Monitoring

Diaphragm Thickness

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

- Conflicts of Interest
  - Equipment from Sonosite
  - Equipment and research support from GE
  - Equipment and speakers’ honoraria from Maquet Getinge
Why Monitor the Diaphragm?

- VILI
- Weaning
- P-V synchrony
- ICU Readmission

Survival & Long-term Outcomes
Anatomy of the Diaphragm
Action of the Diaphragm

De Troyer and Loring, Handbook of Physiology
Diaphragm Shortening and Thickening in the Zone of Apposition

Gauthier et al *J Appl Phys* 1994

Wait JL et al *J Appl Phys* 1989
Imaging Diaphragm Thickness

probe
Zone of apposition

Pleura
Chest Wall
Diaphragm
Peritoneum

B-mode!
Imaging Diaphragm Thickness

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

Cohn JAP 1997
Metrology: Diaphragm Thickening

Viver et al. ICM 2012

Goligher et al. ICM 2015
Thickening: Volume vs Pressure?

End-expiration

Peak inspiration

End-inspiratory hold

![Graph showing diaphragm thickening fraction vs inspiratory volume.]

**Diaphragm thickening fraction (%)**

**Inspiratory Volume**
- 0-24% of IC
- 25-49% of IC
- 50-74% of IC
- 75-100% of IC

**Maneuver**
- Peak
- Hold

**B/A**

**C/A**
Measuring Function: Maximal Thickening

Gottesman et al *AJRCCM* 1997

Ferrari et al *Crit Ultrasound J* 2014
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
Monitoring Mechanical Ventilation

• Inspiratory effort
• Patient-ventilator dyssynchrony
• Diaphragm function
Clinical Insights 1:
Evolution of Diaphragm Thickness During MV

Group: Diaphragm Thickness Change
- >10% loss on or before day 8
- <10% change on or before day 8
- >10% gain on or before day 8

Goligher et al AJRCCM 2015
Clinical Insights 2:
Changes in Diaphragm Thickness and Clinical Outcomes

Under review
Clinical Insights 3: Inspiratory Effort Matters

Goligher et al AJRCCM 2015
Clinical Insights 4: Inspiratory Effort During MV

Goligher et al. *Intensive Care Med* 2015
Clinical Insights 5:
Predicting Successful Extubation

DiNino et al Thorax 2014
Summary: Monitoring Diaphragm Thickness

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

- Yields important insights for clinical management
- Potential intervention and/or outcome in future studies
Mechanical Ventilation
From physiology to clinical practice

April 26 - 28, 2017  Michener Institute, Toronto

mechanicalventilation.ca

Organized by the Interdepartmental Division of Critical Care Medicine, University of Toronto