

Ultrasound in the evaluation of diaphragm

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Learning objectives

- Present the anatomy of the diaphragm its main relationships of the adjacent structures and ultrasonographic appearance
- Describe the main points that should be evaluated in diaphragmatic ultrasound and propose a systematic method of evaluation.
- Present some clinical indications.

Background

Several clinical problems may result in abnormalities of diaphragm function or structure. Intrinsic pathology, but also adjacent or systemic processes can affect the diaphragm, causing altered lung aeration.

Imaging methods for evaluating the diaphragm are limited. Fluoroscopy has typically been the most used one. Nevertheless, ultrasound can be a valuable tool for diaphragmatic evaluation in adults.

Findings and procedure details

1. THE DIAPHRAGM

The diaphragm is a dome-shaped powerful respiratory muscle that separates the thoracic and abdominal cavities. It is composed of an anterior, least mobile, central aponeurotic portion and a peripheral, muscular, more mobile zone innervated by the phrenic nerve.

The diaphragmatic position may vary considerably between subjects, being usually higher in children, young adults, and obese individuals. It can also be higher in cases of lower lobes atelectasis, splenomegaly or hepatomegaly.

Several conditions can affect the diaphragm kinetics and thus have a tremendous impact on lung aeration, such as: obesity, trauma, lower lobes atelectasis/inflammatory processes, pleural effusion, ascitis, among others. Conditions that affect: the central nervous system, the phrenic nerve, the motor neuron, the neuromuscular junction or muscular dystrophies can also affect the diaphragm.

1.1. Clinical findings of diaphragmatic dysfunction

Clinical symptoms of dyaphragmatic paralysis include dyspnea, most evident in the supine position, difficulty weaning from oxygen or mechanical ventilation, diaphragm elevation on chest radiographs, unexplained respiratory distress, paradoxical breathing and even recurrent pneumonia or recurrent unilateral lung collapse. Early diagnosis is important and might modify the therapeutic management.

1.2. Diaphragm imaging

Imaging methods for the evaluation of diaphragmatic kinetics are limited. Fluoroscopy has traditionally been the most used one. It provides assessment of diaphragmatic excursion and mediastinal shift. Paralysed or paradoxical moving diaphragm can be found. Nevertheless, the need of patient transportation to an appropriate room, patient collaboration required and the use of ionizing radiation are important downsides. Besides, the diaphragmatic function evaluated relies mainly on the movement of the highest anterior diaphragm, the least mobile one.

Computed tomography can be used to assess diaphragmatic structure but not its movement. Dynamic magnetic resonance imaging can allow quantitative evaluation of excursion, synchronicity and velocity of diaphragm motion, although it is limited by its availability and higher costs.

Ultrasound is used for diaphragmatic evaluation in children with a greater frequency, but can also be a useful tools in adults. Ultrasound is a fast, cheap, easily-available and a bed-side technique that provides real-time image and does not involve ionizing radiation, making it ideal for the assessment of diaphragmatic thickness and excursion with different manouvers. It has been demonstrated to have a low intra and inter-observer variability. Moreover, it allows a better evaluation of the muscular, more mobile, lateral and posterior parts of diaphragm. Non-visualization of left hemi-diaphragm is a common limitation of ultrasound, especially with maximal inspiration and sniffing. Another problem is that the excursion on maximal inspiratory effort and sniffing are dependent on colaboration of the patient, limiting the interpretation of values in heterogenous groups.

2. DIAPHRAGM ULTRASOUND

On ultrasound, the diaphragm is commonly seen as three layer structure, with two outer echogenic layers of pleura and peritoneum lining an inner hypoechoic layer of muscle. Some authors refer the visualization of five layers - two hyperechoic outer layers of pleura and peritoneum and another echogenic irregular layer of connective tissue and vessels within two hypoechoic muscular stripes.

The use of B-Mode allows assessment of diaphragmatic structure and thickness, but also can reveal pathologies that may influence its kinetics, such as pleural or peritoneal effusion. It also allows identification of a good window for the use of the M-mode.

M-mode uses a single beam of a B-mode image and records the successive positions of a structure - the diaphragm - on a time scale, allowing quantifiable assessment of excursion and velocity.

2.1 Technique

The patient should be in supine position, since it provides less overall variability, side-to-side variation, greater reproducibility and greater excursion. The supine position also increases any paradoxical movement while limiting any compensatory active expiration by the anterior abdominal wall that could mask paralysis.

The right diaphragm should be seen through the liver window, while the left diaphragm is usually more difficult to visualize because of the smaller acoustic window created by the spleen. This limitation can be reduced by a more coronal plan, parallel to the ribs. Conditions such as splenomegaly or hepatomegaly with a large left lobe may facilitate left diaphragm assessment.

2.2. Thickness

A high frequency linear (we used a 12 MHz) probe should be used at the anterior axillary line, between the 7th and 9th intercostal space to measure diaphragm thickness. The measurement should be made at the zone of apposition, inferiorly to the costophrenic angle, where the diaphragm contacts the inner aspect of the chest wall (Fig.1).



Fig. 1: Diaphragm thickness (2.51 cm) measured at the end-expiration on the zone of apposition. A linear 12MHz transducer was used with an intercostal approach.

References: - /PT

Thickness measurement should be performed with visualization of both the pleural and peritoneal membranes with an angle of incidence of the ultrasound beam close to 90 degrees. It is important to define the intercostal space where the thickness of the diaphragm is measured as it varies, with the more inferior portions of the diaphragm being thicker than more upper portions. It has been established that 0.2 cm is the cut-off below which diaphragm atrophy is defined.

Thickness alone might misdiagnose a low weight individual with a normal functioning diaphragm. Thickness increase during inspiration has also been used as a measurement of muscle contraction. A paralyzed diaphragm, is thin and does not thicken during. The most used value is the **diaphragm thickness fraction** (DTF), calculated from the

formula: (thickness at end-inspiration - thickness at end-expiration)/thickness at end-expiration x 100. A DTF inferior to 20% is consistent with paralysis.

2.3. Excursion

Diaphragmatic excursion should be measured with a lower frequency curvilinear probe (we used a 4 MHz probe) in anterior subcostal view. The transducer should be placed between the mid-clavicular and anterior axillary lines, directed medially, cranially and dorsally to visualize the posterior third of the right diaphragm, approximately 5 cm lateral to the inferior vena cava foramen.

Measurement should be made in the M-mode, from the point of maximal excursion to the baseline, in normal breathing and sniffing. With deep breathing, measurement should be made from the maximal to the lowest point of excursion (Figs 2 to 5). Normal values with each maneuver are illustrated in Table 1.

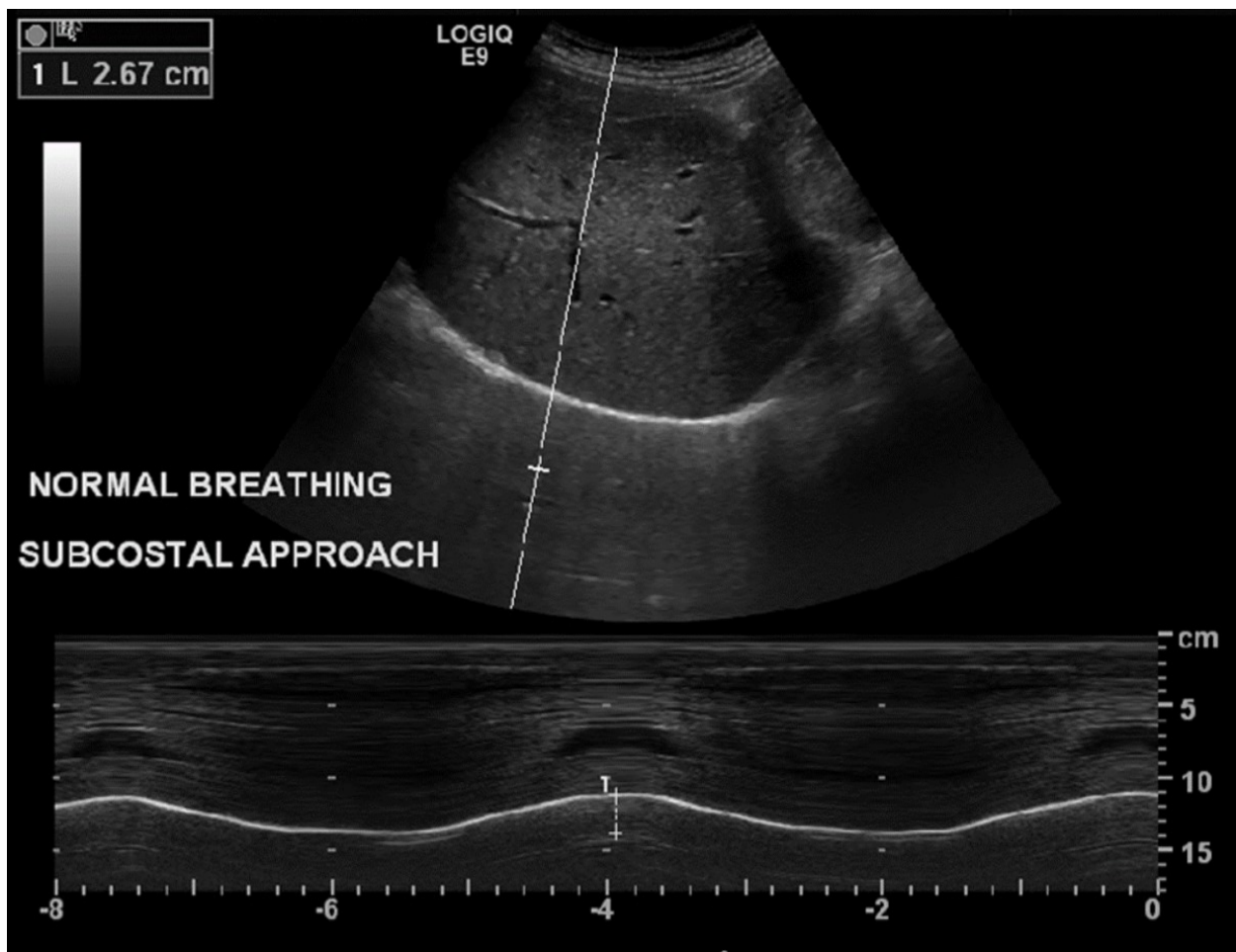


Fig. 2: Diaphragmatic excursion with normal breathing pattern (2.67 cm). A curvilinear 4MHz frequency probe was used with a subcostal approach.

References: - /PT

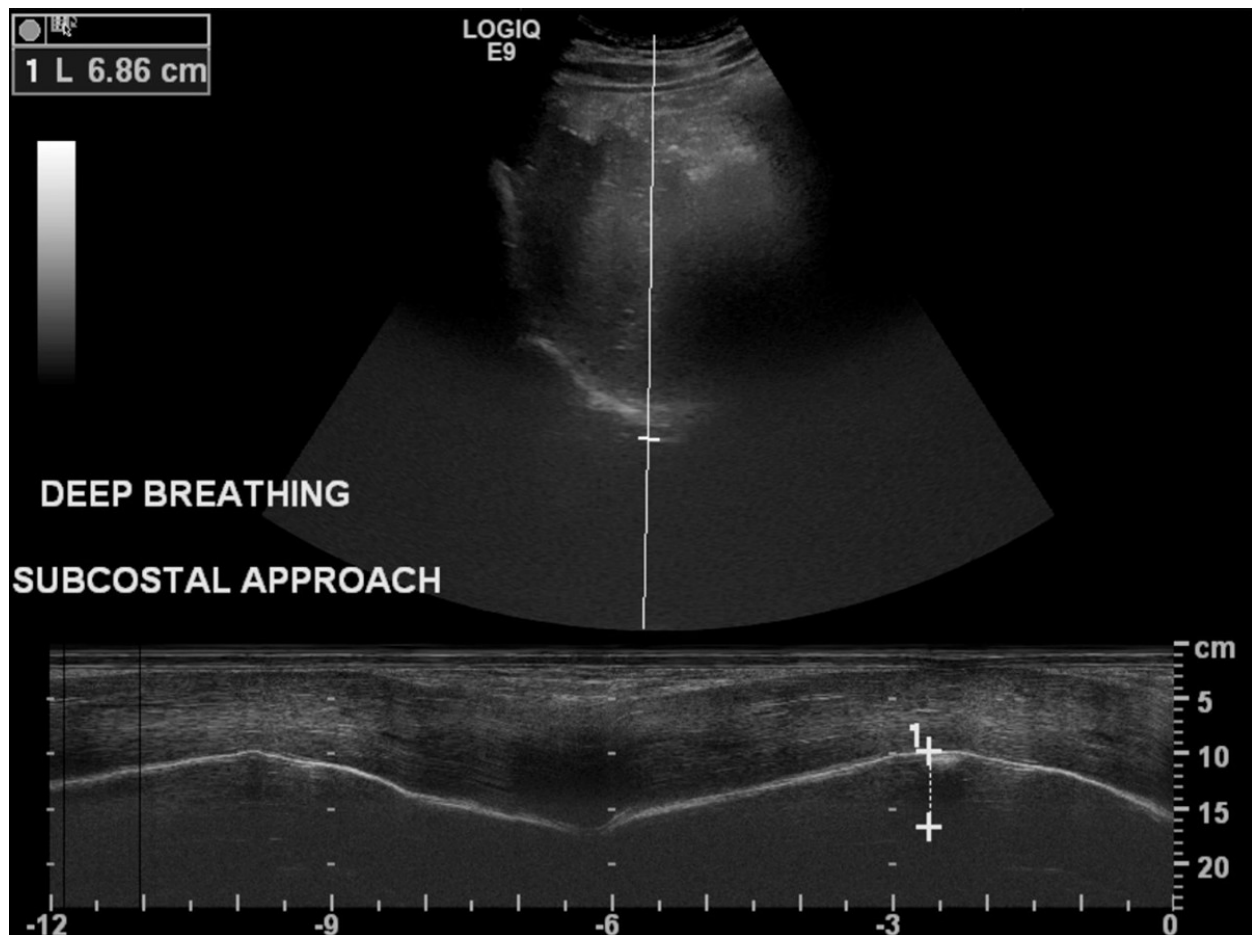


Fig. 3: Diaphragmatic excursion with deep breathing (6.86 cm). A curvilinear 4MHz frequency probe was used with a subcostal approach.

References: - /PT

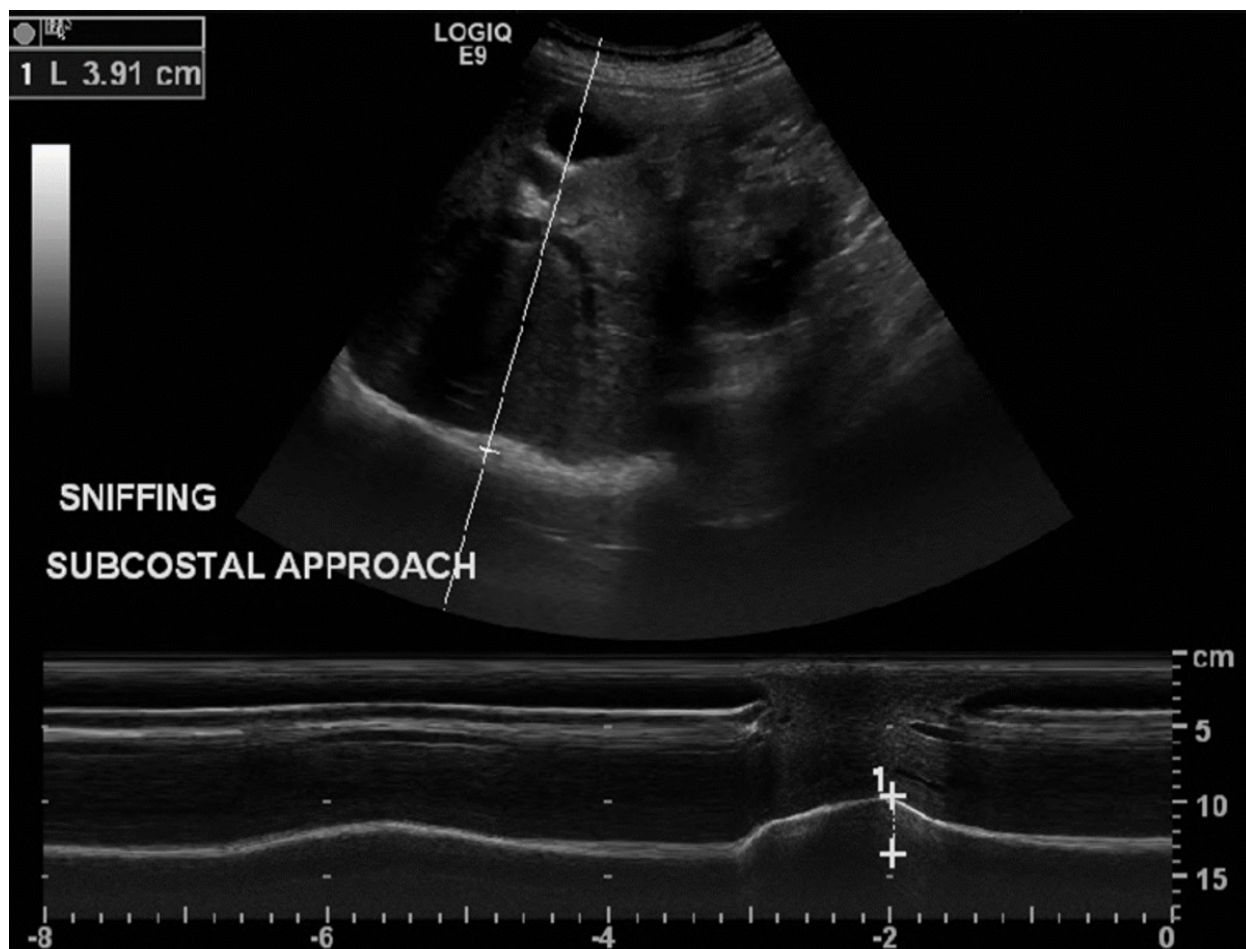


Fig. 4: Diaphragmatic excursion with sniffing (3.91 cm). A curvilinear 4MHz frequency probe was used with a subcostal approach.

References: - /PT

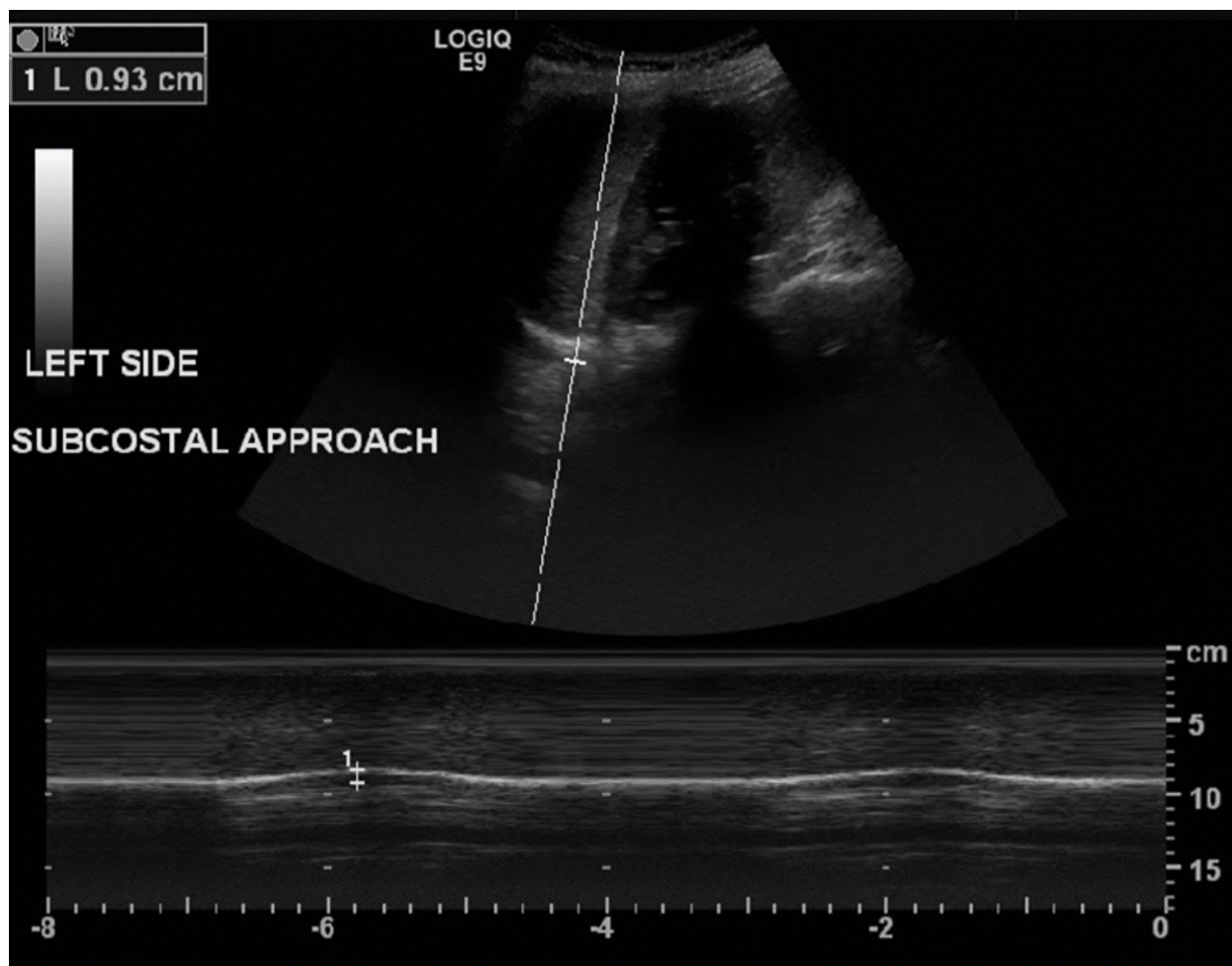


Fig. 5: Left hemi-diaphragmatic excursion with normal breathing pattern (0.93 cm). A curvilinear 4MHz frequency probe was used with a subcostal approach, using the acoustic window created by the spleen.

References: - /PT

	Quiet breathing	Deep breathing	Sniffing
Normal values (cm)	1.5 - 2	6-7	2.5-3
Lower values (cm)	0.9 (women); 1 (men)	3.5 (women); 4.5 (men)	1.6 (women) - 1.8 (men)

Excursion of the diaphragm with maximum inspiration in healthy patients is usually asymmetrical, with greater excursion on the left side. A normal range of side-to-side variability is less than 50%.

3. CLINICAL INDICATIONS

3.1. Diaphragm paralysis

Ultrasound can allow the identification of unilateral or bilateral diaphragm paralysis by demonstrating a diaphragm with decreased thickness that does not thicken during inspiration. With M-mode paralysis it is suggested by the absence of excursion with quiet and deep breathing. Sniffing may show absence of movement or paradoxical motion with the diaphragm moving away from the transducer. Diaphragm weakness is indicated by less than normal amplitude of excursion on deep breathing.

In patients with diaphragm paralysis, an increase in its thickness during inspiration is a good prognostic factor since it has been demonstrated to correlate with improved inspiratory function and increase in vital capacity due to re-inervation.

3.2. Mechanical Ventilation weaning failure

Diaphragm dysfunction is associated with prolonged mechanical ventilation and weaning failure due to decreased muscle strength and decrease in diaphragmatic contractile function within 48 hours of intubation. Ultrasound can be used to predict weaning failure if excursion is inferior to 1.4 cm for the right hemi-diaphragm and 1.2 cm for the left hemi-diaphragm.

3.3. Post-surgical respiratory failure

It is accepted that the pulmonary function might be decreased after thoracic or abdominal surgeries, correlating with complications such as Pneumonia or Atelectasis. Diaphragmatic position and function have been shown to be altered after cholecystectomy. Inspiratory muscle training can be used to improve its function.

Images for this section:



Fig. 1: Diaphragm thickness (2.51 cm) measured at the end-expiration on the zone of apposition. A linear 12MHz transducer was used with an intercostal approach.

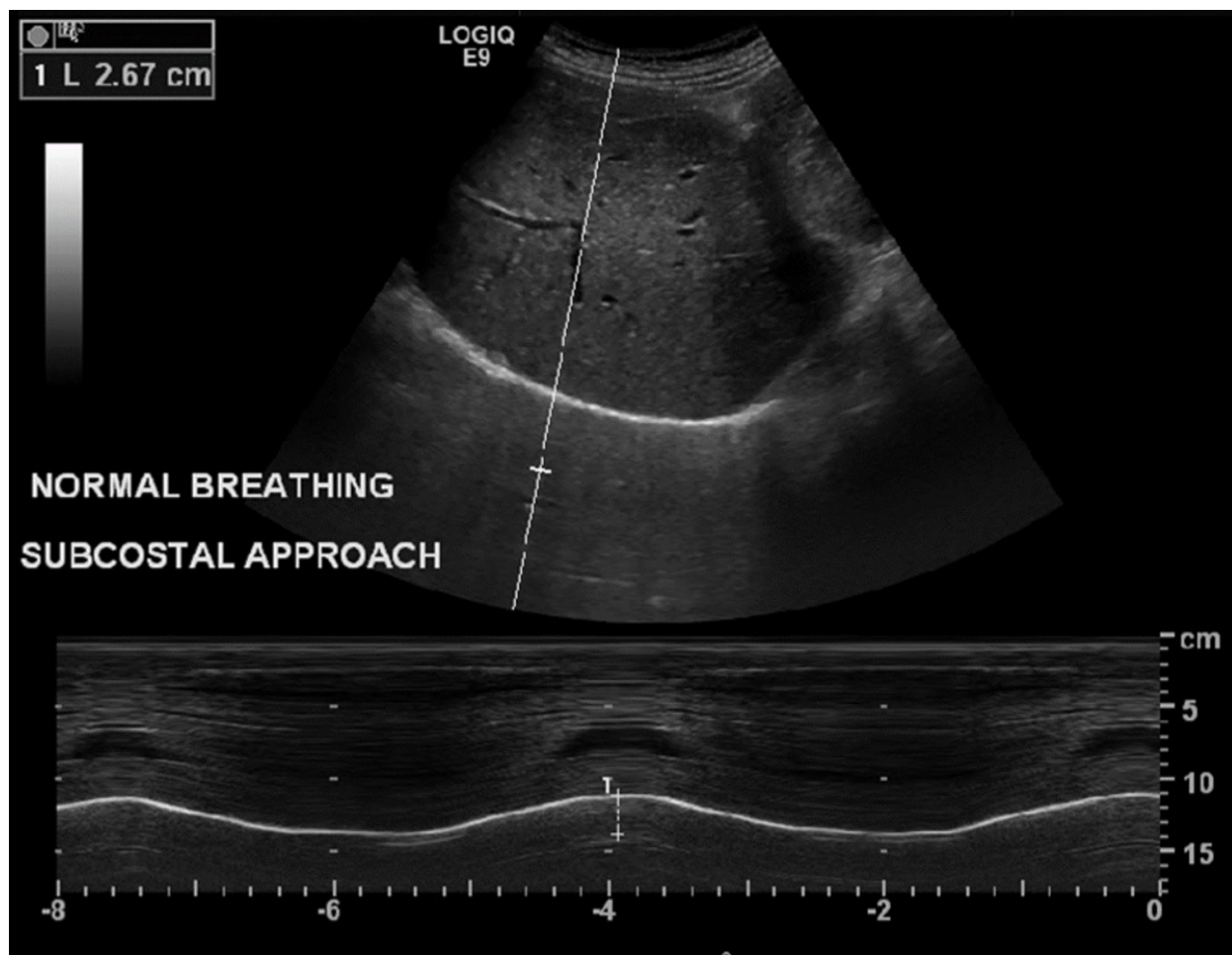


Fig. 2: Diaphragmatic excursion with normal breathing pattern (2.67 cm). A curvilinear 4MHz frequency probe was used with a subcostal approach.

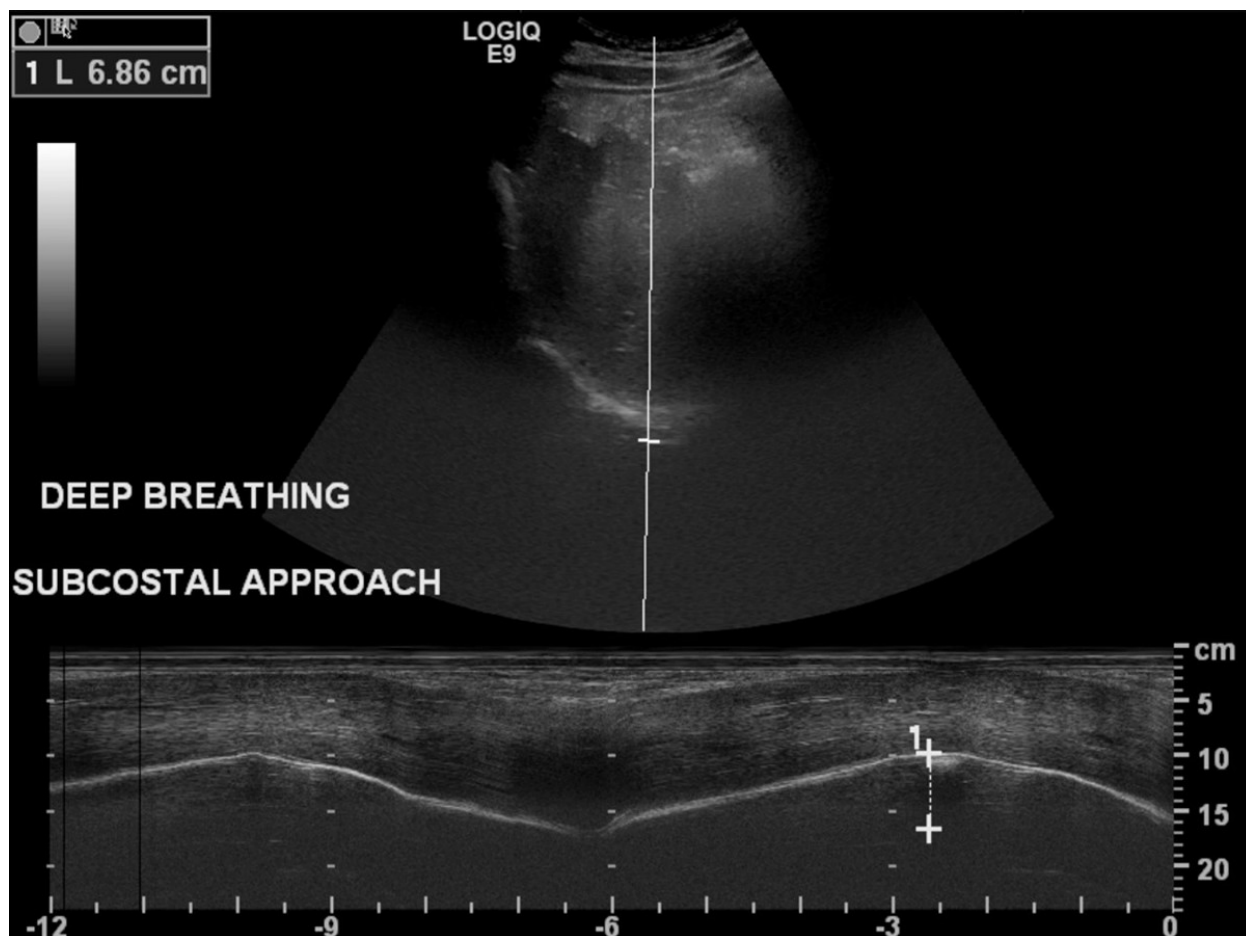


Fig. 3: Diaphragmatic excursion with deep breathing (6.86 cm). A curvilinear 4MHz frequency probe was used with a subcostal approach.

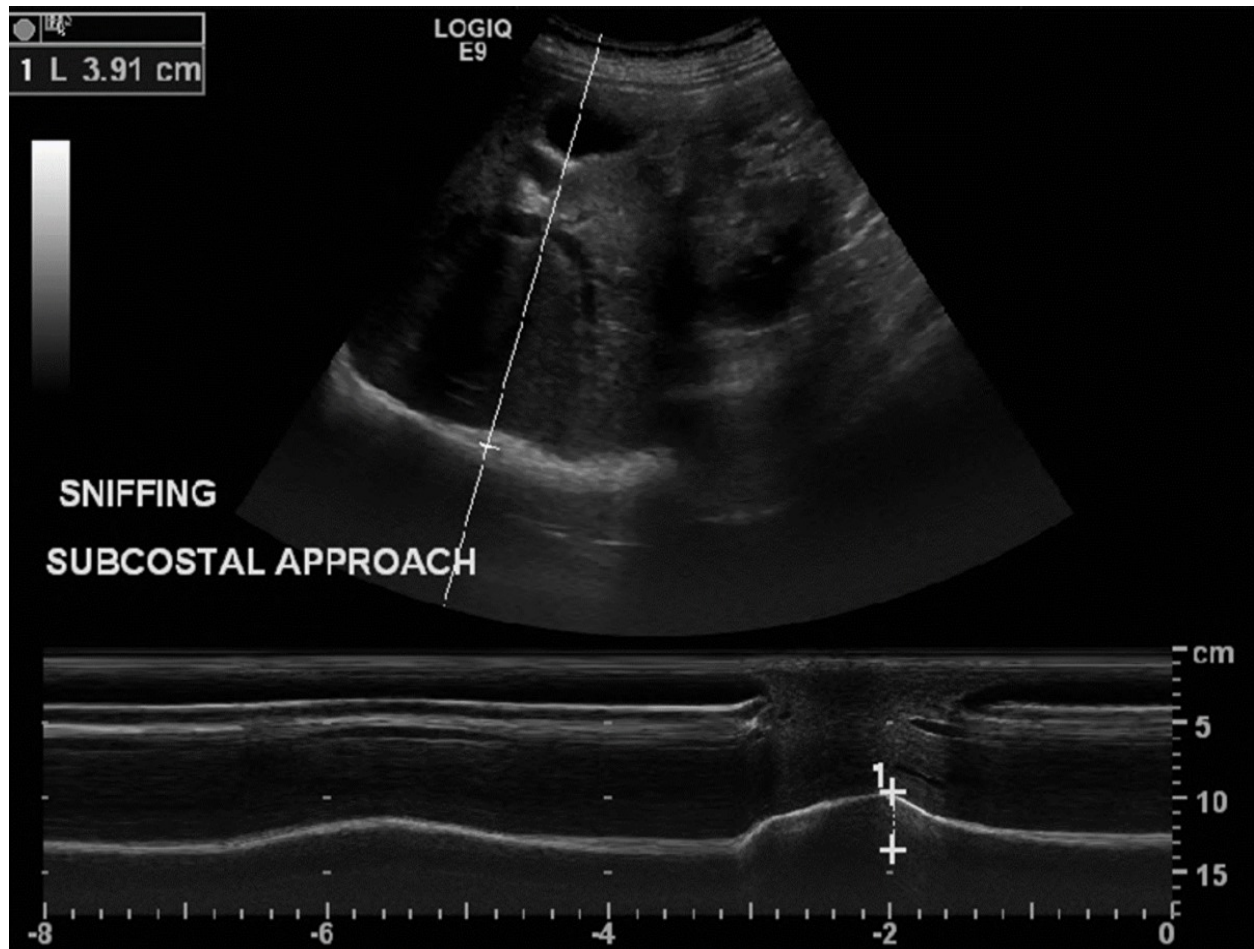


Fig. 4: Diaphragmatic excursion with sniffing (3.91 cm). A curvilinear 4MHz frequency probe was used with a subcostal approach.

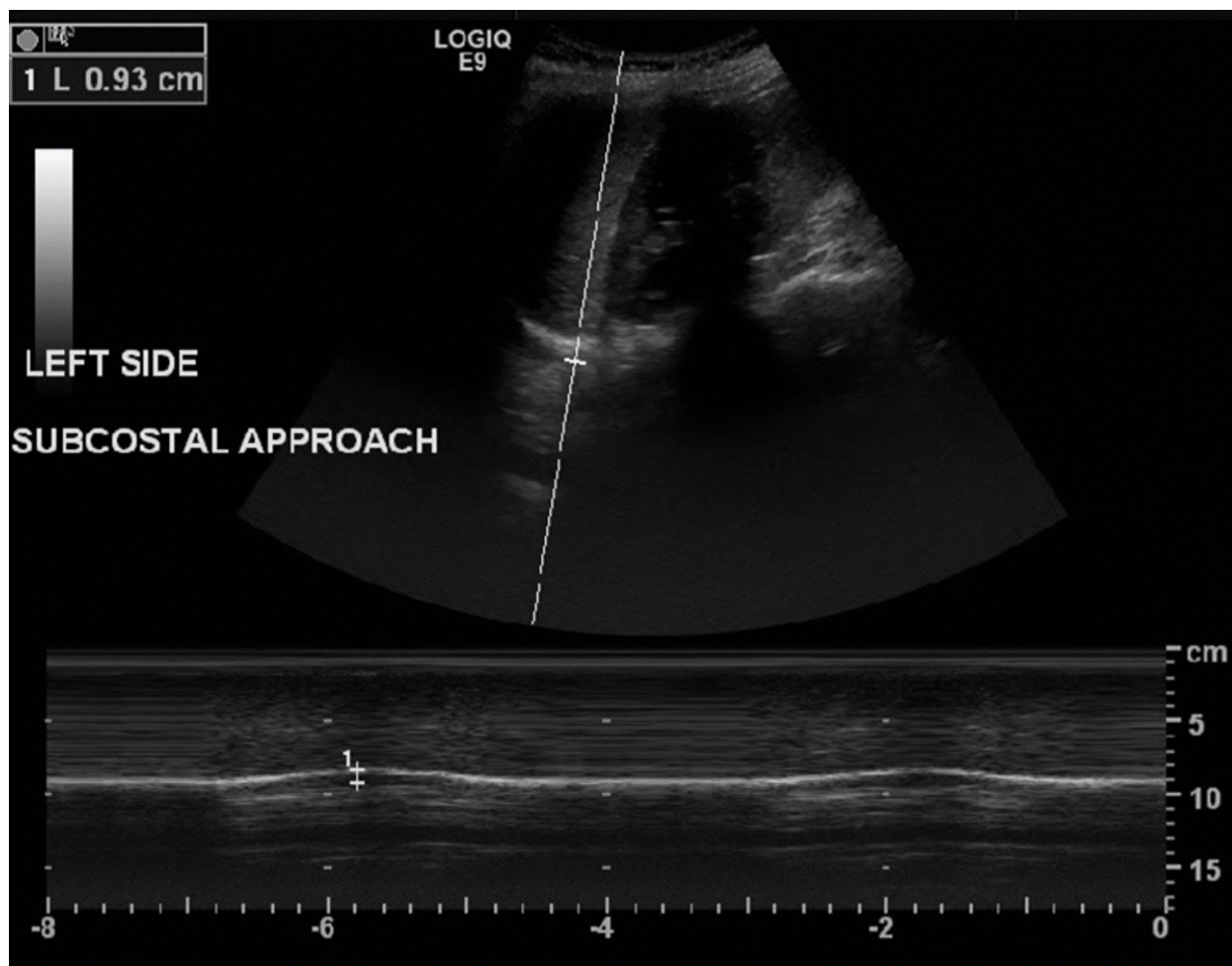


Fig. 5: Left hemi-diaphragmatic excursion with normal breathing pattern (0.93 cm). A curvilinear 4MHz frequency probe was used with a subcostal approach, using the acoustic window created by the spleen.

Conclusion

We believe that diaphragm ultrasound is inexpensive, widely available and a promising technique that should replace fluoroscopy. Diaphragm thickness, diaphragm thickness fraction and excursion in quiet breathing, deep breathing and sniffing should be measured in both hemi-diaphragms.

Personal information

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