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Diaphragmatic Ultrasound: Review Article

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ABSTRACT
Background: Mechanical ventilation (MV) is required for most cases introduced the intensive care unit (ICU) as a portion of their process of care. However, either MV or the chronic illness can result in diaphragm dysfunction, an incident that may contribute to the incapability of MV separation to be done. Prolonged use of the ventilator significantly increases health-care expenses and subject morbidity and mortality. However, muscle disease symptoms and manifestations are frequently difficult to evaluate in a bedridden state ICU case due to complicating variables. A typical evaluation of diaphragm function lacks, non-invasive, time preservative, easy-to-perform bedside equipment or needs subject involvement. Lately, the utilization of ultrasound (US) has elevated a lot of interest as a simple, non-invasive approach for the assessment of diaphragmatic contractile activity. **Objective:** This narrative review aimed to briefly describe the common methods of diaphragmatic function assessment using ultrasound techniques. **Methods:** These databases were searched for articles published in English in 4 databases [PubMed - Egyptian Knowledge Bank - Google scholar- Science direct] and Boolean operators (AND, OR, NOT) had been used such as [Diaphragmatic AND Ultrasound OR Diaphragm function] and in peer-reviewed articles between 1985 and 2021. **Conclusion:** Diaphragmatic ultrasonography has been widely investigated and is still being explored as a predictor of effective mechanical ventilation weaning. Due to the substantial heterogeneity in research design and population, it remains difficult to draw general generalizations from individual studies. Even worse, terminology such as a failed breathing trial or unsuccessful extubation has not been defined across research, making comparisons of outcome measures unfeasible.
Keywords: Diaphragmatic, Ultrasound, Diaphragm function.

INTRODUCTION

The diaphragm is the main muscle of respiration, acting continuously and uninterruptedly to sustain the task of breathing. Diaphragmatic dysfunction can occur secondary to numerous pathological conditions and is usually underdiagnosed in clinical practice because of its nonspecific presentation. Although several techniques have been used in evaluating the diaphragmatic function, the diagnosis of diaphragmatic dysfunction is still problematic. Diaphragmatic ultrasound has gained importance because of its many advantages, including the fact that it is noninvasive, does not expose patients to radiation, is widely available, provides immediate results, is highly accurate, and is repeatable at the bedside. More recently lung and diaphragm ultrasound methods have been introduced, assessing pulmonary airway patterns and diaphragm function [1].

Several parameters measured through diaphragm ultrasound have been proposed for the same purpose. These include diaphragm thickness, diaphragm movement or excursion during the respiratory cycle, and diaphragm thickening or thickening fraction [2-3].

Technical aspects:

The diaphragmatic ultrasound is a valuable approach for evaluating the diaphragm's function and anatomy, exactly diaphragmatic expansion, and thickness. Table 1 explains certain features of this method. The tools required for diaphragmatic ultrasound are straight forward and readily accessible in most medicinal establishments. The ultrasound system must be provided with a convex transducer operating at 2.5-5.0 MHz and a linear transducer operating at 7.5-10.0 MHz [2-4].

Table (1): Diaphragmatic ultrasound (US).

Advantages	
Safety	- Cases should not be exposed to ionizing radiation [5]. - Noninvasive
Feasibility	- Done in less than 15 minutes, and in some cases about 5 minutes [5]. - There is no requirement for the subject to be transported for bedside evaluation. - Multiple repeats are possible.
Availability	- Ultrasonography needs only basic, typically readily available tools.
Accuracy	- Extreme temporal resolution [5, 6] great replicability, and excellent accuracy [1, 4]. - Outperforms fluoroscopy in the diagnosis of diaphragmatic disorder [7]. - Has interobserver acceptance and high interobserver, for thickness [1] and diaphragmatic excursion [6].
Disadvantages	
Availability	- It is not available in all facilities. - On-staff doctors versed in the method are required.
Accuracy	- Visualizing the left hemidiaphragm might be a problem, especially in fat people [8]. - Diaphragmatic excursion is dependent on the patients' maximum voluntary inspiratory activity, which is regulated by case position [9]. - Diaphragmatic excursion is influenced by components and pressure of the abdomen, both of that act as a constraint on diaphragmatic displacement [10].

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Diaphragm echographic appearance:

The diaphragm could be diagnosed using ultrasound within 2 auditory windows: over the subcostal area (SCA), as seen in Figures 1 and 2; and over the ZOA, as represented in Figure 3. US imaging within the SCA window illustrates a deeply arched diaphragm that separates the abdomen from the thorax (Figure 3B). The diaphragm is visible such as a 3-layer structure through the ZOA window (Figure 3) [11].

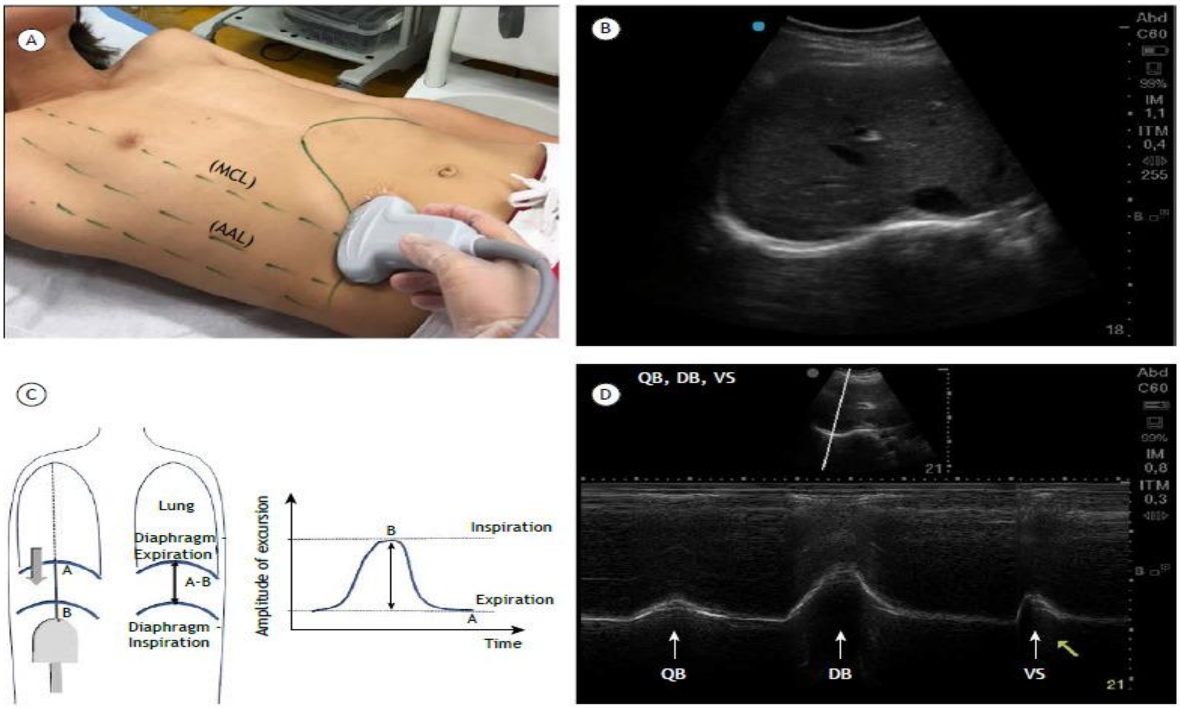

Figure (1): In A, the right hemidiaphragm excursion is determined using an anterior subcostal view and a convex probe positioned beneath the costal border between the anterior axillary line (AAL) and the midclavicular line (MCL). At B, an ultrasound image of the right hemidiaphragm is seen in the subcostal region between the MCL and AAL. C illustrates a schematic illustration of the diaphragmatic excursion measurement: on the left, the probe is positioned in the subcostal region to exhibit the diaphragm in B mode; on the right, the exploratory line is positioned to indicate excursion from expiration to inspiration (points A-B). The diaphragmatic excursion in M mode is determined in D. The figure's upper half depicts a typical right diaphragm in B mode, while the lower section depicts diaphragmatic excursion in M mode during deep breathing (DB), quiet breathing (QB), and voluntary sniffing (VS) [11].

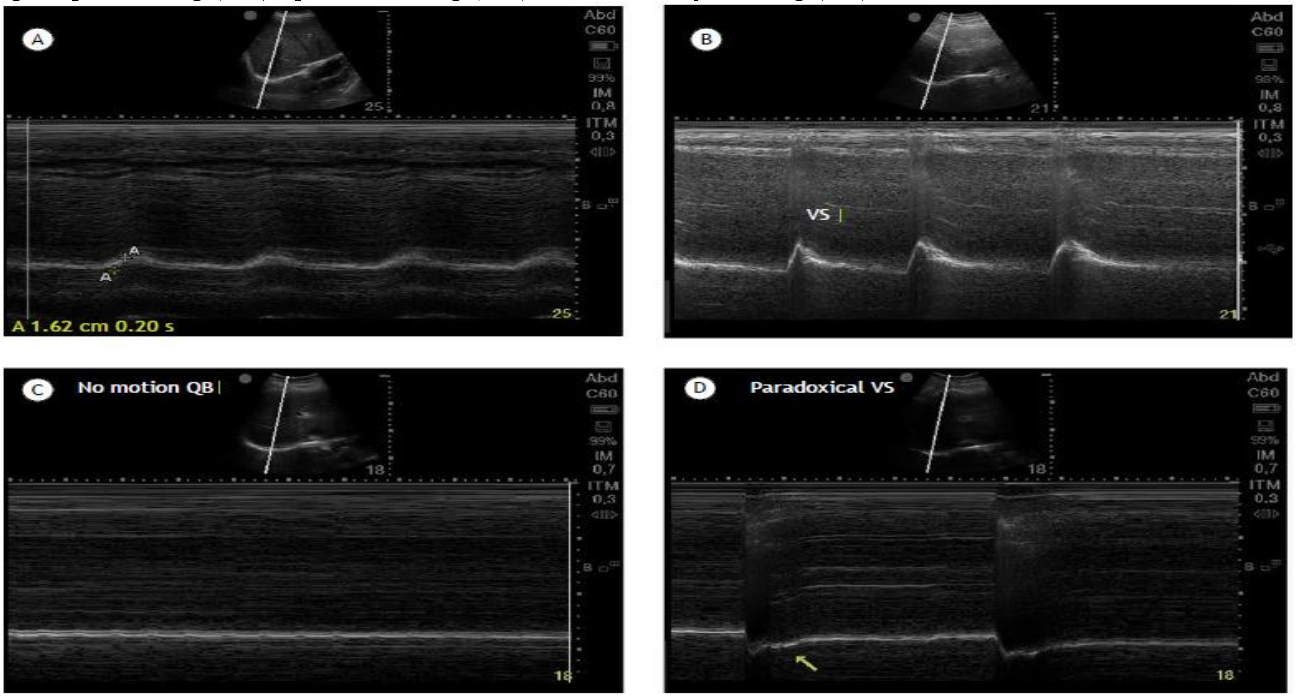

Figure (2): Measuring diaphragmatic excursion. At the top of each panel, B mode photos indicate the position of the probe, whereas M mode images exhibit diaphragmatic excursion (A and B), absence of excursion (C), and paradoxical excursion (D) (D). Panel A depicts diaphragmatic excursion during quiet breathing (QB), whereas panel B depicts voluntary sniffing (VS). Panels C and D exhibit the remnants of a paralyzed diaphragm. In C, no diaphragmatic excursion occurs during QB. The paradoxical motion that happens during VS is seen in Panel D.

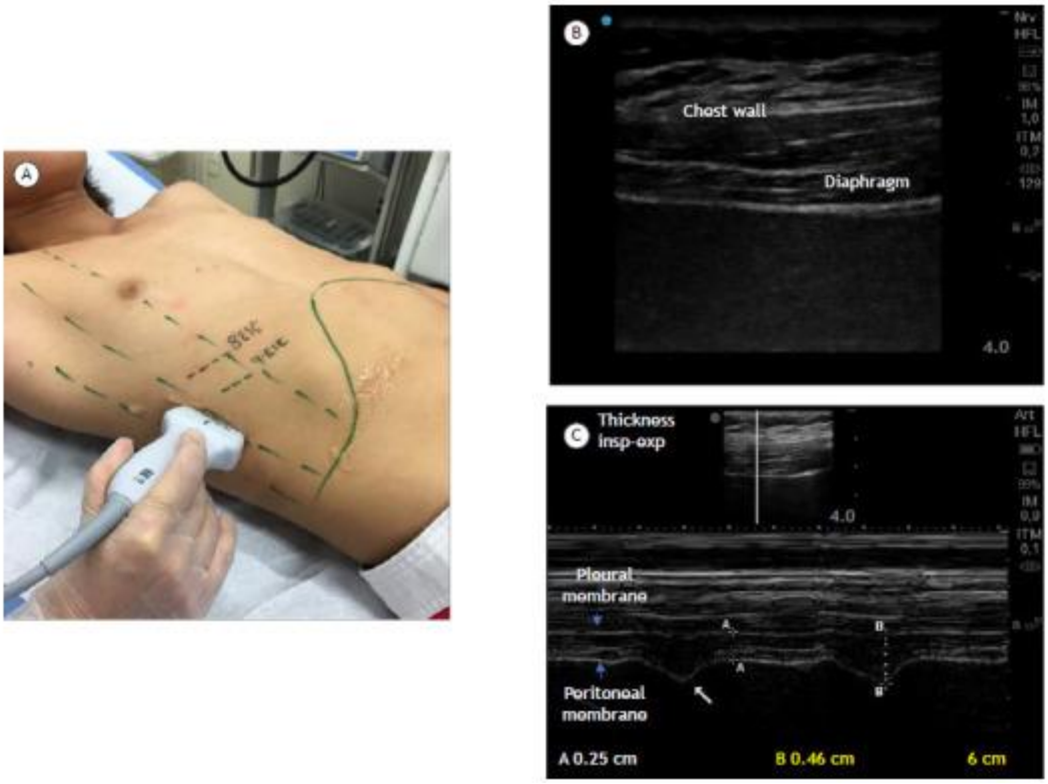

Figure (3): In A, the right hemidiaphragm thickness is measured by positioning the linear transducer above ZOA at the ninth intercostal space, between the midaxillary and anterior lines. In B, an ultrasound image of the left hemidiaphragm around the ZOA between the ninth and tenth intercostal spaces is shown during quiet breathing at functional residual capacity. In C, measurement of diaphragm thickness: The top section of the figure depicts the ZOA of a normal diaphragm in B mode; the bottom section shows the diaphragm thickness at end-expiration (exp) or distance A-A, and diaphragm thickness at distance B-B or end-inspiration (insp), in M mode.

During contraction of the diaphragm in normal subjects, US via the SCA window demonstrates the diaphragm downward in the craniocaudal direction (i.e., toward the transducer), US through the ZOA window, on the other hand, demonstrates muscle shrinkage and thickening. As a result, ultrasound can be used to determine the movement and thickness of the diaphragm. To objectively evaluate diaphragmatic movement and thickening, at least 3 images should be assessed and took the mean values [12].

Diaphragmatic mobility:

Diaphragmatic movement is determined by imagining the hemidiaphragm in two dimensions (B) or one dimension (M) using the anterior subcostal (the best method), the subxiphoid, and the posterior subcostal view. Whatever the method utilized, three-time points are used to determine diaphragmatic mobility: during calm, deep breathing at maximum inspiration, and voluntary inhaling. The posterior subcostal aspect is most frequently employed with the subject seated [13, 14].

M mode is then utilized to determine the magnitude of craniocaudal diaphragmatic movement. Due to the unique subject positioning required, the posterior subcostal sight is often not feasible in critically ill cases or those on MV [13].

The subxiphoid aspect is important in children and slim people. Below a convex transducer with a low frequency is positioned transversely orientation under the xiphoid process, angled cranially and dorsally to the posterior hemidiaphragm. The left and right hemidiaphragms are visible in B mode, which enables a qualitative comparison of their excursion. The excursion of each hemidiaphragm could be clearly determined in M mode [15].

Testa *et al.* provided a full description of the anterior subcostal aspect's application. Briefly, a convex transducer with low frequency is positioned above the anterior SCA, midclavicular to anterior axillary lines. Through the liver and spleen windows, the left and right hemidiaphragms can be assessed. In B mode, Transverse scanning is used to examine hepatic tissue, looking for gallbladder in the center and inferior vena cava on the right [6].

The transducer is strongly attached, and the case is instructed to perform calm, deep breathing and voluntary inhaling (Figure 2D). In M mode, to acquire the greatest excursion, the line of M-mode is set as perpendicularly as feasible (Figures 2C and 2D). The diaphragmatic excursion's intensity is determined by putting calipers at the top and bottom of the inspiratory slope of the diaphragm (Figures 2C and 2D) [6, 11].

Ultrasound measurements of diaphragmatic movement may be used to assess DD. Diaphragmatic paralysis is characterized by the decrease in movement during calm and deep breathing, as well as by the presence of paradoxical movement during deep breathing or voluntary inhaling (Figures 2C and 2D). Diaphragmatic insufficiency is assessed by seeing decreased movement in serious respiration, either with or without paradoxical movement through purposeful inhaling (Figure 2D) [16].

Diaphragm thickness and thickening fraction (TF)

To determine contraction and diaphragm atrophy, it is important to determine the thickness of the diaphragm (Tdi) and the TF. A linear transducer with the increased rate (7-13 MHz) is positioned above the ZOA, between the 18th and 19th intercostal passages, often 0.5-2.0 cm below the costophrenic angle, between midaxillary and anterior lines (Figure 3A). The diaphragm is recognized at a depth of 1.5-3 cm as the hypoechoic inner muscular layer surrounded by 2 hyperechoic membranes (Figure 2B), namely those of the pleura (superficial line) and peritoneum (deeper line). Tdi is assessed from the pleural line to the peritoneal line at end-expiration (Tdi-exp) (Figure 3B), then at end-inspiration (Tdi-insp), in M and B modes (Figure 2C) [17].

The TF is calculated as follows:

$$TF = \frac{Tdi\text{-}insp - Tdi\text{-}exp}{Tdi\text{-}exp} \times 100$$

Tdi evaluation could be used to diagnose DD. Chronically diaphragmatic paralysis is atrophic, thin, and does not thicken during inspiration. Even so, Tdi may be normal in acute or subacute diaphragmatic paralysis, although the capacity for thickening will be reduced [18, 19].

CONCLUSION

Diaphragmatic ultrasonography has been widely investigated and is still being explored as a predictor of effective mechanical ventilation weaning. Due to the substantial heterogeneity in research design and population, it remains difficult to draw general generalizations from individual studies. Even worse, terminology such as a failed breathing trial or unsuccessful extubation has not been defined across research, making comparisons of outcome measures unfeasible.

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