High Resolution Esophageal Manometry
From Basics to Clinical Applications

Objectives

- High Resolution Manometry (HRM) versus Conventional Manometry
- Identifying landmarks on HRM
- HRM Metrics
- Chicago classification for esophageal motility disorders
- Clinical applications of HRM
Ankur Sheth, MD, MPH, CNSC

Anatomy of Esophagus

HRM versus Conventional

Bansal A et al. Current Opinion in Gastroenterol 2010;26: 344-351
HRM versus Conventional Manometry Catheters

- **Solid State assembly**
  - 3-4 sensors
  - 3-5 cm spacing
- **Water Perfused assembly**
  - 4-8 sensors
  - 3-5 cm spacing
  - +/- sleeve for LOS
- **LOS Measurement**
  - Pull through
  - Sleeve sensors at LES

- 36 sensors each at 1 cm distance along the catheter
- 12 circumferential pressure sensitive segments on each sensor
- Total of 432 pressure sensitive segments
- 4.2 mm wide catheter

Conventional to Spatiotemporal Plot

- **X axis:** Time
- **Y axis:** Position as per position on the catheter
- **Z axis:** Pressure recordings

Clouse et al. *AJP* 96
Spatiotemporal plot

Claude et al, AJP 1996
Kahrilas et al, Gastroenterology 2008

High Resolution Manometry: Anatomical Landmarks
Ankur Sheth, MD, MPH, CNSC

High Resolution Manometry: Anatomical Landmarks

UES
UES Relaxation
Thorax
Transition Point
LES
EGJ Relaxation
Stomach

How to Interpret the HRM data?
### Pressure Topographic Metrics

<table>
<thead>
<tr>
<th>Metric</th>
<th>Description</th>
</tr>
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<tbody>
<tr>
<td><strong>Integrated Relaxation Pressure (IRP)</strong></td>
<td>Mean EGJ pressure measured with an electronic equivalent of a sleeve sensor for four contiguous or non-contiguous seconds of relaxation in the ten second window following deglutitive UES relaxation.</td>
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<tr>
<td><strong>Contractile Deceleration Point (CDP)</strong></td>
<td>The inflection point along the 30 mm Hg isobaric contour where propagation velocity slows demarcating the tubular esophagus from the phrenic ampulla.</td>
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<td><strong>Contractile Front Velocity (CFV)</strong></td>
<td>Slope of the tangent approximating the 30 mm Hg isobaric contour between the proximal pressure trough and CDP.</td>
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<tr>
<td><strong>Distal Contractile Integral (DCI)</strong></td>
<td>Amplitude x duration x length of distal esophageal contraction &gt; 20 mm Hg from Proximal to Distal Pressure troughs.</td>
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<td><strong>Peristaltic breaks (cm)</strong></td>
<td>Gaps in the 20 mm Hg isobaric contour of the peristaltic contraction between the UES and EGJ, measures in axial length.</td>
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</table>

Bredenoord A et al. Neurogastroenterol Motil 2012; 24 (supplement 1)-57-65.
Evaluation of EGJ Relaxation
4s-IRP (Integrated Relaxation Pressure)

- Is the lowest averaged pressure during 4 contiguous or non-contiguous seconds of relaxation in the ten-second window following deglutive UES relaxation

- LES relaxation + Crural diaphragm contract + intra-bolus pressure.

- Normal IRP is < 15 mm Hg

- 98% sensitivity and 96% specificity for distinguishing well defined achalasia patients from control subjects

Comparison of EGJ relaxation in 62 achalasia patients

<table>
<thead>
<tr>
<th>EGJ relaxation metric</th>
<th>Achalasia Sensitivity</th>
<th>False positives %</th>
<th>False negatives %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nadir pressure, conventional (≥ 7 mm Hg)</td>
<td>52</td>
<td>0</td>
<td>48</td>
</tr>
<tr>
<td>Nadir EPT pressure (≥10 mmHg)</td>
<td>69</td>
<td>0</td>
<td>31</td>
</tr>
<tr>
<td>Integrated relaxation pressure (IRP) (≥15 mm Hg)</td>
<td>97</td>
<td>0</td>
<td>3</td>
</tr>
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</table>

Kahrilas et al. Neurogastroenterol Motil 2012; 24(suppl 1):S1-S9
Integrated Relaxation Pressure (IRP)
Mean EGI pressure measured with an electronic equivalent of a sleeve sensor for four contiguous or non-contiguous seconds of relaxation in the ten-second window following deglutitive UES relaxation.

Contractile Deceleration Point (CDP)
The inflection point along the 30 mm Hg isobaric contour where propagation velocity slows demarcating the tubular esophagus from the phrenic ampulla.

Contractile Front Velocity (CFV)
Slope of the tangent approximating the 30 mm Hg isobaric contour between the proximal pressure trough and CDP.

Distal Latency (DL)
Interval between UES relaxation and CDP.

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Amplitude x duration x length of distal esophageal contraction > 20 mm Hg from proximal to distal pressure troughs.

Peristaltic breaks (cm)
Gaps in the 20 mm Hg isobaric contour of the peristaltic contraction between the UES and EGIH, measured in axial length.

Bredenoord A et al. Neurogastroenterol Motil 2012; 24 (supplement 1)-57-65.

Esophageal Emptying: 2 phases
Deceleration Contractile Point (DCP)

Contractile Front Velocity (CFV)
Distal Latency (DL)

Contractile Front velocity (CFV)
- Normal < 9 cm/s
- Rapid contraction > 9 cm/s

Distal Latency (DL)
- Normal > 4.5 seconds
- Pre-mature contraction < 4.5 s


Pressure Topographic Metrics

Integrated Relaxation Pressure (IRP)
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Interval between UES relaxation and CDP

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Amplitude x duration x length of distal esophageal contraction > 20 mm Hg from Proximal to Distal Pressure troughs


Strength/Vigor of Distal Contraction

DCI (Distal Contractile Integral) = Pressure x duration x length of distal smooth muscle contraction.

Distal Contractile Integral
(DCI)

Vigor + Duration + length of distal contraction

Normal is < 5000 mmHg/s/cm.

Contraction Pattern
For Intact or weak peristalsis with small break

<table>
<thead>
<tr>
<th>Contraction Type</th>
<th>Description</th>
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<tbody>
<tr>
<td>Premature Contraction</td>
<td>Distal Latency (DL) &lt; 4.5 cm</td>
</tr>
<tr>
<td>Hyper-contractile</td>
<td>DCI &gt; 5000 mmHg/s/cm</td>
</tr>
<tr>
<td>Rapid Contraction</td>
<td>CFV &gt; 9 cm/s</td>
</tr>
<tr>
<td>Normal Contraction</td>
<td>Not achieving any of the above diagnostic criteria</td>
</tr>
</tbody>
</table>

Bredenoord A et al. Neurogastroenterol Motil 2012; 24(supplement 1):S7-68.
**Pressure Topographic Metrics**

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**Integrity of Contraction**

Isobaric Contour at 20 mm Hg.
### Integrity of Contraction

#### 20 mm Hg Isobaric Contour

<table>
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<tr>
<th>Intact Contraction</th>
<th>20 mm Hg Isobaric contour without large or small breaks</th>
</tr>
</thead>
</table>
| Weak Contraction   | 1) Large Break > 5 cm  
2) Small Break 2-5 cm |
| Failed Peristalsis | Minimal (< 3cm) Integrity distal to the proximal trough |


### Intra-bolus pressure pattern: 30 mm Hg Isobaric contour

<table>
<thead>
<tr>
<th>Pan-esophageal pressurization</th>
<th>Uniform pressurization extending from the UES to the EGJ</th>
</tr>
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<tbody>
<tr>
<td>Compartmentalized esophageal pressurization</td>
<td>Pressurization extending from the contractile front to the sphincter</td>
</tr>
<tr>
<td>EGJ pressurization</td>
<td>Pressurization restricted to zone between the LES and CD in conjunction with hiatal hernia</td>
</tr>
<tr>
<td>Normal Pressurization</td>
<td>No bolus pressurization &gt; 30 mm Hg</td>
</tr>
</tbody>
</table>

# New Classification of Esophageal Motility Disorders

## Chicago Classification

<table>
<thead>
<tr>
<th>Diagnosis</th>
<th>Diagnostic Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Achalasia</strong></td>
<td>Classic achalasia: mean IRP &gt; upper limit of normal, 100% failed peristals. Achalasia with esophageal compression: mean IRP &gt; upper limit of normal, no normal peristals, preserved fragments of distal peristals or premature [spastic] contractions with ≥20% of swallows</td>
</tr>
<tr>
<td>Type 1 achalasia</td>
<td>Mean IRP &gt; upper limit of normal; no normal peristals, preserved fragments of distal peristals or premature [spastic] contractions with ≥20% of swallows</td>
</tr>
<tr>
<td>Type 1B achalasia</td>
<td>Mean IRP &gt; upper limit of normal; no normal peristals, preserved fragments of distal peristals or premature [spastic] contractions with ≥20% of swallows</td>
</tr>
<tr>
<td>Type IB achalasia</td>
<td>Mean IRP &gt; upper limit of normal; no normal peristals, preserved fragments of distal peristals or premature [spastic] contractions with ≥20% of swallows</td>
</tr>
<tr>
<td>EGJ outflow obstruction</td>
<td>Mean IRP &gt; upper limit of normal; no normal peristals, preserved fragments of distal peristals or premature [spastic] contractions with ≥20% of swallows</td>
</tr>
<tr>
<td>Motility Disorders</td>
<td>Mean IRP &gt; upper limit of normal; no normal peristals, preserved fragments of distal peristals or premature [spastic] contractions with ≥20% of swallows</td>
</tr>
<tr>
<td>Distal esophageal spasms</td>
<td>Mean IRP &gt; upper limit of normal; no normal peristals, preserved fragments of distal peristals or premature [spastic] contractions with ≥20% of swallows</td>
</tr>
<tr>
<td>Hypercontractile esophagus</td>
<td>Mean IRP &gt; upper limit of normal; no normal peristals, preserved fragments of distal peristals or premature [spastic] contractions with ≥20% of swallows</td>
</tr>
<tr>
<td>Achalasia</td>
<td>Mean IRP &gt; upper limit of normal; no normal peristals, preserved fragments of distal peristals or premature [spastic] contractions with ≥20% of swallows</td>
</tr>
<tr>
<td>EGJ relaxation</td>
<td>Mean IRP &gt; upper limit of normal; no normal peristals, preserved fragments of distal peristals or premature [spastic] contractions with ≥20% of swallows</td>
</tr>
<tr>
<td>Normal EGJ relaxation</td>
<td>Mean IRP &gt; upper limit of normal; no normal peristals, preserved fragments of distal peristals or premature [spastic] contractions with ≥20% of swallows</td>
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</tbody>
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### Abnormal EGJ Relaxation
- Absent peristals
- Intact or Weak Peristals

### Normal EGJ Relaxation
- Distal Esophageal Spasm
- Hypercontractile Disorders
- Borderline Peristaltic abnormalities

### EGJ Outflow Obstruction
- Achalasia variant
  - Mechanical obstruction
  - EoE
  - Malignant/Infiltrating Dr.
  - Hiatal Hernia

### Hypertensive peristalsis
- Hypercontractile Esophagus

### Absent peristals
- Weak Peristals
- Frequent failed peristals
Conventional Manometry: Achalasia

• Aperistalsis

• Failure of EGJ relaxation

Achalasia Subtype I: Classic Achalasia

Inadequate EGJ relaxation + Aperistalsis

Achalasia Subtype II

Inadequate EGJ relaxation + Pan-pressurization


Achalasia subtype III
Vigorous Achalasia

Inadequate EGJ relaxation + Spastic Contraction

HRM: Achalasia: New Classification

Type I
- Classic
- Normal

Type II
- Pan pressurization

Type III
- Vigorous/spastic
- Compartamental Pressurization

Management of Achalasia

- Medical therapy
  - CCB, Nitrates, PDE inhibitors, PPI
  - Sub-optimal efficacy, side effects common.

Botox Injections

Pneumatic dilation

Heller’s Myotomy
Achalasia subtype-Treatment

Achalasia subtype is an independent predictor of treatment success.

<table>
<thead>
<tr>
<th>Author</th>
<th>Subtype</th>
<th>No. patients (%)</th>
<th>Success rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pandolfini</td>
<td>I</td>
<td>31 (31.3)</td>
<td>54*</td>
</tr>
<tr>
<td></td>
<td>II</td>
<td>49 (49.5)</td>
<td>56*</td>
</tr>
<tr>
<td></td>
<td>III</td>
<td>29 (29.3)</td>
<td>29*</td>
</tr>
<tr>
<td>Salvador (LHIM)</td>
<td>I</td>
<td>96 (39)</td>
<td>84.6</td>
</tr>
<tr>
<td></td>
<td>II</td>
<td>127 (53.6)</td>
<td>95.3</td>
</tr>
<tr>
<td></td>
<td>III</td>
<td>23 (9.4)</td>
<td>69.3</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>63</td>
</tr>
<tr>
<td></td>
<td>III</td>
<td>3 (5.8)</td>
<td>33.3</td>
</tr>
<tr>
<td>Rolhef (PD &amp; LHIM)</td>
<td>I</td>
<td>44 (25)</td>
<td>85.7 81</td>
</tr>
<tr>
<td></td>
<td>II</td>
<td>114 (64.7)</td>
<td>100 95</td>
</tr>
<tr>
<td></td>
<td>III</td>
<td>18 (10.2)</td>
<td>40 86</td>
</tr>
</tbody>
</table>


- Type I patient more likely to have esophageal dilation, Type II-III are more likely to have chest pain.
- Type II was much more likely, and type III much less likely to respond to treatment than type I.

Esophageal shortening with Achalasia

Pseudo-relaxation of EGJ

Roman S et al. Dysphagia 2012;27:115-123.
Diffuse Esophageal Spasm

- Uncoordinated (non-peristaltic)
- Simultaneous
- aka corkscrew esophagus

DES: Manometry
HRM: Diffuse Esophageal Spasm

Pandolfi et al., Am J Gastroenterol, 2008;103:27-37

Nut-Cracker and Jackhammer Esophagus

Clarke J et al., J Clin Gastroenterol 2012;46:442-448
HRM: Scleroderma

- Aperistalsis
- Hypotensive LES

Normal
- Peristalsis
- LES Relaxation

Scleroderma
- Aperistalsis
- Hypotensive LES

Achalasia
- Aperistalsis
- Failure of LES to Relax
HRM: Esophageal Peristaltic Abnormality

Focal peristaltic defect

Focal mid-esophageal spasm


HRM: Double Contraction
Hierarchical Analysis of Esophageal Motility: Chicago Classification

1. IRP > Upper limit normal AND absent peristalsis
   - Yes: Achalasia
     - Type I: classic
     - Type II: with esophageal compression
     - Type III: peristaltic fragments or spastic
   - No:

2. IRP > Upper limit normal AND some instances of intact or weak peristalsis
   - Yes: EGJ Outflow Obstruction
     - Achalasia variant
     - Mechanical obstruction
     - May have 1st or 2nd hyper-contractility
   - No:

3. IRP is normal AND absent peristalsis OR reduced distal latency OR DCI > 8000 mmHg/s/cm
   - Yes: Absent Peristalsis
     - Distal Esophageal Spasm (DES)
       - ≥ 20% swallows with reduced latency
       - Hypercontractile (jackhammer) Esophagus
         - Any swallow with DCI > 8000 mmHg/s/cm
   - No:

4. IRP is normal AND Peristaltic abnormalities
   - No: Normal
   - Yes:

HRM: Summary

• Makes esophageal physiology easy to interpret

• Practical advantages
  – Easy to learn
  – Simple to use
  – Cheap to run
  – Time effective

• Improves diagnostic accuracy

New Gold Standard?
How HRM changes the approach to esophageal motility disorders?

- **Achalasia**
  - Improved sensitivity for the diagnosis of achalasia
    - IRP, pseudo-relaxation
  - Distinguishes subtypes of achalasia (Type I, II, III)
  - Predicts treatment response based on subtypes
    - Type II has the best and type III has the worst outcome

- **Comprehensive evaluation of impaired EGJ components**
  - LES
  - Crural diaphragm
  - Intrabolus pressure

- **Spastic nutcracker is most consistent form of esophageal spasm observed with HRM**


HRM: Challenges

- Over-Reading (Too much information)
- Non-specific findings
- Poor correlation between manometric abnormality and symptoms
Questions