Monitoring
Muscle (Diaphragm) Thickness

Ewan C. Goligher MD
Mount Sinai Hospital, Toronto, Canada
Department of Physiology, University of Toronto
Disclosures

• Conflicts of Interest
  – Equipment from Sonosite
  – Equipment and research support from GE
Is the Diaphragm Worth Monitoring?

- VILI
- Weaning
- Hemodynamics
- ICU Readmission
- Survival & Long-term Outcomes
Anatomy of the Diaphragm
Action of the Diaphragm

De Troyer and Loring, Handbook of Physiology
Action of the Diaphragm

De Troyer and Loring, Handbook of Physiology
Inspiratory Diaphragm Thickening


Cohn et al J Appl Phys 1997
Imaging Diaphragm Thickness

probe

Zone of apposition

B-mode!
Imaging Diaphragm Thickness

\[ T_{di} = A \]

\[ TF = \frac{(B - A)}{A} \times 100\% \]
Metrology: Diaphragm Thickness

Cohn JAP 1997
Metrology: Diaphragm Thickness

Values in Healthy Subjects

Reproducibility

Boon et al. *Muscle Nerve* 2013

Goligher et al. *Intensive Care Med* 2015

1.5-5.0 mm

Repeat (same obs)

 +/- 0.4 mm (R)
 +/- 1.9 mm (L)

Site Marked
 +/- 0.2 mm (R)

Repeat (diff obs)

 +/- 2.1 mm (R)
 +/- 1.4 mm (L)

Site Marked
 +/- 0.4 mm (R)
Metrology: Diaphragm Thickening

Viver et al. ICM 2012

Goligher et al. ICM 2015
Metrology: Diaphragm Thickening

Values in Healthy Subjects

- 25-45% @ rest
- >20% @ maximal Inspiratory effort

Reproducibility

- Repeat (same obs): +/- 19% (R)
- Site Marked: +/- 17% (R)
- Repeat (diff obs): +/- 27% (R)
- Site Marked: +/- 16% (R)
Metrology: Diaphragm Thickening

Gottesman et al JAP 1997
Thickening: Volume vs Pressure?

End-expiration

Peak inspiration

End-inspiratory hold

Diaphragm thickening fraction (%)
Thickening vs Excursion

Unpublished observations
Sources of Error

• **Thickness**
  - Variability in diaphragm thickness across its surface
  - Body habitus
  - Changes in muscle echogenicity during MV
  - Left side
  - Failure to mark site

• **Thickening**
  - Combines error of two thickness measurements

• **Function**
  - Variability in volitional inspiratory effort
Clinical Insights 1: Inspiratory Effort During MV

Goligher et al. *Intensive Care Med* 2015
Clinical Insights 2:
Evolution of Diaphragm Thickness During MV

Goligher et al AJRCCM 2015
Clinical Insights 3: Inspiratory Effort Matters

Goligher et al AJRCCM 2015
Clinical Insights 4: Predicting Successful Extubation

DiNino et al Thorax 2014
Summary: Monitoring Diaphragm Thickness

• Valid and reproducible measurements
  – Right hemidiaphragm
  – Mark site for repeated measurements

• Permits evaluation of:
  – Structural changes (thickness, echogenicity)
  – Inspiratory effort (thickening fraction)
  – Muscle function (maximal thickening fraction)

• Yields important insights for clinical management

• Potential intervention and/or outcome in future studies
Acknowledgments

• Mentorship
  – Dr. Niall Ferguson
  – Dr. Laurent Brochard
  – Dr. Brian Kavanagh
  – Dr. Gordon Rubenfeld
  – Dr. Steffen-Sebastian Bolz

• Collaborators
  – Dr. Michael Detsky
  – Alistair Murray
  – Debbie Brace
  – Stefannie Vorona
  – Ashley Lanys
  – Dr. Nuttapol Rittayamai
  – Dr. Michael Sklar

ewan.goligher@mail.utoronto.ca
Questions?
ewan.goligher@mail.utoronto.ca