Diaphragmatic Ultrasound in ICU

by

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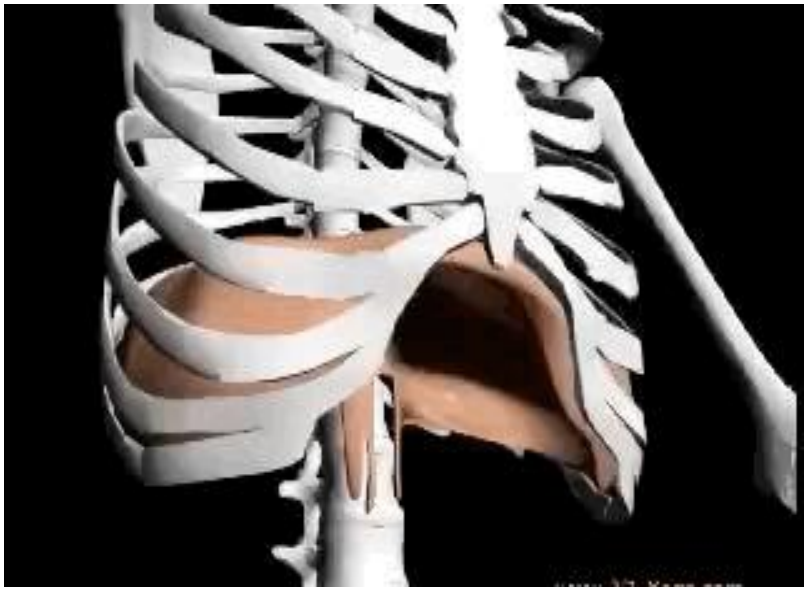
Objectives

- Introduction
- Ultrasound of the diaphragm
  - Thickness
  - Thickening fraction
  - Movement
- Clinical Applications
- Limitations

Introduction

- The diaphragm plays a significant role in the ICU setting, as it forms a crucial part in sustaining spontaneous breathing and ability to wean from mechanical ventilation.



Introduction

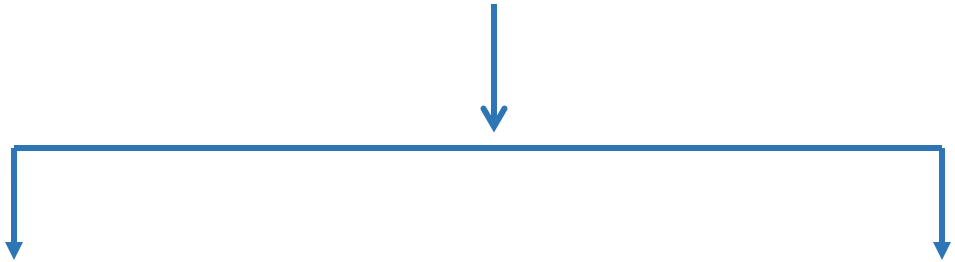
- Diaphragm ultrasonography is a rapidly growing field of research, with close to 3000 PubMed-listed publications over the last decade
- Ultrasonography has become a popular option due to its many advantages:
  - Simple equipment
  - Non- invasive
  - Available
  - Fast
  - Portable
  - Repeatable

Ultrasound of the diaphragm

- Thickness
- Thickening fraction
- Movement

How is ultrasound of the diaphragm used?

- Basic ultrasound offers two approaches to imaging:



Brightness mode (B-Mode)

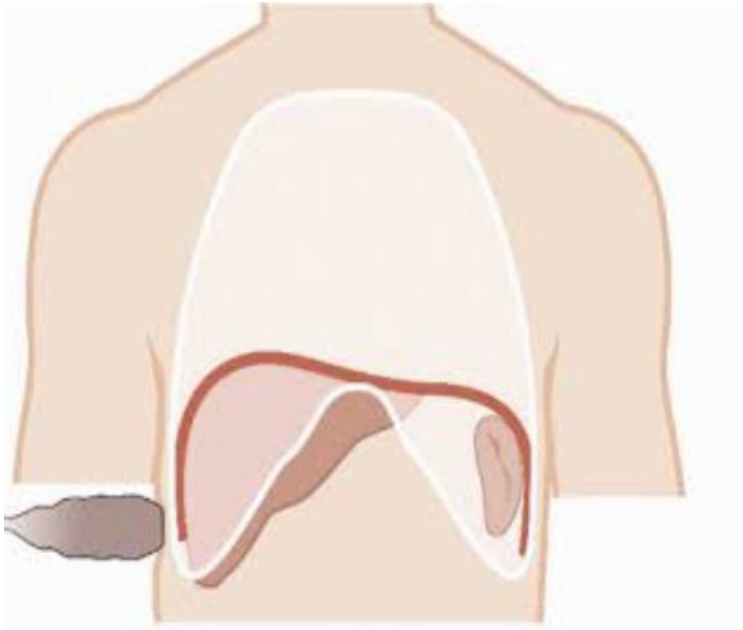
Diaphragm thickness (tdi)

Motion-mode (M-mode).

Diaphragm motion

Diaphragmatic Thickness

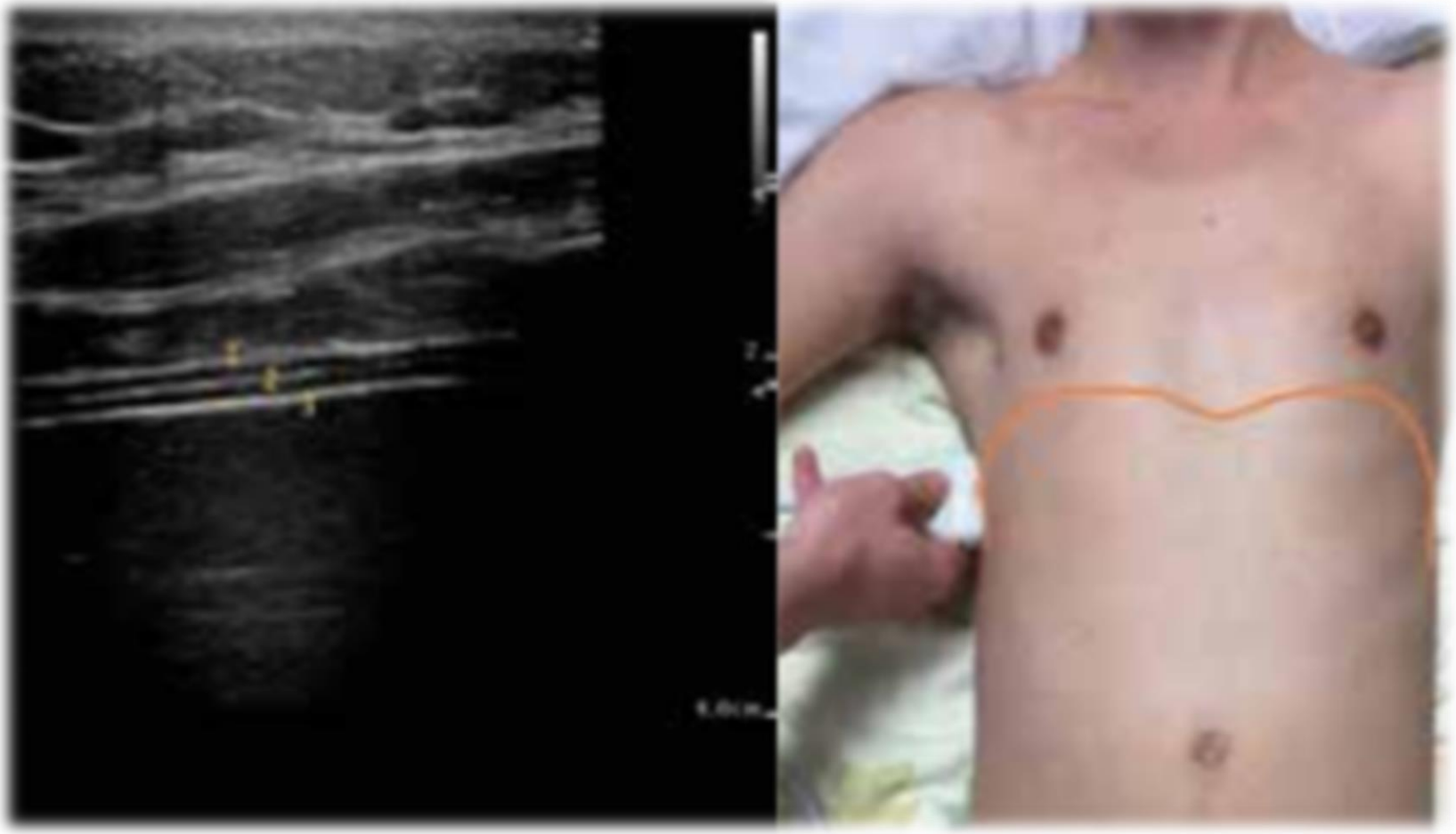
- The diaphragmatic thickness (tdi) is measured in B-mode with a high-frequency probe (≥10 MHz).
- At the mid-axillary line approximately between the 7th and 9th rib.



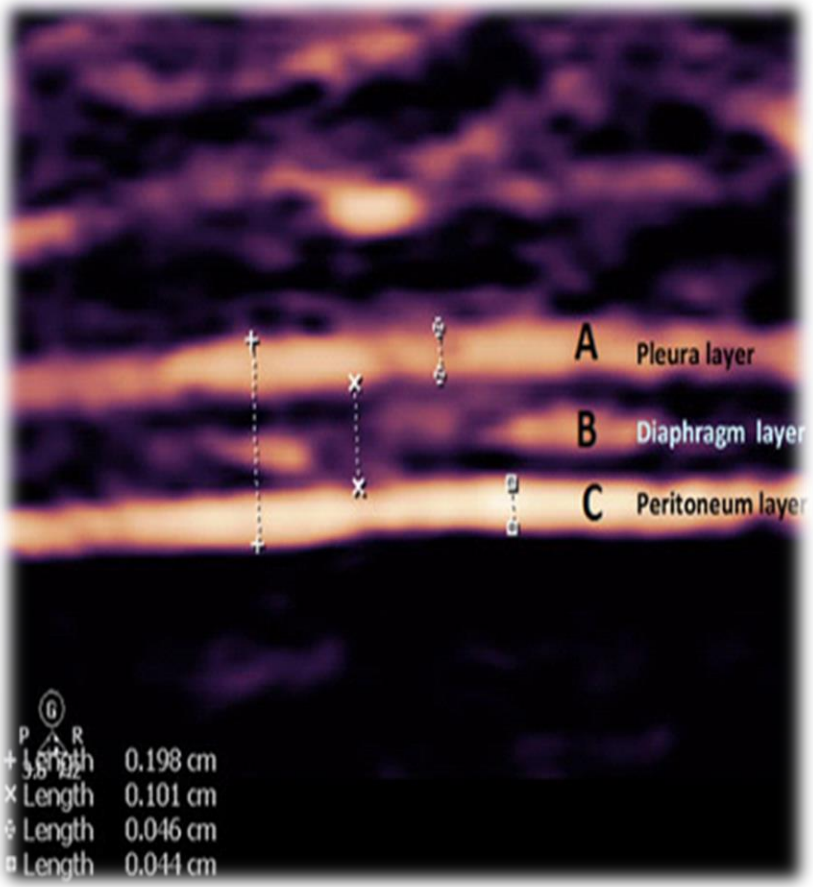
Diaphragmatic Thickness

- The diaphragm is seen as a structure composed of three different echogenic layers:
  - The pleural membrane.
  - Central tendinous layer.
  - The peritoneal membrane.
- The diaphragm seen as two echogenic layer of peritoneum and pleura line sandwiching hypoechoic layer of muscle itself.
- It thickened during inspiration.

Diaphragmatic Thickness

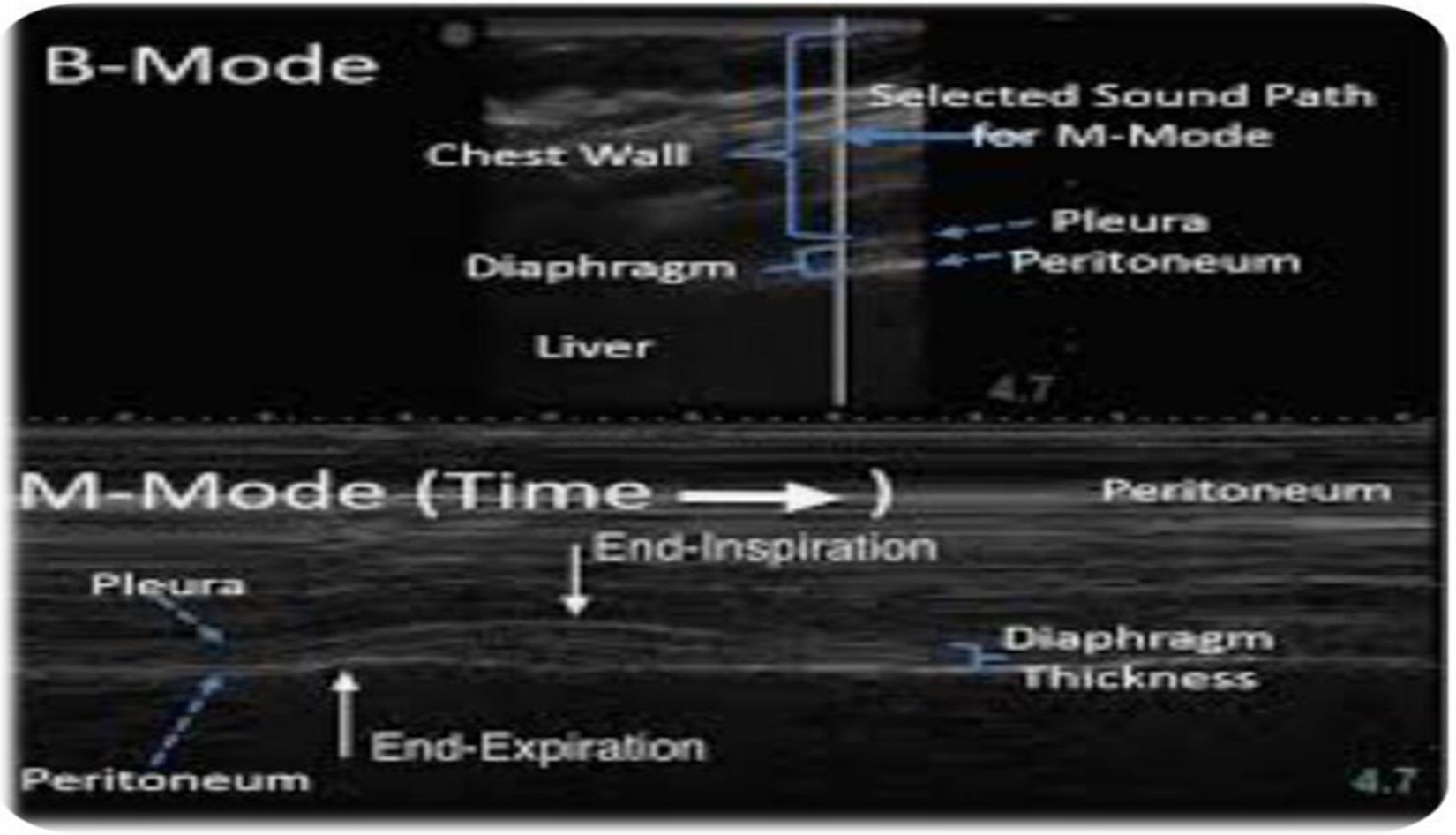


Diaphragmatic Thickness



Diaphragmatic Thickness

Diaphragmatic Thickness



Diaphragmatic Thickness

- The normal thickness of the diaphragm is 2.6 ± 0.6 mm (from 1.65 mm to 3.7 mm) at end inspiration in healthy volunteers.
- Normal thickness at end expiration is 1.9 ± 0.5 mm (from 1.2 mm to 2.79 mm)
- Thickness increases by 45 – 75% with inspiration.

- Carrillo-Esper R, Perez-Calatayud AA, Arch-Tirado E, Diaz Carrllio MA, Garrido-Aguirre E, Tapia-Velazco R, et al. Standardization of Sonographic Diaphragm Thickness Evaluations on Healthy Volunteers. Respir Care. 2016; 61(7): 920-924
- Thimmaiah VT, Geetha MJ, Jain KP. Evaluation of thickness of normal diaphragm by B mode ultrasound. Int J Contemp Med Res. 2016;3:2658–2660.

Diaphragmatic Thickening Fraction

- Diaphragmatic thickening fraction (%) can be calculated.
  - (TF = thickness at end-inspiration - thickness at end-expiration/thickness at end-expiration).

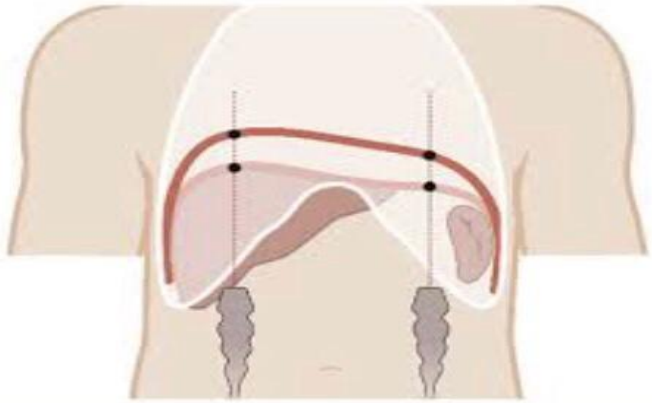
- **It must be kept in mind however, that during controlled modes of ventilation, this measurement is not feasible, as no contractile activity of the diaphragm is present.**

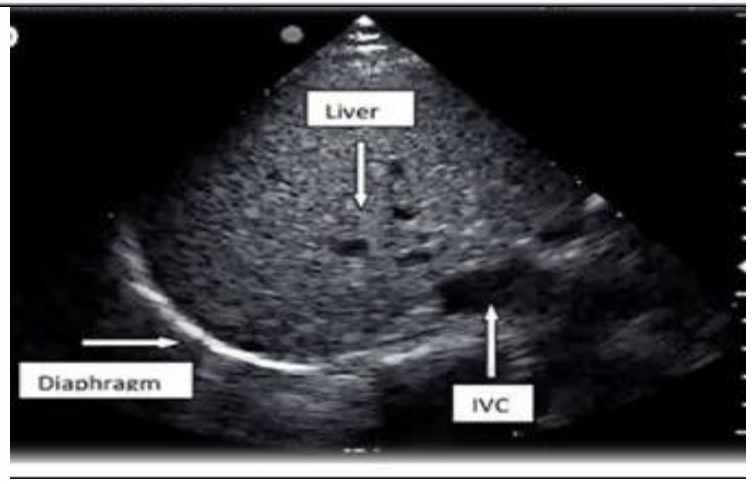
Diaphragmatic Excursion

- Diaphragm excursion (DE) is measured in the M-mode with a low frequency probe (1-5 MHz).
- Just below the costal arch on the midclavicular line, with the probe directed cranially and a small dorsal tilt.
- The excursions are between 10 mm and 25 mm on both sides.

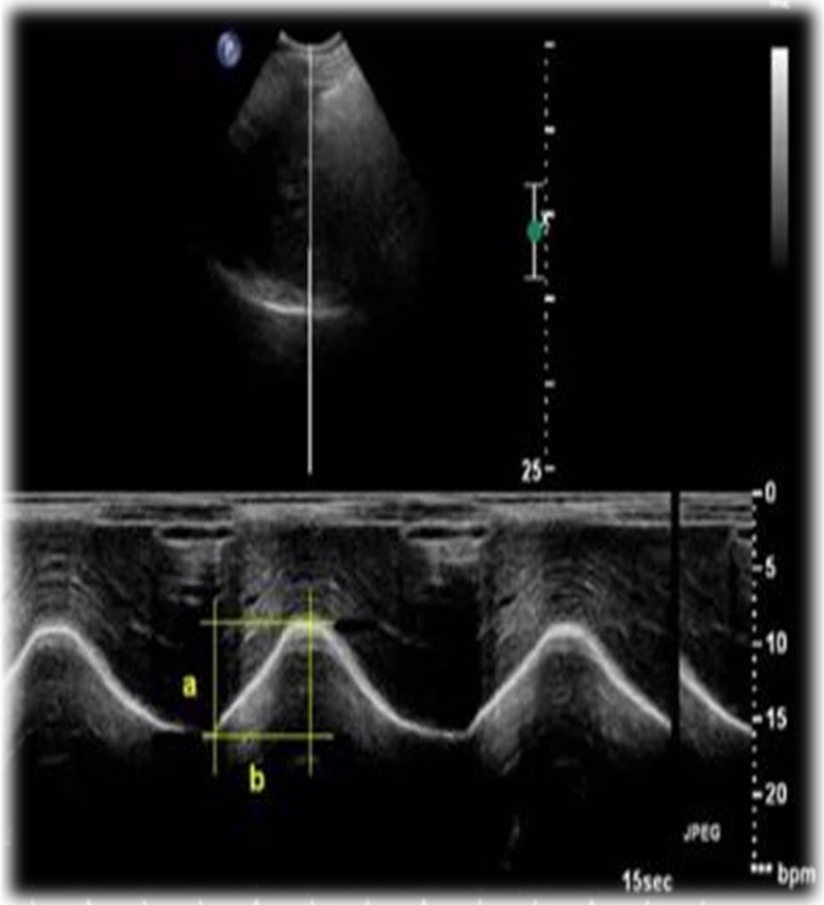
- Boussuges A, Rives S, Finance J, Brégeon F. Assessment of diaphragmatic function by ultrasonography: Current approach and perspectives. World J Clin Cases 2020 ; 8(12): 2408-2424

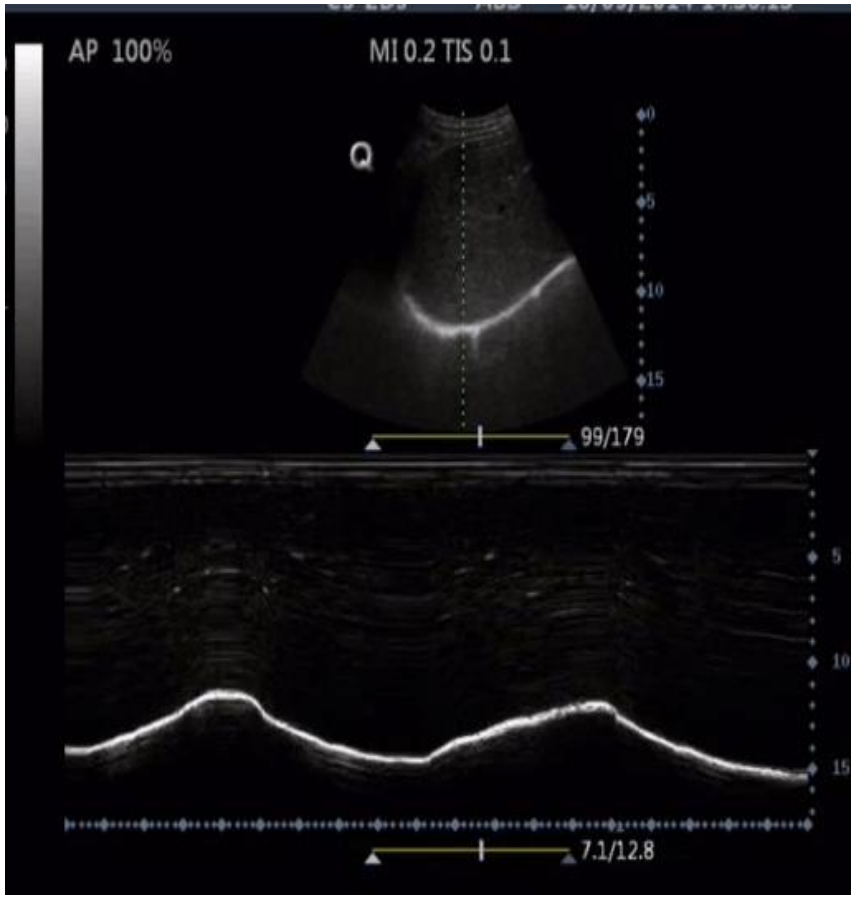
Diaphragmatic Excursion





Diaphragmatic Excursion



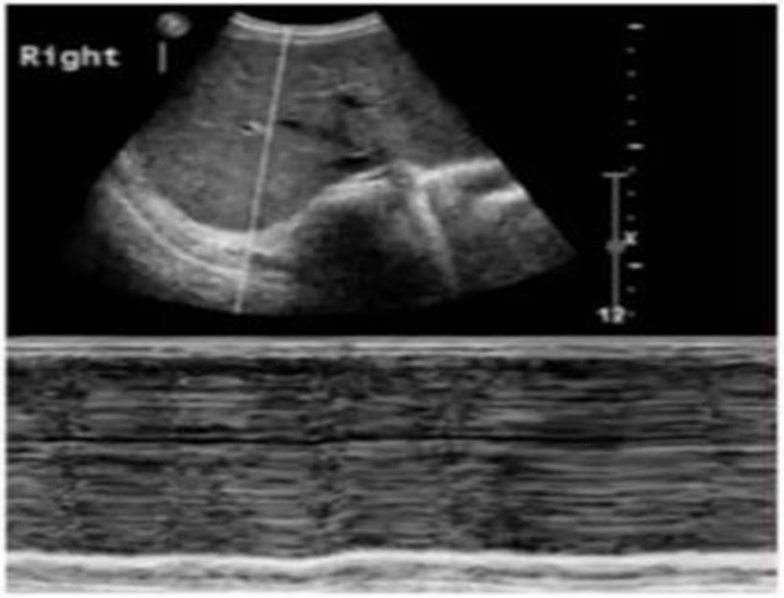


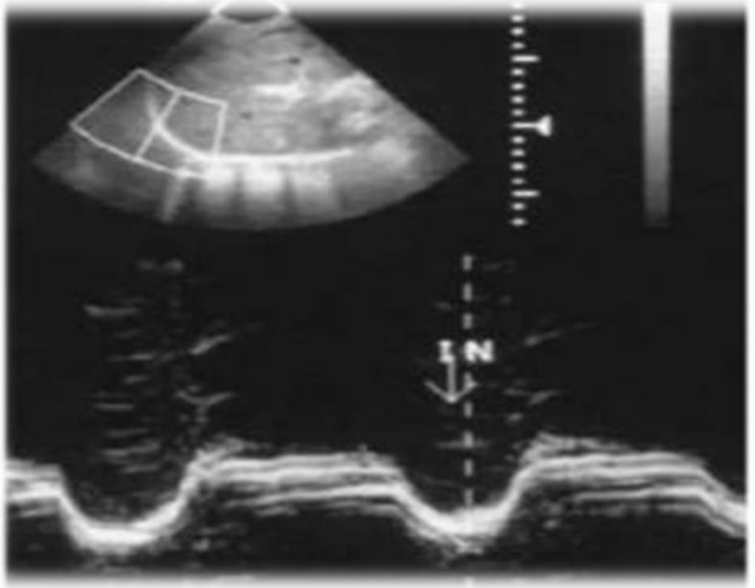
Clinical Applications in ICU

- Identification of diaphragmatic paralysis.
- Weaning from mechanical ventilation.

Identification of diaphragmatic paralysis

- Non invasive bedside method for detection of unilateral or bilateral paralysis.
- In trauma patient.
- Postoperative: e.g., cardiac surgery.





Weaning from mechanical ventilation

- Mechanical ventilation is associated with decrease in muscle weight and alter contractile element of the diaphragm within 48 hr. of intubation.
- This led to a suspicion of diaphragmatic dysfunction even in patients with no obvious pathology.

Weaning from mechanical ventilation

Weaning from mechanical ventilation

Medicine. 97(22):e10968, JUN 2018
DOI: 10.1097/MD.0000000000010968, PMID: 29851847
Issn Print: 0025-7974
Publication Date: 2018/06/01

Print

Diaphragmatic ultrasonography for predicting ventilator weaning: A meta-analysis

Caifeng Li;Xin Li;Hongqiu Han;Hailong Cui;Guolin Wang;Zhiqiang Wang;

Weaning from mechanical ventilation

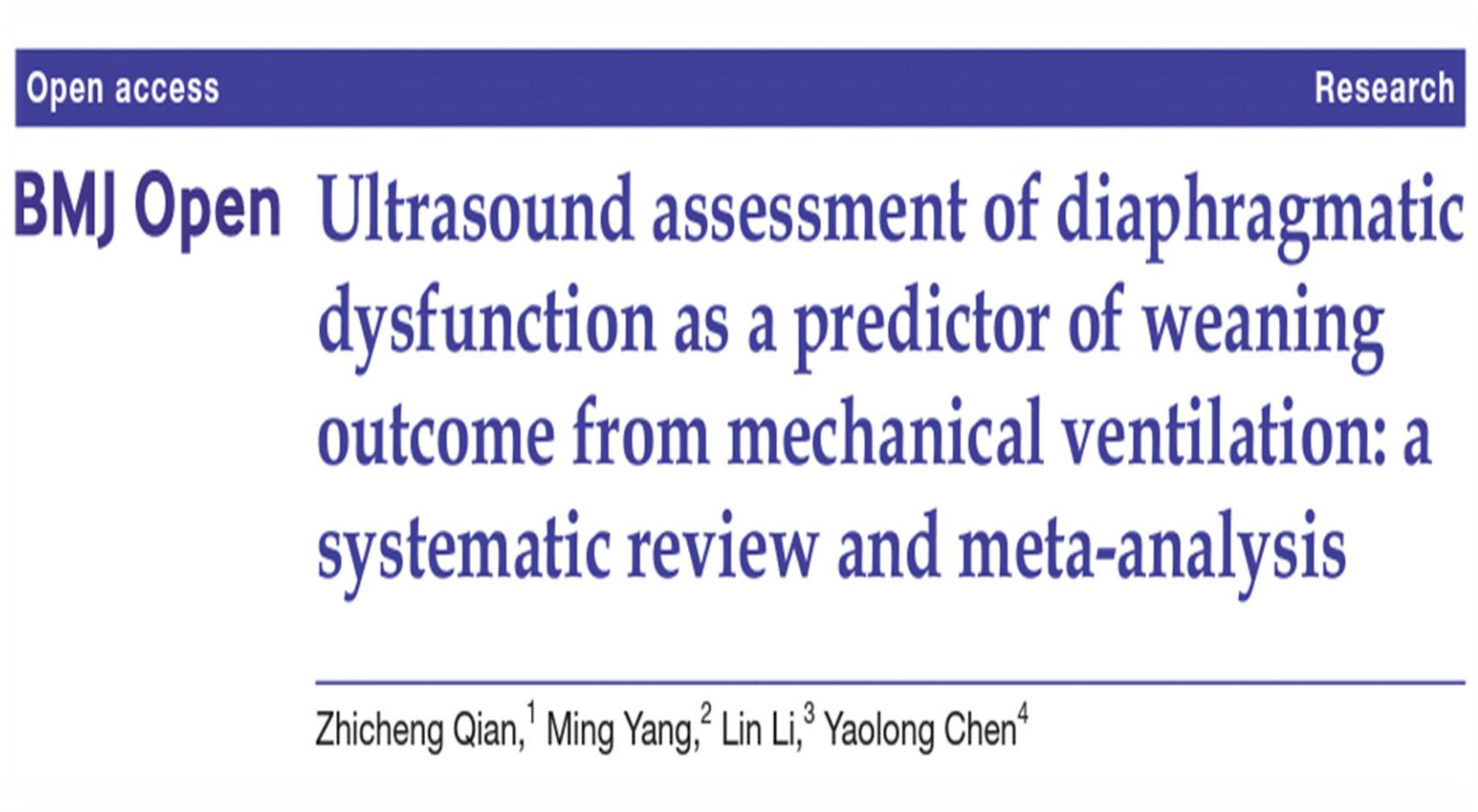
Results:

Thirteen studies with 742 subjects were included in this meta-analysis. The pooled sensitivities for diaphragm excursion (DE) and diaphragm thickness fraction (DTF) were 0.786 and 0.893, and the pooled specificities were 0.711 and 0.796, respectively. The area under curve (AUC) for DE and DTF were 0.8590 and 0.8381. The DORs for DE and DTF were 10.623 and 32.521. No publication bias was observed among these studies.

Conclusions:

Diaphragmatic ultrasonography is a promising tool for predicting reintubation within 48 hours of extubation. However, due to heterogeneities among the included studies, large-scale studies are warranted to confirm our findings.

Weaning from mechanical ventilation



Weaning from mechanical ventilation

Results Eleven studies involving a total of 436 patients were included. There were eight studies comparing diaphragmatic excursion (DE), five comparing the diaphragmatic thickening fraction (DTF) and two comparing DD between groups with and without successful weaning. Overall, the DE or DTF had a pooled sensitivity of 0.85 (95% CI 0.77 to 0.91) and a pooled specificity of 0.74 (95% CI 0.66 to 0.80) for predicting weaning success. There was high heterogeneity among the included studies (I^2=80%; p=0.0006). The rate of weaning failure was significantly increased in patients with DD (OR 8.82; 95% CI 3.51 to 22.13; p<0.00001).
Conclusions Both DE and DTF showed good diagnostic performance to predict weaning outcomes in spite of limitations included high heterogeneity among the studies. DD was found to be a predictor of weaning failure in critically ill patients.

Weaning from mechanical ventilation

Crit Care. 2023; 27: 174. Published online 2023 May 5. doi: 10.1186/s13054-023-04430-9

PMCID: PMC10161591 | PMID: 37147688

Effectiveness of diaphragmatic ultrasound as a predictor of successful weaning from mechanical ventilation: a systematic review and meta-analysis

Henry M. Parada-Gereda,[1] Adriana L. Tibaduiza,[2] Alejandro Rico-Mendoza,[3] Daniel Molano-Franco,[4] Victor H. Nieto,[4,5] Wanderley A. Arias-Ortiz,[6] Purificación Perez-Terán,[7] and Joan R. Masclans[7,8]

Weaning from mechanical ventilation

- 19 studies (articles published between January 2016 and July 2022) were included in the meta-analysis (1204 patients).
- For diaphragmatic excursion (DE) , sensitivity was 0.80 (95% CI 0.77–0.83), specificity 0.80 (95% CI 0.75–0.84).
- For the diaphragmatic thickening fraction (DTF), sensitivity was 0.85(95%CI 0.82–0.87), specificity 0.75 (95% CI 0.69–0.80).

Weaning from mechanical ventilation

- The high sensitivity reported in the study with values above approximately 29% for DTF and > 10 mm for DE have a high probability of successful extubation; however, it is essential to mention that weaning success may be affected by additional factors such as nutritional status, respiratory and cardiovascular integrity and psychological conditions.

Weaning from mechanical ventilation

Conclusion

- Measurement of diaphragmatic excursion and diaphragmatic thickening fraction predict the probability of successful weaning from mechanical ventilation with satisfactory diagnostic accuracy; however, significant heterogeneity was evident in the different included studies.

Recommendations

Recommendations of the European Society of Intensive Care Medicine (2021)

Recommend that the estimation of diaphragmatic excursion for diaphragmatic function assessment, mainly in patients to be weaned from mechanical ventilation should be considered a basic skill for intensivists.

Unable to provide recommendation on the evaluation of diaphragmatic thickening fraction for diaphragmatic function assessment, mainly in patients to be weaned from mechanical ventilation.

Limitations

- A 5% inaccuracy in measurements has to be accepted.
- Downward excursion of the lung and small window in spleen potential obstacles for clear visualization.
- The variability between observers (To improve this variability placement of the ultrasound probe can be standardized by marking the measurement site).
- Ultrasonography of the diaphragm is limited by ventilatory settings.

Key Message

It is reasonable to suppose that in the near future, the use of diaphragmatic ultrasound by intensivists will be prevalent and that it will have new applications in the diagnosis, monitoring of diseases and interventions.

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Thank You