with bolus movement
- Maximum impedance = highest resistance to flow
- Inverse of impedance is admittance
- Admittance is the absence of resistance to flow
- Maximum admittance = least resistance to flow

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HRPM Core Outcomes

Metric class	Metric [Delphi group agreement level]	Acronym	Definition
Pharyngeal lumen occlusive pressure	Pharyngeal contractile integral [Agree 100%, Neutral 0%, Disagree 0%]	PhCI	PhCI is a global measure of pharyngeal contractile vigor within a space–time box on the pressure topography plot spanning from the velopharynx superiorly to the upper margin of the UES. The PhCI is the mean pressure within this domain multiplied by duration (s) and length (cm) in units of mmHg s cm
	Velopharyngeal contractile integral [Agree 100%, Neutral 0%, Disagree 0%]	VCI	VCI is a measure of contractile vigor within a space–time box on the pressure topography plot spanning the velopharyngeal region only. VCI is the mean pressure within this domain multiplied by duration (s) and length (cm) in units of mmHg s cm
	Mesopharyngeal contractile integral [Agree 90%, Neutral 0%, Disagree 10%]	MCI	MCI is a measure of contractile vigor within a space–time box on the pressure topography plot spanning the mesopharyngeal region only. MCI is the mean pressure within this domain multiplied by duration (s) and length (cm) in units of mmHg s cm
	Hypopharyngeal contractile integral [Agree 90%, Neutral 0%, Disagree 10%]	HCI	HCI is a measure of contractile vigor within a space-time box on the pressure topography plot spanning the hypopharyngeal region only. HCI is the mean pressure within this domain multiplied by duration (s) and length (cm) in units of mmHg s cm
UES relaxation & opening	UES integrated relaxation pressure [Agree 100%, Neutral 0%, Disagree 0%]	UES IRP	UES IRP is a measure of the extent of UES relaxation. UES IRP is the median of the lowest non-consecutive 0.20–0.25 s of e-sleeve pressure in units of mmHg
	UES relaxation time [Agree 90%, Neutral 0%, Disagree 10%]	UES RT	UES RT is a measure of the duration of UES relaxation. UES RT is the e-sleeve pressure interval below 50% of baseline or 35 mmHg, whichever is lower, in units of sec
	UES maximum admittance [Agree 80%, Neutral 0%, Disagree 20%]	UES MaxAd	UES MaxAd is a measure of extent of UES opening. UES MaxAd is the highest admittance value recorded during trans-sphincteric bolus flow in units of millisiemens (mS)
Hypopharyngeal intrabolus distension pressure	Hypopharyngeal intrabolus pressure [Agree 80%, Neutral 10%, Disagree 10%]	IBP	IBP is defined by the pressure 1 cm superior of UES apogee position at the time of maximum hypopharyngeal distension deduced from impedance topography in units of mmHg

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HRPM International Working Group, Protocols & Metrics, Omari et al., 2019

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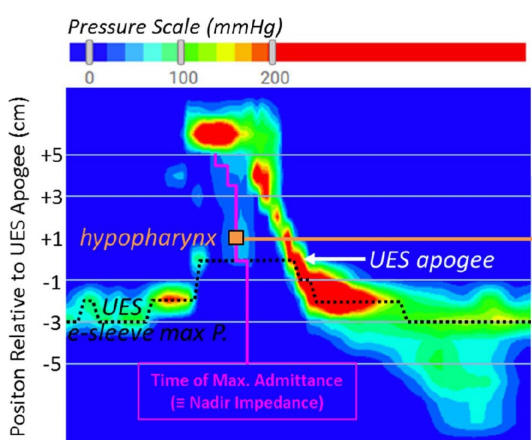
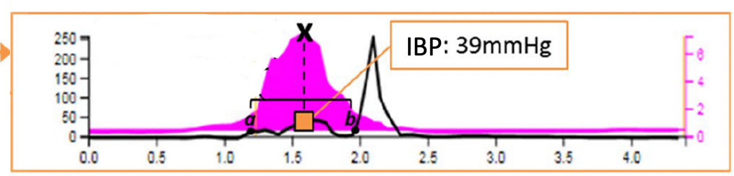
Hypopharyngeal Intrabolus Pressure (hIBP)

- **Marker of UES restriction to bolus flow during swallowing.**
- The pressure 1 cm superior of UES apogee position at the time of maximum hypopharyngeal distension (max admittance).





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Omari et al., 2019

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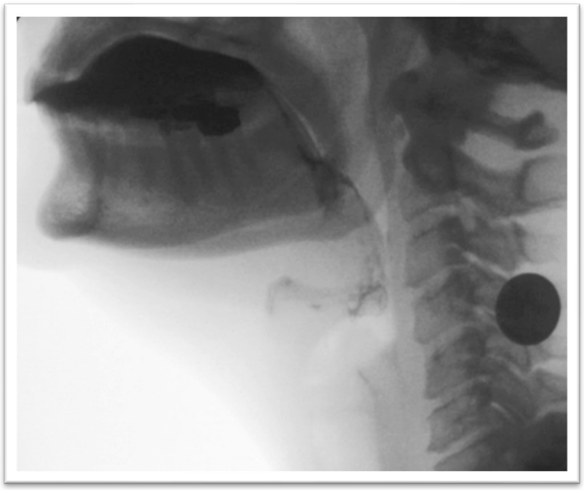
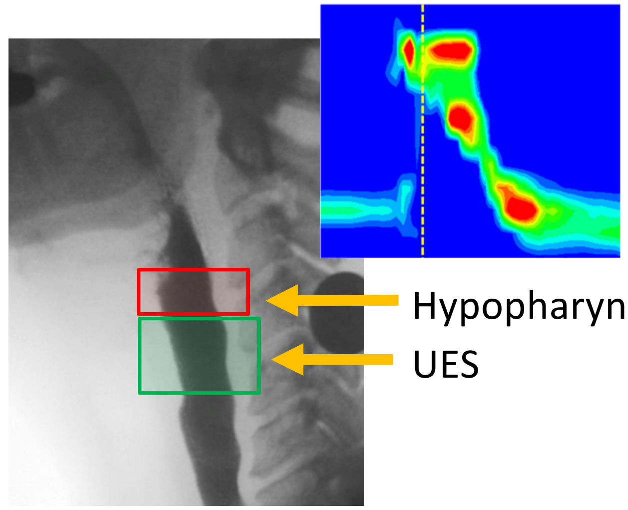
Hypopharyngeal Distension





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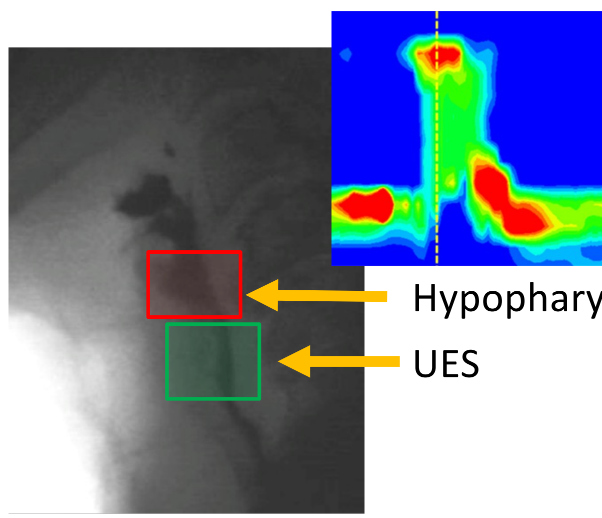
Hypopharyngeal Distension



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Normative Reference Values

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Pharyngeal High-Resolution Manometry: A Scoping Review and Meta-Analysis of Normative Data

Rameen K. Walters BS, Rachana Gudipudi, MD, Tamar Gordis, BA, Kate Davidson, MS, Shaun A. Nguyen, MD, Ashli K. O'Rourke, MD

Provisionally accepted for publication in
Neurogastroenterology and Motility

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Background

- High resolution pharyngeal manometry (HRPM) is an emerging technology with increasing adoption and need for standardization of practices
- Previous studies have reported some relevant normative data [1-2] but numbers are small and variability is high
- Unknown if normative data from one manufacturer/catheter is comparable to next
- Commercially available integrated software programs do not include pharyngeal normative data

MUSC 1) Cock C. et al. *Geriatrics (Basel)* 2018; 3. 2) Nativ-Zeltzer et al Neurogastroenterology & Motility 2016; 28:721-731

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Study Objective

We aimed to **analyze the HRPM normative data available in the existing literature** for different high resolution manometry systems with a **focus on core outcomes** identified by a HRPM International Working Group consensus.

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Diagnostic Metrics

Dysphagia
https://doi.org/10.1007/s00455-019-10023-y

ORIGINAL ARTICLE

High-Resolution Pharyngeal Manometry and Impedance: Protocols and Metrics—Recommendations of a High-Resolution Pharyngeal Manometry International Working Group

Taher I. Omari[1] · Michelle Ciucci[2] · Kristin Gozdzikowska[3] · Ester Hernández[3] · Katherine Hutcheson[4] · Corinne Jones[2] · Julia Maclean[5] · Nogah Nativ-Zeltzer[6] · Emily Plowman[7] · Nicole Rogus-Pulia[2] · Nathalie Rommel[8] · Ashli O'Rourke[9]

Metric	Acronym
Pharyngeal contractile integral	PhCI
Velopharyngeal contractile integral	VCI
Mesopharyngeal contractile integral	MCI
Hypopharyngeal contractile integral	HCI

Metric	Acronym
UES integrated relaxation pressure	UES IRP
UES relaxation time	UES RT
UES maximum admittance	UES MaxAd
Hypopharyngeal intrabolus pressure	IBP

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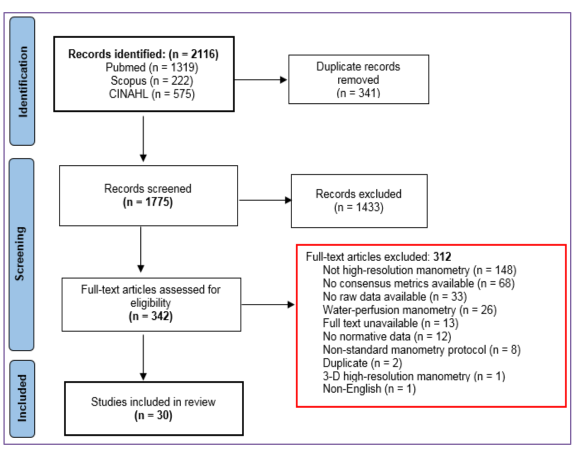
Methods

Prisma Diagram



Search Terms

- Combination of MeSH terms and key words for the following concepts and related words:
  - pharynx
  - upper esophageal sphincter
  - manometry
  - high resolution pharyngeal manometry,
  - high resolution impedance
- Search developed by librarian and peer-reviewed by colleagues
- June 2021

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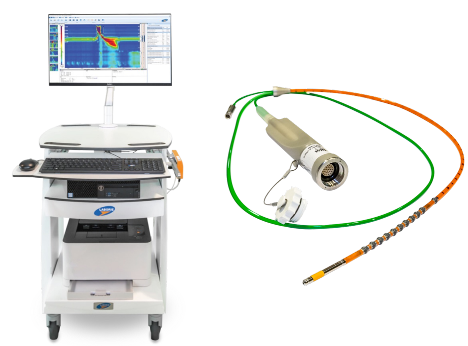
Results

- 30 studies met final inclusion criteria
  - Only 12/30 studies (40%) provided data for >2 consensus metrics
- Significant heterogeneity in methodology
  - **4** different manufacturers
  - **6** different catheter diameters
  - **5** different software analysis programs
  - **12** different bolus types (including different volumes and viscosities)
  - **3** different types of positioning

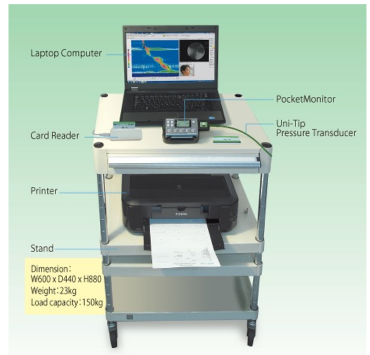
Types of Catheters and Systems Used

Medtronic System: Manoscan
Catheters: 2.64, 2.7, 2.75, 4, 4.2 mm
Software: Manoview, MATLAB



Laborie System: Unisensor, Unisensor AG,
Catheters: 2.7, 3.2, 4.2 mm
Software: Swallow Gateway, Laborie/MMS Database, MATLAB

Types of Catheters and Systems Used



Sandhill System: InSIGHT
Catheters: 4, 4.2 mm
Software: BioVIEW

StarMedical System: PD1236K
Catheters: 4mm
Software: Swallow Gateway

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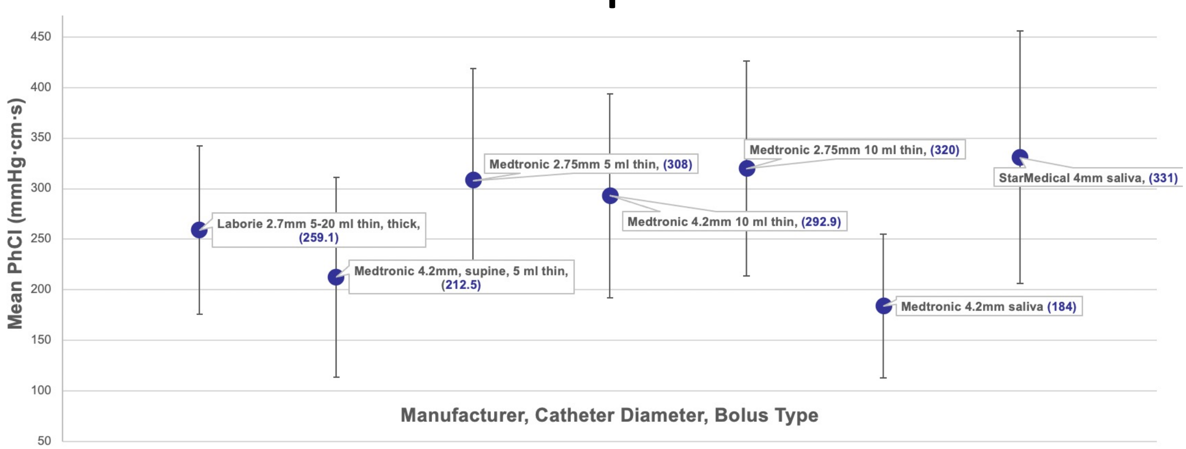
MUSC https://www.machinio.com/sandhill-scientific/insight/general-medical-equipment#results
http://starmedical.co.jp/eng/Product_Guid/Starlet/index.html

Mean PhCI Reported Values



In studies stratifying young and old participants, the mean PhCI in younger individuals was significantly less than in older individuals (p<0.001).

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Pharyngeal Contractile Integral

Laborie 2.7mm, 5-20 mL thin and thick boluses (averaged)

Study	n	Mean PhCI (mmHg·cm·s)	SD	Bolus	Manometry Catheter Type	Catheter diameter (mm)	Sampling Frequency (Hz)	Positioning	Analysis Software
Ferris 2021 Young (< 60 years)	36	253	96	5-20 ml thin, thick	Unisensor (Laborie, Attikon, Switzerland)	2.7	NR*	Upright	Swallow Gateway
Ferris 2021 Old (> 60 years)	14	237	105	5-20 ml thin, thick	Unisensor (Laborie, Attikon Switzerland)	2.7	NR	Upright	Swallow Gateway
Schar 2021	19	287	43.3	5-20 ml thin, thick	Unisensor AG (Attikon Switzerland), Solar GI (MMS)	2.7	NR	Upright	Swallow Gateway
Weighted Average	69	**259.1**	**83.3**						

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*NR = not reported

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Pharyngeal Contractile Integral

Medtronic 4.2mm, 5 mL thin boluses

Study	n	Mean PhCI (mmHg·cm·s)	SD	Bolus	Manometry Catheter Type	Catheter diameter (mm)	Sampling Frequency (Hz)	Positioning	Analysis Software
Balasubramanian 2017	32	182	76	5ml water	Manoscan (Medtronic)	4.2	50	Upright	Manoview
Balasubramanian 2017	32	200	83	5ml water	Manoscan (Medtronic)	4.2	50	Supine	Manoview
Suntrup-Krueger 2021	10	252.6	148.6	5ml water	Manoscan Eso Z (Medtronic)	4.2	NR	Supine	Manoview
Weighted Average (supine only)	42	**212.5**	**98.6**						

Medtronic 2.75mm, 5 mL thin boluses

Study	n	Mean PhCI (mmHg·cm·s)	SD	Bolus	Manometry Catheter Type	Catheter diameter (mm)	Sampling Frequency (Hz)	Positioning	Analysis Software
Nativ-Zeltzer 2016	44	**308**	**111**	5ml barium	Manoscan 360 (Medtronic)	2.75	35	Upright	Manoview

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*NR = not reported

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Pharyngeal Contractile Integral

Medtronic 4.2mm, 10 mL thin boluses

Study	n	Mean PhCI (mmHg·cm·s)	SD	Bolus	Manometry Catheter Type	Catheter diameter (mm)	Sampling Frequency (Hz)	Positioning	Analysis Software
Balasubramanian 2017	32	288	128	10 ml water	Manoscan (Medtronic)	4.2	50	Upright	Manoview
Rosen 2020	11	307	22	10 ml barium	Manoscan 360 (Medtronic)	4.2	50	Upright	MATLAB
Weighted Average	43	**292.9**	**100.9**						

Medtronic 2.75mm, 10 mL thin boluses

Study	n	Mean PhCI (mmHg·cm·s)	SD	Bolus	Manometry Catheter Type	Catheter diameter (mm)	Sampling Frequency (Hz)	Positioning	Analysis Software
Nativ-Zeltzer 2016	44	**320**	**106**	10 ml barium	Manoscan 360 (Medtronic)	2.75	35	Upright	Manoview

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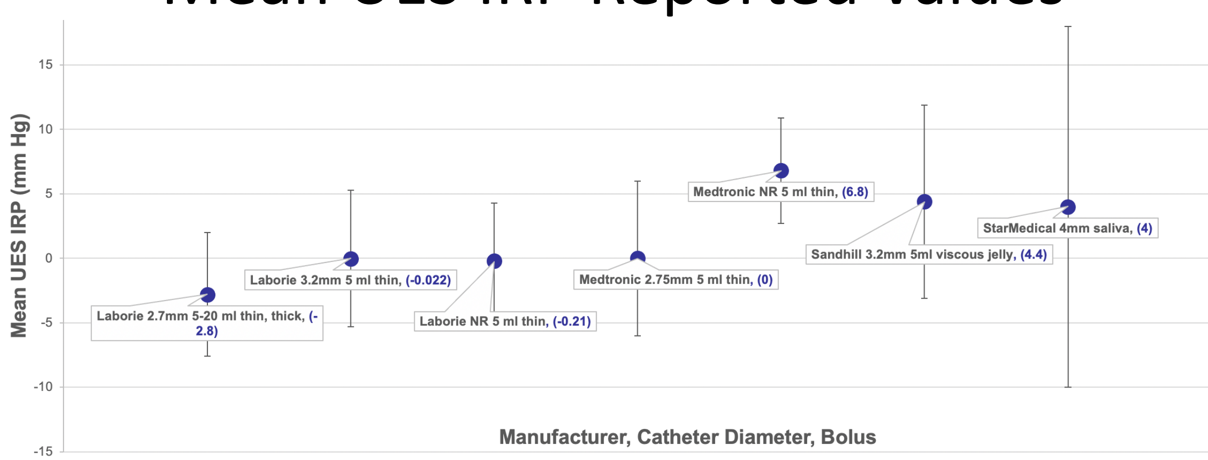
Mean UES IRP Reported Values



In studies stratifying young and old participants, the mean UES IRP in younger individuals was significantly less than in older individuals (p<0.001).

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UES Integrated Relaxation Pressure

Laborie 2.7mm, 5-20 mL thin and thick boluses (averaged)

Study	n	Mean UES IRP (mm Hg)	SD	Bolus	Manometry Catheter Type	Catheter diameter (mm)	Sampling Frequency (Hz)	Position	Analysis Software
Ferris 2021 Young (< 60 years)	36	-3.6	4.8	5-20 ml thin, thick	Unisensor (Laborie, Attikon Switzerland)	2.7	NR	Upright	Swallow Gateway
Ferris 2021 Old (> 60 years)	14	-1.8	5.1	5-20 ml thin, thick	Unisensor (Laborie, Attikon Switzerland)	2.7	NR	Upright	Swallow Gateway
Schar 2021	19	-2	4.4	5-20 ml thin, thick	Unisensor AG (Laborie); Acquisition: Solar GI	2.7	NR	Upright	Swallow Gateway
Weighted Average	69	**-2.8**	**4.8**						

UES Integrated Relaxation Pressure

Laborie 5mL thin boluses

Study	n	Mean UES IRP (mm Hg)	SD	Bolus	Manometry Catheter Type	Catheter Diameter (mm)	Sampling Frequency (Hz)	Position	Analysis Software
Baha 2020	40	0	4.4	5 ml water	Unisensor AG (Laborie/MMS)	NR	NR	Semi-supine	Laborie/MMS Database
Cock 2016 Young (< 80 years)	50	-1.6	3.9	5 ml saline	Unisensor (MMS)	NR	20	Upright	MATLAB
Cock 2016 Old (> 80 years)	16	3.6	6.5	5 ml saline	Unisensor (MMS)	NR	20	Upright	MATLAB
Omari 2015 Young (< 58 years)	32	-3.0	3.0	5 ml saline	Unisensor (Laborie); Pressure acquisition: Solar GI	3.2	20	Upright	NR
Omari 2015 Old (> 58 years)	35	2.7	7.4	5 ml saline	Unisensor (Laborie); Pressure acquisition: Solar GI	3.2	20	Upright	NR

UES Integrated Relaxation Pressure

Medtronic 5mL thin boluses

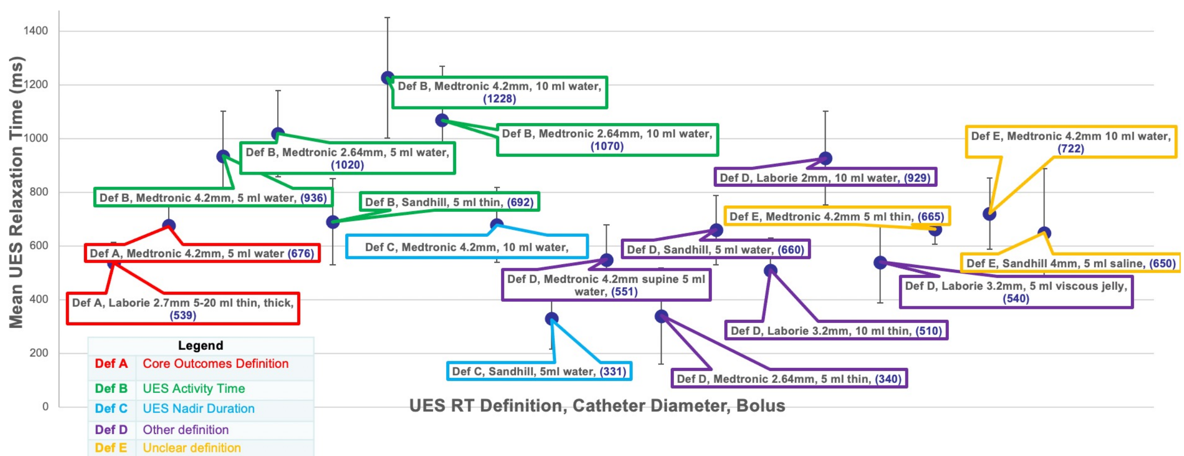
Study	n	Mean UES IRP (mm Hg)	SD	Bolus type	Manometry Catheter Type	Catheter diameter (mm)	Sampling Frequency (Hz)	Positioning	Analysis Software
Nativ-Zeltzer 2016	44	0	6	5 ml barium	Manoscan 360 (Medtronic)	2.75	35	Upright	Manoview
Weijenborg 2014	50	6.8	4.1	5 ml water	Medtronic	NR	37	Supine	Manoview

UES Relaxation Time

Great Variability in Definitions!

- Definition A: **Core outcomes definition** (4 studies)
  - interval in which pressure is below 50% of baseline or 35 mmHg, whichever is lower, in units of seconds
- Definition B: **UES activity time** (6 studies)
  - interval between pre-UES peak and post-UES peak
- Definition C: **UES nadir duration** (3 studies)
  - duration of relaxation after pre-swallow UES constriction or bolus passage time
- Definition D: **Various other definitions** (7 studies)
  - e.g., interval between opening and closing, 10% decrease in pressure from resting value, different algorithm calculations, etc.
- Definition E: **Unreported definition** (5 studies)

Mean UES Relaxation Time Reported Values



UES Relaxation Time Reported Values

- Average UES RT was longer in the upright position compared to supine ($p<0.001$)
- 10mL thin boluses had significantly longer average UES RT compared to 5mL thin ($p<0.001$).
- Average UES RT was longer with both a 10mL and 5mL bolus, when utilizing a 2.64mm catheter compared to a 4 or 4.2mm catheter ($p<0.001$).
- Circumferential catheters demonstrated a higher average UES RT compared with unidirectional catheters ($p<0.001$).

Conclusion

- Depending on the equipment used, definitions and the protocols performed, there can be considerable variability in normative values for high-resolution pharyngeal manometry.
- Must take these variables into account in clinical practice and when comparing results in the literature.
- Given low numbers in the studies, more normative data are needed to establish valid reference values for high-resolution pharyngeal manometry metrics.

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Published in final edited form as:
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Pressure Topography Metrics For High-Resolution Pharyngeal-Esophageal Manofluorography - A Normative Study of Younger and Older Adults

Nogah Nativ-Zeltzer[1], **Jeri A. Logemann**[1,†], **Steven G. Zecker**[1], and **Peter J. Kahrilas**[2]
[1]Department of Communication Sciences and Disorders, Evanston, Illinois
[2]Department of Medicine, Northwestern University, Feinberg School of Medicine, Chicago, Illinois, U.S.A

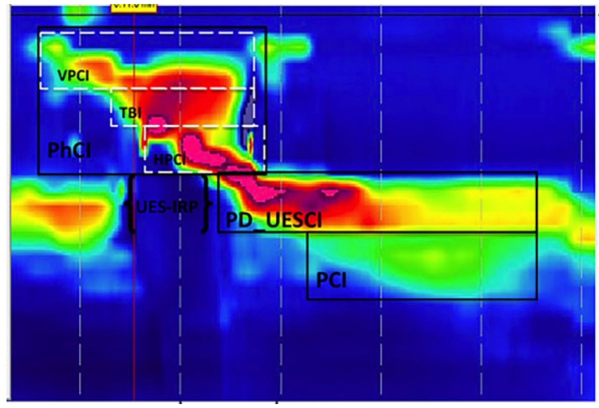
Abstract

Background—We aimed to define normative values for novel pressure topography metrics for high-resolution pharyngeal-esophageal manofluorography. The effects of age, gender and bolus properties were examined.

Methods—Concurrent high-resolution manometry (HRM) and videofluoroscopy data were collected from 22 younger (aged 21–40) and 22 older (aged 60–80) healthy subjects. Pressure topography was analyzed by correlating pressure domains with videofluoroscopic events. Nine pressure topography metrics of the pharyngeal and proximal esophageal swallow were extracted; four of these were also compared with previously obtained esophageal HRM studies to assess the effects of catheter diameter.

Methods

- Demographics
  - 44 healthy subjects
  - Dichotomized ages:
    - 22 participants aged < 40
    - 22 participants > 60
- Methods
  - Simultaneous pharyngeal manometry-fluoroscopy
  - Upright positioning
  - Medtronic 2.75 mm catheter and software
  - Various volumes & consistencies
    - 1 mL, 5 mL, 10 mL thin liquid
    - 3 mL pudding
    - 1/4 cookie with 3 mL barium paste



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Nativ-Zelzter et al., 2016

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Results

Table 2 Statistical summary of pharyngeal HREPT measurements for 44 normal subjects; 22 young and 22 elderly

	Liquid					
	1 mL	5 mL	10 mL	Pudding (3 mL)	Effortful	Cookie
PhCI (mmHg/s/cm)	308 ± 110 (169–504)	308 ± 111 (162–504)	320 ± 106 (176–541)	305 ± 94 (161–480)	495 ± 252 (235–1060)	296 ± 99 (148–500)
Young	259 ± 58* (169–374)	256 ± 84* (154–433)	276 ± 97* (164–502)	272 ± 87* (159–475)	494 ± 270 (229–1081)	259 ± 92* (138–483)
Old	355 ± 128* (180–708)	363 ± 110* (216–588)	364 ± 97* (191–548)	339 ± 89* (170–487)	497 ± 238 (231–1094)	333 ± 94* (173–501)
P-Max (mmHg)	228 ± 60 (148–327)	229 ± 62 (142–338)	222 ± 51 (153–317)	233 ± 61 (157–364)	247 ± 69 (146–353)	218 ± 45 (154–294)
Young	207 ± 61* (138–379)	211 ± 64* (130–342)	202 ± 47* (134–286)	216 ± 59* (149–345)	232 ± 56 (143–330)	200 ± 37* (148–268)
Old	248 ± 52* (163–328)	249 ± 54* (173–340)	241 ± 47* (173–334)	249 ± 58* (164–365)	262 ± 77 (174–475)	237 ± 44* (168–324)
VPCI (mmHg/s/cm)	122 ± 64 (43–276)	129 ± 63 (51–291)	147 ± 69 (63–319)	116 ± 54 (37–243)	199 ± 103 (65–429)	109 ± 49 (31–204)
Young	103 ± 39* (0–172)	106 ± 52* (18–211)	125 ± 61* (54–292)	107 ± 57* (9–231)	215 ± 130 (114–463)	94 ± 40* (29–184)
Old	140 ± 76* (60–333)	152 ± 65* (70–308)	167 ± 70* (72–323)	125 ± 50* (41–248)	184 ± 69 (63–334)	122 ± 53* (33–230)
TBI (mmHg/s/cm)	103 ± 38 (52–172)	99 ± 39 (43–166)	94 ± 38 (43–160)	103 ± 34 (49–170)	164 ± 93 (61–383)	99 ± 36 (47–171)
Young	93 ± 26* (52–158)	88 ± 33* (42–160)	86 ± 37* (44–166)	94 ± 32* (45–175)	178 ± 111 (58–413)	92 ± 39 (39–197)
Old	112 ± 44* (50–215)	110 ± 41* (49–177)	102 ± 38* (38–159)	111 ± 34* (60–169)	151 ± 71 (69–340)	106 ± 32 (59–172)
HPCI (mmHg/s/cm)	82 ± 40 (37–155)	73 ± 36 (31–142)	71 ± 32 (28–134)	81 ± 36 (35–154)	127 ± 101 (46–337)	80 ± 35 (34–156)
Young	59 ± 21* (31–107)	55 ± 21* (25–93)	55 ± 24* (20–105)	63 ± 25* (31–109)	99 ± 56 (44–236)	66 ± 32* (30–157)
Old	103 ± 42* (49–166)	92 ± 39* (45–162)	86 ± 33* (46–142)	98 ± 37* (53–171)	154 ± 125 (65–531)	94 ± 32* (51–163)

Values are mean ± SD (5–95th percentile). Asterisks denote statistical significance ($p < 0.05$) for comparison between the two age groups.

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Nativ-Zelzter et al., 2016

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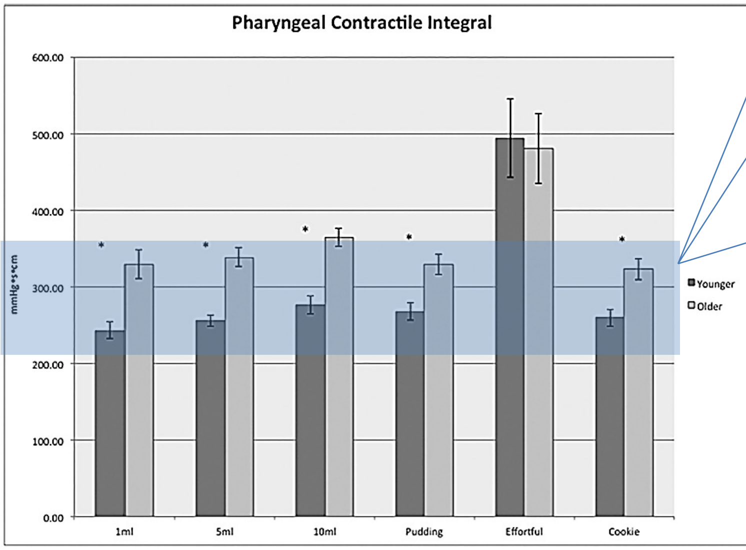
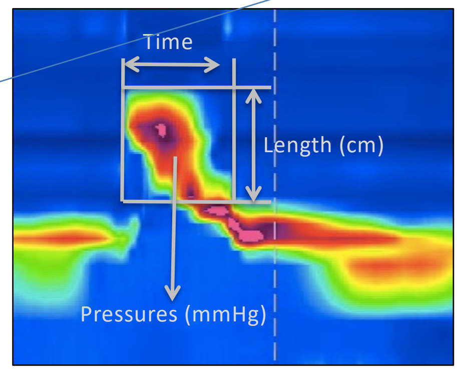
Results



Mean PhCI
308 mmHg x cm x s (±100)



Highlighted Findings

- Age Related Differences
  - For normal swallows, older individuals had higher pharyngeal contractility & UES IBP as compared to younger subjects
    - Compensatory response with aging?
- No consistent gender differences were observed with normal swallows

"Age-related differences found in this study should be considered when applying these data to clinical populations."

PhCI may suffice as a "summary measure of pharyngeal contractility … with the more discrete measures … adding resolution in situations of impairment."

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