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Diaphragmatic ultrasound: a review of its methodological aspects and clinical uses

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A BRIEF REVIEW OF METHODS OTHER THAN ULTRASOUND USED IN ORDER TO EVALUATE THE DIAPHRAGM

Fluoroscopy

Although fluoroscopy is widely available, simple to perform, and easy to interpret, it has proven to be inaccurate in some situations.[1] Investigators have reported false-positive results of fluoroscopy during the sniff maneuver test in approximately 6% of patients with bilateral diaphragmatic dysfunction (DD).[1] False-negative results can also occur when, at the onset of inspiration, abrupt diaphragmatic caudal motion occurs due to the active contraction of the abdominal muscles during the previous expiration (that brought lung volume down to the functional residual capacity), followed by abrupt relaxation of the abdominal muscles.[1] In addition, fluoroscopy has certain limitations[2]: it requires patients to breathe spontaneously, it involves significant radiation exposure, and it requires transportation of the patient to the fluoroscopy unit.

Figure S1. Measuring the excursion of right hemidiaphragm using the posterior subcostal view with the convex transducer placed posteriorly at the midscapular line.

Pulmonary function testing

Pulmonary function testing (PFT) may be helpful to diagnose DD because it is inexpensive, largely available, and noninvasive, as well as having well-known reference values. A 10-30% decrease in the lung vital capacity from the upright to the supine position is suggestive of unilateral DD, whereas a reduction greater than 30% is suggestive of bilateral DD.[3] One important limitation of PFT is that some individuals are intolerant of the supine position. Other limitations are the wide range of normal values, the volitional nature (dependence on patient effort), and the low sensitivity to detect early involvement of the respiratory muscles.[2]

Evaluation of global respiratory muscle strength

Tests to determine MIP, sniff nasal inspiratory pressure (SNIP), and MEP are simple, noninvasive, and widely used methods of investigating global respiratory muscle strength. In patients with unilateral diaphragmatic paralysis, MIP and SNIP are usually reduced to approximately 60% of the predicted value, whereas in bilateral diaphragmatic paralysis, a more marked reduction (to less than 30% of the predicted value) may be observed. The MEP is generally preserved if muscle dysfunction spares the abdominal expiratory muscles. Concomitant reductions in MIP (or SNIP) and MEP suggest generalized muscle dysfunction. Limitations include the volitional nature and variability of the tests.[4]

Measurement of transdiaphragmatic pressure

Measurement of transdiaphragmatic pressure (Pdi) is considered the gold standard for the diagnosis of bilateral diaphragmatic dysfunction.[4] During a sniff maneuver or a maximal inspiratory effort, a Pdi value ≥ 80 cmH_2O in men and ≥ 70 cmH_2O in women rules out clinically significant diaphragmatic weakness.[4] In patients unable to perform the maneuvers, magnetic stimulation of the phrenic nerve is a helpful surrogate.[4] The Pdi measurement is limited because it is invasive, uncomfortable, and time-consuming; because it requires technical skills and expensive equipment to yield reliable results; and because it is usually restricted to research laboratories.[4]

CT

Although chest CT can assess the diaphragm thickness and the height of the lungs, it has several limitations: the diaphragm measurement is not standardized[5]; the exposure of patients to radiation; the requirement for the supine position, which many patients with DD cannot tolerate; the high cost; the static measurement without assessment of muscular motion; and the fact that the hemidiaphragms are thin and isodense in relation to the liver and spleen, making them indistinguishable from the adjacent organs.

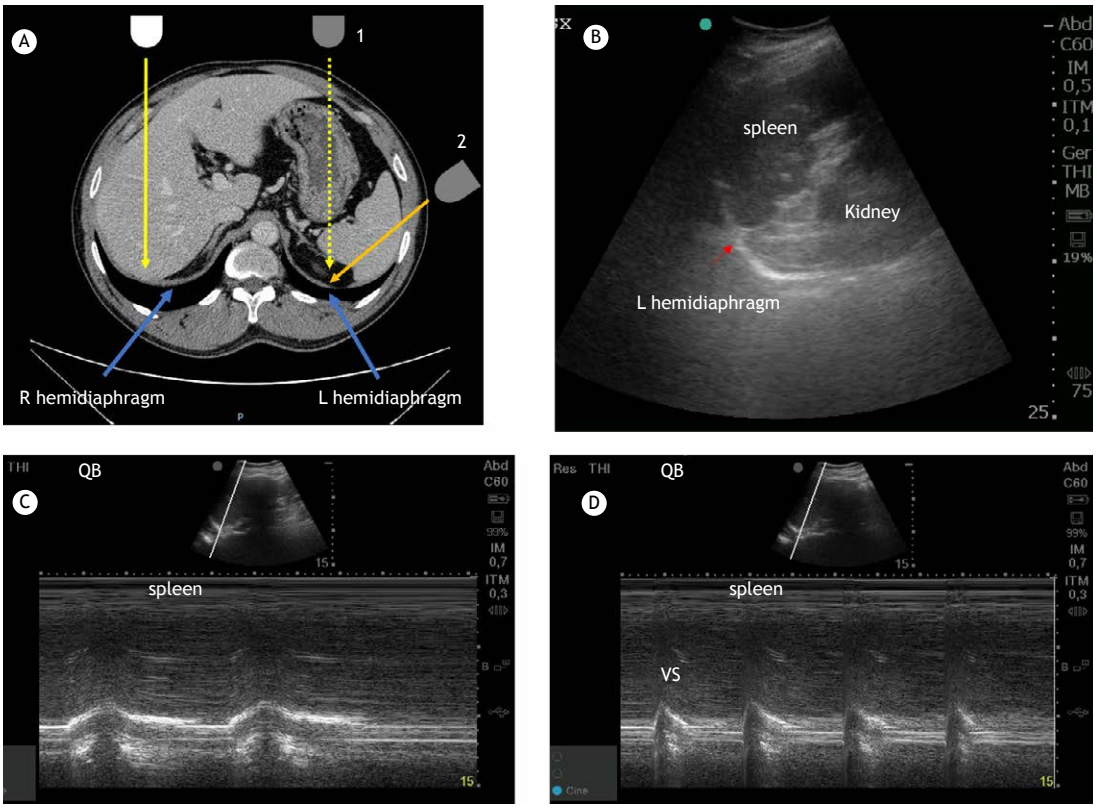

Figure S2. In A, CT appearance of right (R) and left (L) hemidiaphragms. Note that the identification of the left hemidiaphragm is blurred by the stomach because of the placement of the probe over the subcostal area below the midclavicular line.[1] Placing the probe at a lateroposterior point[2] can improve the visualization of diaphragm, as shown in A (point 2) and B (diaphragmatic ultrasound in B mode). C and D show the excursion of the left hemidiaphragm, during quiet breathing (QB) and voluntary sniff (VS), respectively, in M mode.

Video S1. Imaging the diaphragm with ultrasound on B-mode to assess the diaphragm excursion. [Link]

Video S2. Imaging the diaphragm with ultrasound on B-mode to assess the diaphragm thickness and thickening. [Link]

Magnetic resonance imaging

Magnetic resonance imaging has rarely been employed for the evaluation of diaphragmatic function, because it has some of the same limitations as CT (no standardization; the requirement for the supine position; high cost, and static measurement).[6]

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