Tissue Doppler Imaging of the Diaphragm: A New Kid on the Block?

The diaphragm is the primary constituent of the respiratory pump. Like the cardiac pump, diaphragm performance can be best characterized in terms of the force and velocity generated at a given muscle length. In the respiratory system, these parameters can be assessed by measuring the pressure and flow achieved at a given lung volume (1). The maximal inspiratory pressures and flows developed with either inspiratory efforts or phrenic nerve stimulation have provided the framework upon which diaphragmatic performance has been assessed in both ICU and non-ICU settings. However, methods used to assess maximal transdiaphragmatic pressure are relatively invasive and not practical for widespread clinical use (2).

To make diaphragm evaluation more assessable to the clinician, there is a growing interest in applying cardiac ultrasound methods to the diaphragm. Over the past four decades, M-mode (time based) and B-mode (2 dimensional) ultrasound have been used to image the diaphragm dome and the diaphragm muscle in the zone of apposition (ZOA) of the diaphragm to the rib cage. Ultrasound measures of the diaphragm dome evaluate its caudal motion, whereas ultrasound measures of the diaphragm in the ZOA allow the clinician to directly assess diaphragm musculature. The following two factors should be considered when assessing motion of the diaphragm dome: first, the visualized image is the intensely echogenic lung–diaphragm interface and not the diaphragm muscle itself, and second, as much as 35% of the diaphragm dome may be central tendon (3). Despite these considerations, several studies have documented that caudal dome motion of more than 1–1.7 cm reasonably predicts extubation success in mechanically ventilated patients (4–6). The velocity of the dome has also been measured using traditional M-mode ultrasonography but did not discriminate between those who could and could not be weaned (6).

Additional information regarding diaphragm function can be derived from visualizing the diaphragm muscle itself in the ZOA. When the diaphragm contracts, it shortens and thickens. Precontraction diaphragm thickness reflects its strength (7). The degree of diaphragm thickening (thickening fraction) is related to the volume inhaled (8). It has been used to identify diaphragm dysfunction in ICU settings (9) and to predict extubation success or failure (10, 11). A thickening fraction >20–30% suggests extubation success, and its measurement has been useful in shortening the time to extubation (12). However, one series found that the diaphragm thickening fraction was not helpful in predicting extubation outcomes (13).

Tissue Doppler Imaging (TDI) is a newer ultrasound technique introduced more than two decades ago to evaluate cardiac function. Unlike the traditional Doppler technique, which assesses high-frequency low-amplitude blood velocities, TDI uses a low-pass filter to characterize low-velocity high-amplitude signals arising from myocardial tissue. For the heart, TDI mainly interrogates tissue velocities in the longitudinal direction, where the apex of the heart is considered immobile and the base of the heart moves toward the apex (transducer) in systole and away from the apex in diastole (14). Two factors that may lead to erroneous results with cardiac TDI are an insonation angle that is not parallel or within 15° of the structure being interrogated and translational motion errors related to movement of the interrogated region of interest (ROI) into and out of the Doppler beam (15). Despite these limitations, cardiac TDI can provide a wealth of information about regional and global myocardial systolic and diastolic function.

In this issue of the *Journal*, Soilemezi and colleagues (pp. 1005–1012) applied cardiac TDI methods to study the diaphragm (16). They identified a ROI of the posterior third of the diaphragm dome and measured how quickly this ROI moved toward (inspiration) and away from (expiration) the ultrasound transducer. Despite an overlap in values for inspiratory velocity, patients who failed weaning trials had significantly higher peak dome velocities and higher dome maximal relaxation rates than patients who weaned from the ventilator. In the small group of patients in whom transdiaphragmatic pressure (Pdi) was measured, the peak Pdi, the diaphragmatic pressure–time index, and the maximal relaxation rates of Pdi were also higher in the patients who failed weaning (16).

Unlike cardiac TDI, in which contraction of the heart is usually not influenced by surrounding structures, motion of the diaphragm dome can be influenced by factors such as compliance of the rib cage and abdomen as well as by the impedance of neighboring structures such as the liver or by the presence of pleural adhesions. Other methodologic factors that can affect diaphragm TDI are the same as those that can lead to erroneous cardiac TDI measurements. These include translation of the ROI into and out of the Doppler beam and assuring that the Doppler beam is parallel to the structure being evaluated. Cardiac TDI implements algorithms and other means to mitigate these errors. Similar processes need to be considered when applying TDI to the diaphragm.

The study by Soilemezi and colleagues reemphasizes the relationship between velocity of muscle contraction and muscle endurance (16). Diaphragm performance can be interpreted in the construct of its Pdi–inspiratory flow (VI) relationship, analogous to the force–velocity relationship of a contracting muscle (1). At a given lung volume (diaphragm length), Pdi and VI are negatively related. There is a similar trade-off between Pdi and VI for a given level of $\dot{V}O_2$ (17). Because high contraction velocities can lead to fatigue, it is not surprising that Soilemezi and colleagues found that subjects who failed weaning had higher velocities of dome motion (16).

Soilemezi and colleagues have provided an important first step for implementing TDI to assess diaphragm function (16). However, more questions need to be addressed before TDI can be established as a valuable tool for the intensivist. Does the interrogated ROI of the dome truly capture diaphragmatic muscle contraction velocity? To what extent is motion of a small ROI influenced by other factors such as translational motion of the diaphragm or tethering to the rib

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cage or by pleural adhesions? Does contraction of the inspiratory rib cage muscles (load sharing) or contraction of abdominal muscles (i.e., respiratory alternans) influence caudal diaphragm dome velocity? Other questions are sure to arise as this new method for evaluating diaphragm function evolves over the next decade. ■

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The ABCs of Granulomatous Lung Diseases: Age-associated B Cells

At the mention of B cells, your likely first thought is the production of antibodies, mostly beneficially directed against microbial threats but also potentially pathogenic, as when allergy is triggered in a susceptible host by excessive antigenic exposure or when inappropriate self-sensitization leads to autoimmunity (1). Immunoexclusion by secretory IgA is essential to prevent bacterial damage to the lower airways (2, 3), and IgG indispensably protects against respiratory viruses (4), a current worldwide concern. However, independently from immunoglobulin production, B cells also play important roles as antigen-presenting cells (5) and as regulatory cells akin to regulatory T cells (6). Hence, defining mechanistically what B cells are doing in specific lung diseases is a crucial investigative area.

Lying beneath the broad umbrella of possible B-cell functions in lung diseases are a lot of things, not all good. In asthma, their roles range from propagating T-helper cell–mediated responses to antigens such as house dust mites to IgE elaboration by specific memory B cells (7). As chronic obstructive pulmonary disease severity mounts, there are progressive increases in the numbers and size of B-cell–rich lung lymphoid follicles (8–10) and in concentrations of autoantibodies in blood and lung samples, especially in the emphysematous phenotype (11). Less is known about B-cell immune

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