High Resolution Manometry: Optimal Technique and Diagnostic Insights
University of Pennsylvania

John E. Pandolfino, MD, MSci
Department of Medicine
Feinberg School of Medicine
Northwestern University

Functional Imaging of Esophageal Peristalsis
MANOMETRY

Functional Imaging of Esophageal Peristalsis
HIGH-RESOLUTION MANOMETRY

Functional Imaging of Esophageal Peristalsis
ESOPHAGEAL PRESSURE TOPOGRAPHY

Clouse Plot
Pressure Topography of Esophageal Motility

What does it add

- More akin to an imaging modality
  - Defines important anatomical landmarks and abnormalities.
  - Refines measurement of important motor events
    - EGJ relaxation
    - Peristaltic velocity
    - Contractile activity
  - Defines intra-luminal pressurization patterns

Esophageal Pressure Topography: The Method: Procedure

- Device: High-Resolution Manometry Catheter
  - Spans from the pharynx to the stomach with sensor separation of no more than a centimeter within and around the sphincters.
  - Greater than 32 pressure sensors
  - Temporal frequency response matched to the zone of the esophagus
  - The immediate advantages of HRM are:
    - 1) a simplified procedural set up with improved sphincter localization,
    - 2) elimination of movement artifact
    - 3) simplified data interpretation and
    - 4) ability to perform more sophisticated analysis of esophageal function.

- Procedure
  - Protocol
    - Studies are done in a supine position and the manometric assembly is positioned transnasally with at least 5 intragastric sensors to optimize EGJ and intragastric recording.
    - The manometric protocol includes at least ten 5 ml swallows and a 5-minute period to assess basal sphincter pressure in the supine position.
      - Addition of upright and provocative swallows may be helpful in specific patients
      - Eliminate vascular Artifact
      - Increase the yield of eliciting abnormalities not seen in the supine position
  - Practicality
    - Patient tolerance is excellent
      - Studies complete in less than 30 minutes
    - Major risks are rare [sore throat, epistaxis]
    - Performed by motility technician/nurse

Esophageal Pressure Topography: The Method: Data Analysis

- a stepwise EPT analysis algorithm is performed:
- 5-7 swallows many be adequate
Pressure Topography of Esophageal Motility

The Chicago Classification

**Step 1-EGJ**
- **Assess EGJ**
  - PIP
  - EGJ Morphology
  - Basal pressure

**EGJ relaxation measure**
- Median (IQR) (mmHg)
  - HRM nadir: 3.6 [1.9 – 5.8]
  - 4s Integrated Relaxation Pressure: 7.9 [6.4 – 10.0]

**95th percentile**
- HRM nadir: ≥ 10 mmHg
- 4s Integrated Relaxation Pressure: ≥ 15 mmHg

**Step 2**
- **Assess Peristalsis**
  - Characterize Peristaltic Integrity
    - Using the IBC set at 20 mmHg
      - Intact
      - Weak
      - Small versus large
      - Failed
  - Characterize Contractile Pattern
    - Calculate DCI, Latency and CFV for each swallow
      - Jackhammer
      - Hypercontractile
      - Spasm
      - Rapid
Pressure Topography of Esophageal Motility

*The Chicago classification*

- **Step 3**
  - Assess Pressurization Pattern
    - Using the IBC set at 30 mmHg
    - Panesophageal versus Compartmentalized

**Figure 3**

**Pressure Topography of Esophageal Motility**

Measure: Integrated Relaxation Pressure

**Validation of the IRP: Flow Permissive Time**

- Videofluoroscopy + Endoclips
- High Resolution Manometry (HRM)
- 3D High Resolution Manometry (3D-HRM)
- Time: 5.3 s

**Pressure Topography of Esophageal Motility**

*EGJ pressures during swallowing*

- Measuring EGJ relaxation is complicated
  - Must consider anatomy and peristalsis
  - The 4 second IRP provides an integrated measurement of all the components affecting bolus transit across the EGJ
    - LES, Crural opening, IBP and axial position of LES
    - Thresholds for abnormality are determined by mechanical forces of peristalsis
- Elevated Intrabolus pressure
  - Provides important information regarding esophageal emptying
  - > 30 mm Hg supports an outflow obstruction

Clinical Evolution of Achalasia
Assessing clinically relevant phenotypes

Early
Type II or III

Chronic
Type II/III–I

Late
Type I

NU IRB

Type I

Type II

Type III


• Type I achalasia is associated with absent peristalsis and minimal esophageal body pressurization.
• Type II achalasia is associated with pan-esophageal pressurization related to a compression effect.
• Type III achalasia has evidence of abnormal contractility (spastic).

Response Rates of Achalasia Treatments
Patients categorized by pressure topography subtype

<table>
<thead>
<tr>
<th>Author</th>
<th>Subtype</th>
<th>No. patients (%)</th>
<th>Success rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pandolfino</td>
<td>I</td>
<td>23 (21.1)</td>
<td>56%</td>
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<tr>
<td></td>
<td>II</td>
<td>40 (39.3)</td>
<td>96%</td>
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<tr>
<td></td>
<td>III</td>
<td>29 (28.8)</td>
<td>92%</td>
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<tr>
<td>Salvador (LHM)</td>
<td>I</td>
<td>16 (15.9)</td>
<td>88.6%</td>
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<tr>
<td></td>
<td>II</td>
<td>127 (31.6)</td>
<td>99.3%</td>
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<tr>
<td></td>
<td>III</td>
<td>23 (19.4)</td>
<td>83.9%</td>
</tr>
<tr>
<td>Pratap (PD)</td>
<td>I</td>
<td>24 (47.1)</td>
<td>63%</td>
</tr>
<tr>
<td></td>
<td>II</td>
<td>24 (47.1)</td>
<td>93%</td>
</tr>
<tr>
<td></td>
<td>III</td>
<td>3 (5.9)</td>
<td>33.3%</td>
</tr>
<tr>
<td>Robeh (PD &amp; LHM)</td>
<td>I</td>
<td>44 (25)</td>
<td>81%</td>
</tr>
<tr>
<td></td>
<td>II</td>
<td>114 (56.7)</td>
<td>100%</td>
</tr>
<tr>
<td></td>
<td>III</td>
<td>18 (10.1)</td>
<td>40%</td>
</tr>
</tbody>
</table>

LHM, laparoscopic Heller myotomy; PD, pneumatic dilatation.

Refining the IRP
Classification Regression Analysis Tree

EPT with aperistalsis and an IRP of 10 mmHg

EndoFLIP with impaired EGJ opening

• EPT studies from 522 consecutive patients were studied (10 supine water swallows). Mean IRP values and EPT swallow patterns from each study based on Chicago Classification criteria were used as inputs to train a classification and regression tree (CART) model with a MATLAB program.
  - The optimal IRP threshold for distinguishing type I achalasia from absent peristalsis is reduced to ≥10 mmHg due to the low intrabolus pressure associated with absent peristalsis.
  - The optimal IRP threshold for distinguishing type III achalasia from DES is increased (≥17 mmHg secondary to the effect of reduced latency on shortening the deglutitive relaxation window to less than 4.5 seconds.)
Type III Achalasia: not all the same

*Impaired EGJR, ≥20% spastic contractions*

**Illia: Premature contraction**
Reduced Distal Latency

**Illib: Residual contraction**
Normal Distal Latency

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**Increased IRP and IBP with EGJ Outflow Obstruction**

<table>
<thead>
<tr>
<th>Pressure (mmHg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
</tr>
<tr>
<td>Asymptomatic Control</td>
</tr>
<tr>
<td>Symptomatic Post Fundoplication</td>
</tr>
<tr>
<td>Idiopathic Functional Obstruction</td>
</tr>
</tbody>
</table>

* = p < 0.05 vs. asymptomatic control

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**Pressure Topography of Esophageal Motility**

The Chicago classification

- IRP ≥ upper limit of normal AND some instances of intact or weak peristalsis
- Yes

- EGJ Outflow Obstruction
- No

- Achalasia variant
- Yes

- Pseudoachalasia
- No

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**Pressure Topography of Esophageal Motility**

EGJ Outflow Obstruction:

- Yes

- Achalasia variant

- Versus mechanical obstruction

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Increased IRP and IBP with EGJ Outflow Obstruction

- Asymptomatic Control
- Symptomatic Post Fundoplication
- Idiopathic Functional Obstruction

* IRP = intra-esophageal pressure
* IBP = intrabdominal pressure

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**Recommended**

- Further evaluation in selected cases: cause of symptoms

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**Special Considerations**

- Type I - Absent peristalsis
  - Requires complete obliteration of LES
- Type II - Pseudounicollare
  - Best prognosis
- Type III - Spasm
  - Likely required adjunct treatment of spasm

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**Special Considerations**

- Possible achalasia variant
  - Trial of medication
- Consider Pneumatic dilation if no response
- Possible EoE
  - PPI/Fluticasone/Diet
- Old peptic injury
  - Empiric dilation with Balloon or Bougie
- Hiatus hernia
  - May require surgery

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**Increased IRP and IBP with EGJ Outflow Obstruction**

- Asymptomatic Control
- Symptomatic Post Fundoplication
- Idiopathic Functional Obstruction

* = p < 0.05 vs. asymptomatic control

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**Pressure Topography of Esophageal Motility**

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- IRP ≥ upper limit of normal AND some instances of intact or weak peristalsis
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EGJ Outflow Obstruction

Weak Peristalsis IRP 21.5 mmHg
HTN Contraction, IRP 19 mmHg

Measuring EGJ Relaxation Pressure
Functional Obstruction due to Hiatal Hernia

Elevated CD Relaxation Pressure and Intrabolus Pressure Among HH-Dysphagia Patients

Pressure Topography of Esophageal Motility

Integrity of the Wavefront
Peristaltic Defect

Gaps in the peristaltic waveform

Pill Esophagitis with Chest Pain

Transition Zone Defect

Combined HRM with MII

Esophageal pressure Topography with Bolus Transit

Large: >20% large breaks in the 20 mmHg isobaric contour (>5 cm in length)
Small: >30% small breaks in the 20 mmHg isobaric contour (2-5 cm in length)

Pressure Topography of Esophageal Motility

Measure: Contraction pattern [DCI]

Hypercontractile
• DCI > 8000 mmHg-s-cm

Hypertensive
• DCI > 500 mmHg-s-cm

Hypotensive/Weak Swallow
• A threshold DCI value of 500 mmHg-s-cm in EPT plot could be utilized to predict IES.
• DCI can also distinguish failed swallows using a threshold value of 150 mmHg-s-cm

Nutcracker heterogeneity

**Figure 9**

B) Hypertensive

A) Normal

C) Hypercontractile - Jackhammer

Time (s)

Length along the esophagus (cm)

10

30

35

15

20

25

DCI = 6508 mmHg - s - cm

DCI = 3212 mmHg - s - cm

DCI = 2045, 452 mmHg - s - cm

Hypertensive - Hypercontractile

Esophagus

Based on DCI [mmHg - s - cm]

Pressure Topography of Esophageal Motility

**Contractile Vigor**

- **Weak peristalsis/ Hypotensive**
  - Transition Zone Defects
  - Defined by defect size of first trough
  - Distal (segments 2 and 3): IEM
    - A threshold DCI value of 500 mmHg - s - cm in EPT plot could be utilized to predict IES.
    - DCI can also distinguish failed swallows using a threshold value of 150
  - The manometric correlate of IEM in EPT is a mixture of swallows with either failed peristalsis or IBC-breaks in the middle and distal pressure troughs.

- **Hypertensive/ Hypercontractile**
  - Hypertensive: DCI > 5000
  - Hypercontractile: DCI > 8000

Pressure Topography of Esophageal Motility

**Measure: Define the CDP**

Pressure Topography of Esophageal Motility

**Measure: Contraction Pattern [Latency]**

Latency measured with conventional manometry

EPT: normal latency swallow

EPT: short latency swallow
Rapid Contractions  
**Normal Deglutitive Inhibition-Normal Latency**

- **Intact Swallow**
- **Weak Peristalsis**

Distal Esophageal Spasm  
**Abnormal Deglutitive Inhibition-Abnormal Latency**

- **Spastic Achalasia**
- **Distal Esophageal Spasm**

### Phenotypes of Rapid Contraction

**A)** Rapid Contraction  
**B)** Weak Contraction  

**C)** Premature Rapid Contraction  
**D)** Premature Contraction

### Distal Esophageal Spasm

**Defining Relevant Phenotypes**

- 1070 consecutive patients with clinical EPT studies
- 91 Patients with rapid propagation

- Premature Contractions (n=24)  
  [Distal Latency < 4.5 sec]
- Rapid Contractions (n=67)  
  [CFV > 13 cm/sec, Normal Distal Latency]
Pressure Topography of Esophageal Motility

Phenotypes of Rapid Contraction

- There is a difference between rapid contractions and spastic contractions.
- Does the contraction occur too early [latency]? 
- Should consider whether contraction is altered by deglutitive inhibition.
- The effect of peristaltic defects should be considered.
  - Revising criteria may improve treatment outcomes.

Pressure Topography of Esophageal Motility

The Chicago Classification

The Future of Evaluating PPI non-responders

Simultaneous HRM-Impedance-pH