Thoracic Diaphragm Limited

I. Patient Preparation

a. None

II. Equipment

a. Performed with real-time scanner using a linear transducer with frequencies ranging from 8 MHz to 12 MHz, higher frequencies often necessary for thin patient's, children and infants.

III. Procedure Protocol

a. Transducer placed over the lower rib cage between the seventh and ninth intercostal spaces in the midaxillary line. A linear array transducer allows for more accurate measurement of tdi (thickness of the diaphragm).
b. The diaphragm muscle is displayed as a two-dimensional image cross-sectional view of the structure. The diaphragm muscle in the zone of apposition is represented as a nonechogenic central structure bordered by two echogenic lines, the peritoneal and diaphragmatic pleurae.
c. Patient position must be annotated. Erect, semi-recumbant, supine. Label diaphragm side (left or right). Must image each hemidiaphragm. Three separate measurements of diaphragmatic thickness during maximum inspiration and expiration are obtained for each hemidiaphragm.
d. Caliper placement on the inner to inner edge of the echogenic diaphragmatic pleura and echogenic peritoneal layer.
e. Measurement of the diaphragm thickness obtained at maximum expiration (FRC, functional residual capacity).
f. Measurement of the diaphragm thickness obtained during maximum inspiration (TLC, total lung capacity).
g. Cine clip obtained starting at maximum expiration, and terminating at maximum inspiration.
h. Criteria for diaphragm paralysis, (a) measured thickness of the diaphragm is less than 2 mm and (b) the diaphragm does not thicken during inspiration (less than 20% thickening of diaphragm, number can even be negative percentage)
i. Criteria for diaphragm atrophy, measured thickness of the diaphragm is less than 2 mm

IV. General information

a. Ultrasound can be used to evaluate the diaphragm in the zone of apposition to the rib cage rather than assessing motion of the dome. With this approach, the contraction of the diaphragm muscle itself can be visualized.
b. The zone of apposition is the area of the chest wall where the abdominal contents abut the lower rib cage. On the right side, the diaphragm is sandwiched between the lower rib cage and the liver. This provides an ideal area for visualizing the pleura, diaphragm muscle, and peritoneum.

c. Once visualized, diaphragm thickness (tdi) at end-expiration can be measured along with the change in tdi during inspiration. Changes in tdi during inspiration are proportional to diaphragm shortening in adults and infant, whereas tdi measured at end-expiration is proportional to diaphragm strength.
d. Distinguish between a paralyzed and normally functioning diaphragm. In addition, chronically paralyzed diaphragm would be atrophic and not shorten, therefore it would be thin and not thicken during inspiration.

References:

1. Sarwal A, Walker FO, Cartwright MS. Neuromuscular ultrasound for evaluation of the diaphragm. Muscle Nerve. 2013;47(3):319-329. doi:10.1002/mus.23671
2. Gottesman, E., McCool, FD, Ultrasound evaluation of the paralyzed diaphragm, Am J Respir Crit Care Med. 1997 May; 155(5):1570-4. The thickness of the diaphragm (tdi) was measured to the nearest 0.1 mm at FRC (t(di)FRC) and TLC (t(di)TLC). Diaphragm thickening during inspiration (delta t(di)) was calculated as (t(di)TLC - t(di)FRC)/t(di)FRC. In patients with unilateral paralysis, t(di) and delta t(di) for the paralyzed hemidiaphragm were significantly less than those values for the normally functioning hemidiaphragm (1.7 +/- 0.2 mm versus 2.7 +/- 0.5 mm [mean + SD] $p < 0.01$ for t(di), and -8.5 +/- 13% versus 65 +/- 26% [$p < 0.001$] for delta t(di)). The t(di) and delta t(di) for patients with bilateral diaphragm paralysis were significantly less than those values for the healthy volunteers (1.8 +/- 0.2 versus 2.8 +/- 0.4 and -1 +/- 15% versus 37 +/- 9% for t(di) and delta t(di), respectively) ($p < 0.001$).
3. McCool, FD. Dysfunction of the diaphragm. NEJM. March 2012; 366:932-942.
4. DePalo, V., McCool, FD. Respiratory Evaluation of Patient with Neuromuscular Disease: Specific Assessment of Diaphragm Function. Semin Respir Crit Care Med. 2002; 23(3). With diaphragm paralysis, tdi is less than 2 mm and the diaphragm does not thicken during inspiration.
5. https://www.youtube.com/watch?v=ci4E3ELjnlY
6. http://www.wakehealth.edu/uploadedFiles/User_Content/SchoolOfMedicine/Educational_Programs/Medical_Ultrasound,_Program_for/Handout_Material/NerveMuscle/Sarwal%202013%2004%20Diaphragm%20Muscle%20Ultrasound%20NM%20USG%20course.pdf
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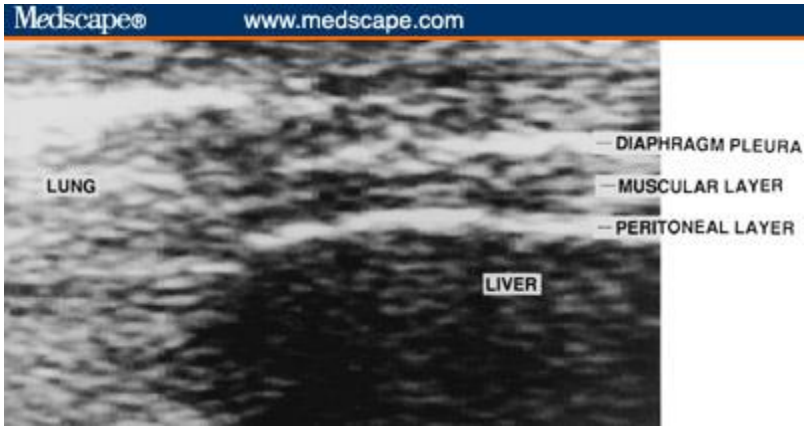
8. http://www.slideshare.net/basselericsoussi/diaphragm-movement-and-contractility-evaluation-by-thoracic-ultrasound-1072198



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