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● *Original Contribution*

ULTRASOUND M-MODE ASSESSMENT OF DIAPHRAGMATIC KINETICS BY ANTERIOR TRANSVERSE SCANNING IN HEALTHY SUBJECTS

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Abstract—The purpose of this study was to set an effective standardized method to assess diaphragmatic kinetics by ultrasound. Forty healthy volunteers were submitted to a B- and M-mode ultrasound study using a convex transducer positioned in the subcostal anterior area for transverse scanning. Ultrasound examination was completed in 38/40 cases (95%), spending on average <10 min for examination. The resting and forced diaphragmatic excursions were 18.4 ± 7.6 and 78.8 ± 13.3 mm, respectively, unrelated to demographic or anthropometric parameters: intraobserver variability on three successive measurements resulted in 6.0% and in 3.9%, respectively. An inexperienced sonographer completed the ultrasound examination in 37/40 cases, spending on average >15 min, with significant, although marginal, interobserver variability (31.9% and 14.7% for resting and forced diaphragmatic excursion, respectively). Bedside ultrasonography by an anterior subcostal transverse scanning on semi-recumbent patient proves to be a safe, feasible, reliable, fast, relatively easy and reproducible way to assess diaphragm movement. (E-mail: americotesta@gmail.com) © 2011 World Federation for Ultrasound in Medicine & Biology.

Key Words: **Diaphragmatic kinetics, Diaphragm motion, Right hemidiaphragm, Dyspnea, Clinical ultrasound, M-mode, Emergency ultrasound, Bedside ultrasound, Pulmonary function.**

INTRODUCTION AND LITERATURE

The diaphragm is the major respiratory muscle, contributing to 75% of resting lung ventilation, with an excursion of 1–2 cm. During forced breathing, its excursion reaches 7–11 cm, variable with individual characteristics and methods (Gierada et al. 1995; Wade 1954; Yamaguti et al. 2007). Paralysis and weakness of the diaphragm can result from abnormalities at any site along its neuromuscular axis, although it most frequently arises from phrenic nerve pathologies or from myopathies affecting the diaphragm itself. Bilateral diaphragmatic failure usually causes orthopnea or dyspnea at rest, while unilateral diaphragmatic weakness or paralysis may be asymptomatic (Scillia et al. 2004). Indeed, it may be suspected from the complaint of sleeping hypoventilation, recurrent lung infections, exercise limitation, presence of rapid or shallow breathing, paradoxical inward motion of the abdomen during inspiration on physical examination, restrictive pattern on lung function testing and hemidiaphragm elevation on chest radiograph (Hart et al. 2002; Houston et al. 1995b; Wilcox and Pardy 1989). Therefore, diaphragmatic dysfunction is likely frequently unrecognized because appropriate tests to detect its presence are not performed (Wilcox and Pardy 1989) and the need of its assessment is strong, both in outpatients and inpatients and especially in an emergency setting.

Techniques traditionally employed to diagnose diaphragmatic weakness or paralysis are invasive or associated with radiation and require the patient to be moved (electromyography, fluoroscopy) (Ayoub et al. 1997; McCauley and Labib 1984); or indirect, time-consuming and uncomfortable (transdiaphragmatic pressure measurements, plethysmography) (Lerolle et al. 2009; Scott et al. 2006); or highly complex and expensive (dynamic echo-planar MRI) (Gierada et al. 1995).

The use of B- and M-mode ultrasound (US) to qualitatively evaluate diaphragmatic kinetics was first

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proposed by Haber et al. (1975), with evidence of diaphragm motion involvement in intra-abdominal diseases. Afterwards, Harris et al. (1983) studied ventilatory movement of diaphragmatic right dome on sagittal plane using simultaneous B-mode US by anterior view and spirometry. Houston et al. (1992, 1994, 1995a, 1995b) realized cranio-caudal more accurate measurement of diaphragm excursion by B-mode using a longitudinal anterolateral intercostal approach to correlate diaphragmatic motion to respiratory volumes and Jousela et al. (1992) studied the effect of various tidal volumes on the right hemidiaphragm motion, while other authors proposed subcostal lateral transverse scanning to reach nearly perpendicularly the posterior part of the dome (Ayoub et al. 1997; Targhetta et al. 1995). Finally, Dorffner et al. (1998) validated the role of bedside US in the intensive care unit for the detection of diaphragmatic paralysis (100% sensitivity) and Lerolle et al. (2009) determined a quantitative US technique for diagnosing severe diaphragmatic dysfunction based on transdiaphragmatic pressure measurements as a reference technique.

Apart from the different US approaches, the majority of authors emphasized US value to assess diaphragmatic kinetics. Unfortunately, the various US techniques were poorly detailed or proposing undefined views and the need of more standardized diaphragmatic assessment by US has been recently recognized (Boussuges et al. 2009). The aim of this study was to set an easy, fast, reliable and reproducible method to evaluate diaphragmatic kinetics by B-mode and M-mode US during spontaneous breathing, usable in emergency setting with portable US machines for bedside approach to dyspneic patients. An original right anterior subcostal approach by a transverse scanning is presented. First, providing one placement point of the transducer at the right midclavicular line. Second, showing two-dimensional anatomy of right hemidiaphragm by B-mode, up to achieve the target point (*i.e.*, the dome position). Finally, obtaining a reproducible permanent M-mode trace on which measurements can be performed.

MATERIALS AND METHODS

Subjects, setting and study design

Forty Caucasian healthy volunteers (18 male and 22 female) without specific sporting training were studied from December 1, 2008 to February 28, 2009 in the emergency department (ED). None of them had history of diseases affecting respiratory function, or consumed drugs daily, or were smokers; pregnancy was investigated in all female volunteers, those who were pregnant were excluded. No fasting or any preparation was required. After having given their informed consent, all subjects underwent a medical history interview, physical examination, pulmonary function tests by standard spirometry and right hemidiaphragmatic kinetics measurements by US during resting and forced breathing. The study was performed after the approval of the ethics committee of the hospital (protocol n° 767/2008).

Personal data and spirometric tests

Sex, age, weight, height, body mass index (BMI) and body surface area (BSA) were recorded. On the same day of ultrasonography, standard spirometry was performed by an independent operator (S.B.) using a Cosmed Pony graphic (Rome, Italy) according to the international guidelines (Miller et al. 2005). Based on the air flow and volume curves collected to assess individual respiratory performance, forced vital capacity (FVC) and forced expiratory volume in 1 s (FEV_1) were interpreted according to previous studies (Knudson et al. 1983).

Ultrasonographic technique

A Hitachi H21 (Tokyo, Japan) US machine was used, setting up depth 210 mm, appropriate total gain, slowest sweep speed (10 s per screen) and equipped with a 4 MHz convex transducer. Before each examination, all subjects were asked to lie in semirecumbent position (bed slope of 45°) and to rest and breathe quietly with their eyes closed. Then, every subject was instructed to inhale and soon after exhale as quickly and as deeply as possible on demand, approximating over the range of the inspiratory capacity, the manoeuvres being repeated several times. An anterior approach was carried out applying freehand transducer on abdomen at the right midclavicular line immediately below the costal margin with firm pressure, steering in cranial direction (Fig. 1).

A B-mode transverse scanning was performed looking across the liver for inferior vena cava (IVC) on the right of the screen and gallbladder in the middle. In this view, the right hemidiaphragm (actually, the large interface between the air-inflated lung and liver parenchyma, acting as a specular reflector) appeared as a thick hyperechogenic curved line. Therefore, the dome position (the highest diaphragmatic point) could be searched as the maximal distance from the top of the screen along a craniocaudal direction (Fig. 2). In this position, US beam intercepts the diaphragm ranging from the dome position to a posterior point located halfway between the former position and the costophrenic angle (Fig. 3). Indeed, this midposterior diaphragm portion produces the greatest craniocaudal excursion during spontaneous breathing, as previously measured by US (Harris et al. 1983; Jousela et al. 1992) and by magnetic resonance (MR) imaging in healthy subjects (Gierada et al. 1995). The transducer was firmly held in this position during all phases of the respiratory cycle.