Evaluation of Thickness of Normal Diaphragm by B Mode Ultrasound

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ABSTRACT

Introduction: Measurement of normal diaphragm thickness by B mode ultrasound is very usefull in clinical practice for evaluation of various diaphragmatic pathologies. Study aimed to evaluate the thickness of diaphragm on B mode ultrasound and to measure Diaphragmatic thickness Fraction. (DTF) in healthy volunteers.

Material and methods: 200 normal subjects were included in a cross sectional study to measure diaphragm thickness and DTF using high frequency linear probe of 12 MHz. Diaphragm thickness at the end of inspiration (TI) and expiration (TE) were measured. DTF was calculated by TI-TE/TE x 100 and results were stratified for age and gender.

Results: Of the 200 healthy subjects recruited, ranging in the age groups from 8 to 85 years, mean age for men were (mean +/- SD) 44.8+/-26.9 and for women were (mean +/- SD) 43.8 +/- 25.7. For the age group as a whole the difference between TI and TE was significant (*P*<.0001) with diaphragm thickness lesser in younger and older age groups compared to middle age groups in both sexes.

Conclusion: Diaphragm thickness measurement and DTF are very usefull for diaphragm evaluation in clinical practice. Normal values should be known to assess various diaphragmatic pathologies.

Keywords: Diaphragm, Diaphragmatic thickness Faction, Inspiration.

INTRODUCTION

Diaphragm is a very important muscle for respiration requiring both for inspiration in the form of contraction of muscles and expiration by relaxation. First measurement of diaphragm thickness on ultrasound was done by Wait in the year 1989 to find the correlation between thickness and lung volumes.[1] Despite its importance, the diaphragm is often underappreciated and incompletely evaluated by clinicians and radiologists. Average thickness of the diaphragm in healthy volunteers is between 0.22–0.28 cm. Thickness of <0.2 cm, measured at the end of expiration, has been defined as a cutoff for diaphragm atrophy.[2] B-mode ultrasound is very usefull non invasive imaging modality to measure the thickness of diaphragm muscle over a wide range of lung volumes.[3] Ultrasound measures accurately the thickness with high reproducibility and DTF acts as a surrogate marker for diaphragmatic muscle strength.[4] The aim of this study was to establish a range of normal values of diaphragm thickness during normal respiration and to introduce this imaging technique as a diagnostic and educational tool in clinical practice.

MATERIAL AND METHODS

200 healthy subjects, selected randomly, from all age groups were included in a cross sectional study for a period of 2 months for measurement of normal diaphragm thickness. Study was done in department of radiology, JSS hospital Mysore after taking informed consent from the subjects.

Inclusion criteria: Healthy subjects of all age groups.

Exclusion criteria: Subjects with abnormal diaphragmatic dysfunction or pathologies.

Measurement of diaphragm thickness by B mode Ultrasound

High frequency linear probe with frequency 7-12 MHz was used to measure diaphragm thickness at the zone of apposition. Supine position was preferred as it was comfortable to patient, shows less variability, minimal side to side variation and allows greater excursion of diaphragm. Right dome was used to measure the thickness, as in the literature it is shown that there is no much difference from left dome thickness. Probe was placed at the anterior axillary line in longitudinal plane, between 7th and 9th intercostal space to measure diaphragm thickness. Liver window was used to visualize diaphragm. Right dome thickness was measured as there is no significant difference in thickness from left side. Visualization of Both pleural and peritoneal membranes are visualized by angling ultrasound beam close to 90 degrees. On B mode diaphragm appears as a thick echogenic linear structure between highly reflective pleural and peritoneal membranes. Thickness **was** measured by placing calipers on reflective lines at the end of inspiration and expiration (Figure-1). DTF was calculated by TI- TE / TE x 100.

STATISTICAL ANALYSIS

Done with SSPS software. Descriptive variables like frequency, percent, mean and standard deviation were applied to interpret the results.

RESULTS

Of the 200 healthy subjects recruited, ranging in the age groups from 8 to 85 years, mean age for men were (mean +/- SD) 44.8+/-26.9 and for women were (mean +/- SD) 43.8 +/-25.7. Diaphragm thickness measured at normal inspiration and expiration are shown in the Table-1 and Table-2 along and Mean DTF value in Figure-2. Diaphragm thickness ranged from 1.65 mm to 3.70 mm for inspiration and from 1.20 to 2.79 mm for expiration with mean thickness higher for males compared to females. For DTF mean value ranged from 24.5 to 53.2, with

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Age years		N =200	Mean	Standard Deviation
Thickness of diaphragm at Inspiration (TI)	< 10	24	1.8846	.23476
	11-20	24	2.7200	.43215
	21-30	22	2.6127	.36339
	31-40	21	2.7210	.49735
	41-50	29	2.6203	.60295
	51-60	22	2.9691	.55529
	61-70	14	3.0886	.62056
	71-80	20	2.5585	.86745
	> 80	24	2.6179	.71476
	Total	200	2.6184	.63506

Table-1: Thickness of diaphragm at Inspiration in various age groups.

Age in years		N=200	Mean	Standard Deviation
Thickness of diaphragm at Expiration (TE)	< 10	24	1.4091	.20113
	11-20	24	2.0029	.40407
	21-30	22	1.8986	.31142
	31-40	21	1.9524	.38888
	41-50	29	1.7707	.45987
	51-60	22	2.1264	.46291
	61-70	14	2.2807	.59650
	71-80	20	1.8595	.72160
	> 80	24	1.9429	.61575
	Total	200	1.8927	.51710

Table-2: Thickness of diaphragm at Expiration in various age groups

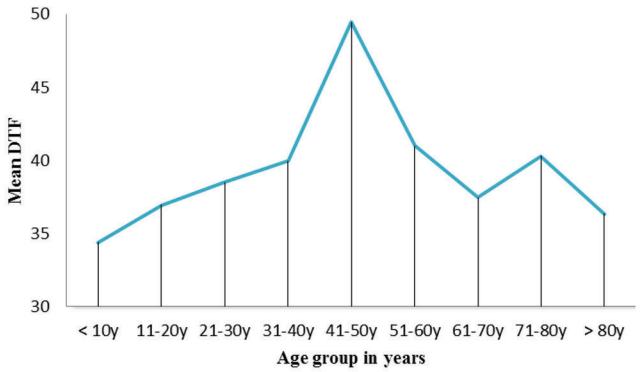

Figure-1: Measurement of normal Diaphragm thickness by B mode ultrasound

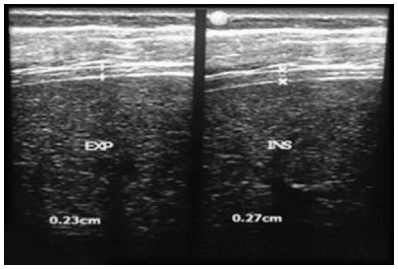

Figure-2: Mean values of DTF among various age groups.

mean values slightly higher for females compared to males. Diaphragm thickness was lesser in younger and older age groups compared to middle age groups in both sexes. Maximum thickness was seen between 51 to 70 years of age groups during both inspiration and expiration. DTF showed a higher mean value among 40 to 60 years age groups. For the group as a whole the difference between TI and TE was significant (P<.0001). There was no significant difference in thickness of diaphragm at end inspiration or expiration between 11 to 50 years of age and higher at 60 to 70 years of age and again decreasing beyond 70 years. Mean DTF was maximum at 41 to 50 years of age and lower values from 11 to 40 years.

DISCUSSION

Diaphragm is a primary muscle for ventilation and develops from components of septum transversum, pleuroperitoneal membrane, medial dorsal portion of primary esophageal mesentery and marginal in growth of the body wall between 4-12 week of embryogenesis.[5] Motor nerve supply to diaphragm is from phrenic nerve and sensory from both phrenic and lower intercostals nerves. Diaphragm is a principle muscle of respiration and its contraction along with accessory muscles causes increase in intrathroacic pressure for inhalation of air and relaxation causes expiration of air along with respiration diaphragmatic contraction also increases intraabdominal pressure that aid for urination, defecation, prevention of reflux. Diaphragm thickness can be measured by both invasive and noninvasive methods. Invasive method includes direct placement of probe for diaphragmatic contraction measurement by stimulating phrenic nerve and electromyography. Non invasive methods include Radiograph, Fluoroscopy Ultrasound, Computerized Tomography (CT)and Magnetic Resonance Imaging (MRI). Radiographs, Fluoroscopy and CT are associated with radiation exposure and are contraindicated in pregnant subjects. Dynamic MRI and invasive methods are complex in nature and require skilled operator.[6]

Diaphragm thickness can be measured by both B-mode and M mode ultrasound. Although M mode can be used to measure thickness, had limitations of representing precise anatomy of diaphragm B mode ultrasound provides good anatomical definition of the muscle and with its adjacent structures to measure thickness both at inspiration and expiration in comparison with M-mode.[7] B mode Ultrasound is a fast, cheap, easily-available

and real-time imaging technique that does not involve ionizing radiation, low inter and intra observer variability compared to other modalities.[8] Repeatability between Intraobserver and inter observer are were above 0.97.[9] Diaphragmatic US has the benefit of portability and is often considered the preferred examination in children and young adults owing to the absence of ionizing radiation. Diaphragm thickness is measured by High frequency probe placed at chest wall between 7 to 9 th ribs at Zone of apposition, where the abdominal contents touches the lower ribs. In this area diaphragm appears as a three layered structure with central non echogenic muscle and two echogenic layers, diaphragmatic pleura and peritoneum.[10] Few limitations being poor acoustic window in 2 to 10% of patients and ultrasound beam should be as much as possible perpendicular to diaphragm.

Change in diaphragm thickness of 28–96% is seen in healthy volunteers, with a change of 35 % to 5% in those with a paralyzed diaphragm Absence of change in thickness of diaphragm is more sensitive and specific in the diagnosis of diaphragm paralysis than measurement of thickness alone.[11] DTF has been a more sensitive measurement than thickness alone because, measurement of thickness alone can miss an acutely paralyzed diaphragm with normal diaphragm thickness and misinterpretation of atrophy in a low weight individuals who has thin and normal diaphragm thickening of less than 20% is proposed to be consistent with paralysis.[12]

Diaphragmatic thickness measurement has many clinical applications in day today practice. Identification of Diaphragm Paralysis is the most important one**.** Direct visualization of the diaphragm and measuring its thickness by B mode ultrasound provides a best method for detection of unilateral or bilateral paralysis in patients with the clinical suspicion of diaphragm dysfunction.[13] In identification of etiology of Diaphragm Paralysis, whether neurological or myogenic is usefull. Neurological causes usually will have normal thickness of muscle where as intrinsic musculogenic cause will have abnormal thickness. Resting diaphragm muscle thickness is increased in Duchene muscular dystrophy below the age of 12 compared to many myopathies where it is decreased.[14] To assess Prognosis in patients with Diaphragm Paralysis, serial ultrasound measurements for Increases in thickness of the diaphragm muscle during inspiration is correlated well with reinnervation, and has been associated with improvement of inspiratory function and increases in vital capacity over time.[15] For Assessment of Weaning Failure in critically ill patients on chronic ventilation ultrasound can be used as a bedside imaging modality by serial measurement of diaphragm thickness and its movement.[16] B mode ultrasound forms a very usefull noninvasive imaging modality for diaphragm thickness assessment which can be applied in various diaphragmatic pathologies.

CONCLUSION

B mode Ultrasound is a simple noninvasive imaging method that can be used for measurement of diaphragmatic thickness. Thickness at inspiration, expiration and DTF are valid parameters and can be used for assessment in various clinical conditions that affect diaphragmatic dysfunction.

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