Diaphragmatic ultrasound: A new frontier in weaning from mechanical ventilation

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The weaning of ventilated patients is a critical phase in intensive care. The weaning process allows patients to resume spontaneous breathing after a gradual reduction in support and, ultimately, liberation from mechanical ventilation. Weaning from mechanical ventilation in intensive care is usually based on the clinical condition of the patient and rapid shallow breathing index (RSBI).[1] The difficult-to-wean patients have a very high chance of reintubation, which leads to a poor prognosis. The aim of using various parameters is to avoid premature extubation as well as to avoid reintubation or the need for non-invasive support within 48 hours of weaning.[2]

With the advent of point-of-care ultrasound in critical care, diaphragmatic ultrasound emerged in a big way to assist in the decision-making of weaning from mechanical ventilation. Diaphragmatic thickness (DT) is the most studied parameter for the prediction of successful weaning.[3] Diaphragmatic excursion (DE) and diaphragm thickness fraction (DTF) are other ultrasound parameters used to predict successful weaning.[3] A study by Lalwani LK *et al*.[4] concluded that percentage change in DT is better than RSBI for weaning prediction.

Inspiration is an active process, and the diaphragm is one of the primary muscles for this mechanism. Various neuromuscular disorders that affect the functioning of the diaphragm, such as amyotrophic lateral sclerosis, poliomyelitis, Guillain–Barré syndrome, spinal muscular atrophy, transverse myelitis, cervical spine disease, Lyme disease, neuropathy, myasthenia gravis, and Lambert–Eaton syndrome, are responsible for difficult weaning from mechanical ventilation. Various studies has demonstrated that muscle integrity and contractile capacity of diaphragm predicted with accuracy by DT.[5]

The ultrasonographic assessment of the diaphragm is a real-time, non-invasive, and feasible method in critical care settings for precise evaluation of a patient's progress and suitability of weaning from mechanical ventilation. DE >1.2 cm and DTF >36% have been shown to predict successful weaning.[6] The DT is measured in M-mode image with the help of a 10-MHz linear probe at the 8^{th}–10^{th} intercostal space.[7] The diaphragm muscle is sandwiched between two hyperechoic lines of pleura and peritoneum. The DT is measured in a frozen image from the centre of the pleural line and peritoneal line at the end of inspiration and end-expiration. It is estimated three times, and the results are averaged. DTF is the difference in DT at end inspiration and thickness at end-expiration divided by thickness at end-expiration.[3] Excursion of the right hemidiaphragm is measured in the mid-axillary line, whereas left hemidiaphragm excursion is measured in the posterior axillary line in 6–10 intercostal space by using a 3–5-MHz curvilinear ultrasonic probe. The liver serves as an acoustic window for the right hemidiaphragm. In inspiration, the diaphragm contracts and moves caudally towards the probe and moves away from the probe during expiration. The vertical distance between baseline to maximum height during inspiration is depicted as DE. The time to peak inspiratory amplitude is measured with the help of M-mode tracing beginning from time to the start of diaphragmatic contraction till the maximal amplitude of diaphragmatic inspiratory excursion.[3] All these parameters were used in comparison to the conventional parameters such as RSBI (RSBI = respiratory rate/tidal volume; RSBI >105 predicts weaning failure) and were found to be better predictors of weaning failure or success.[8]

A DT change of >30% has a 91% positive predictive value (PPV) and a 63% negative predictive value (NPV) for the prediction of successful weaning.[9] In comparison, another study showed a sensitivity of 87.5%, 77.5%, 80%, and 90% for DE, DT at end-inspiration, DT at end-expiration, and DTF, respectively, for predicting successful extubation.[10] Hyat *et al.* showed a sensitivity and specificity of 78.95% and 70.83%, respectively, for DE to predict successful weaning. The DTF has a sensitivity of 82% and a specificity of 88%. A DTF of >36% exhibited a 92% PPV and a 75% NPV among 46 cases.[7] Ramakrishna*n P et al*. compared DE with RSBI to predict successful weaning in 20 intensive care unit patients and found a larger area under the curve in DE in comparison to RSBI (0.92 vs 0.58).[11] The cut-off value of DE >1.21 cm, DTF >37%, and RSBI <82 was suggested as weaning criteria for mechanical ventilation.[2]

As DT varies in intercostal space and also depends on functional residual capacity and total lung capacity, prolonged mechanical ventilation in intensive care and abdominal or thoracic surgery may be considered for the interpretation of ultrasound of the diaphragm. The visualisation of the left hemi diaphragm is complex in patients with higher body mass index; hence, the measurement of accurate DT is an arduous task.[12] The diaphragmatic parameters are also dependent on maximal voluntary inspiratory effort and the position of the patient. The movement of the diaphragm is also affected by the abdominal content and pressures.[13]

The role of DT in the weaning process presents a novel perspective; however, several challenges persist. Standardisation of measurement techniques, the establishment of normative values, and the incorporation of DT assessment into existing protocol necessitate further research and validation. Comprehensive longitudinal studies are imperative to show long-term results of DT on respiratory function and patient outcomes.

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