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Original Research Article

Feasibility and Utility of Ultrasonography in Evaluation of Diaphragmatic Motion and Thickness in Indian Population

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ABSTRACT

Introduction: A properly functioning diaphragm is necessary for lung aeration and survival. Various clinical conditions affect normal motion of the diaphragm. Fluoroscopy used to assess diaphragmatic motion requires ionizing radiation and patient transportation. It would be ideal and cost effective if sonography is used for evaluation of motion of the diaphragm.
Objective: Present study aimed to evaluate feasibility & utility of ultrasonography in evaluation of diaphragmatic motion and diaphragmatic thickness. Material and Methods: Record of 60 healthy, adult men and women were analysed. Participants were examined in supine position. Diaphragmatic movements were measured through anterior sub-costal and sub-xiphoid approach by using M-mode sonography. Diaphragmatic thickness was measured through anterior-axillary sagittal low intercostals approach by using B-mode sonography.
Results: Out of 60 participants, 53%& 47% were women &men respectively. Average age (Mean± SD) was 32.4±10.1 years. BMI and respiratory rate were 15-32 Kg/m^2 and 14-22 respectively. Motion of right & left hemi-diaphragm during quit, deep and Sniff breathing was 1.72±0.32 &1.85±0.45, 4.73±0.54 & 4.97±0.39 and 2.4±0.57& 2.7±0.5cms respectively. Average motion of right& left hemi diaphragm was positively correlated with BMI. Correlation coefficient was 0.08 &0.16 respectively. Average diaphragmatic thickness fraction was 32.6±7.2 percent. Difference in diaphragmatic thicknesses at inspiration & expiration was statistically significant ($P<0.003$).
Discussion: Present study helps in defining diaphragmatic movement and thickness fraction which will be useful in diagnosis and prognostic follow up of diaphragmatic paralysis.
Conclusion: Ultrasonography is useful in evaluating diaphragmatic motion and thickness in Indian population.
Key words: Diaphragm; diaphragmatic motion, Ultrasonography; Feasibility & Utility, Indian population

INTRODUCTION

The diaphragm is a C -shaped structure of muscle and fibrous tissue that separates the thoracic cavity from the abdomen. The dome curves upwards. The superior surface of the dome forms the floor of the thoracic cavity, and the inferior surface the roof of the abdominal cavity. [1-3]

The diaphragm functions in breathing. During inhalation, the diaphragm contracts and moves in the inferior direction, thus enlarging the volume of the thoracic cavity. When the diaphragm relaxes, air is exhaled by elastic recoil of the lung and the tissues lining the thoracic cavity. [4,5]

The diaphragm is also involved in non-respiratory functions, helping to expel vomit, feces, and urine from the body by increasing intra-abdominal pressure, aiding in child birth, and preventing acid reflux by exerting pressure on the esophagus as it passes through the esophageal hiatus. [4-6] Various clinical conditions like basal pulmonary atelectasis, pneumonia, brain infarction or tumor, and trauma to phrenic nerve results in diaphragmatic paralysis. [6] A properly functioning diaphragm is necessary for lung aeration and survival. Structure and functional status of diaphragm has clinical importance. Structure and functional status of diaphragm can be studied by measuring the thickness and movements of diaphragm during the respiration. [6,7] Fluoroscopy is the conventional method to evaluate the movements of diaphragm. However, fluoroscopy requires transportation of patients which is time consuming and often difficult. Also the conventional fluoroscopy exposes the patients to the risk of ionizing radiation. [7] Bedside ultrasonography, which is already crucial in several aspects of critically illness, [8] has been recently proposed as a simple, non-invasive method of quantification of diaphragmatic contractile activity. [9] Ultrasound can be used to determine diaphragm excursion, [10,11] which may help to identify patients with diaphragm dysfunction. [12] Ultrasonographic examination can also allow for the direct visualization of the diaphragm thickness in its zone of apposition. [13] Thickening during active breathing has been proposed to reflect the magnitude of diaphragmatic effort, similarly to an ejection fraction of the heart. [14] Present study aimed to evaluate feasibility & utility of ultrasonography in evaluation of diaphragmatic motion and diaphragmatic thickness.

Objectives:

1. To study the utility and feasibility of ultrasonography in evaluation of diaphragmatic motion in Indian population.
2. To study the thickness of diaphragm in Indian population by using ultrasonography.

MATERIALS AND METHODS

Study was conducted in western region of India. Data was collected from 3 different centers located in Maharashtra, namely Kasturi Diagnostics, Mumbai; Thunga Hospital, Thane and Shreyash Diagnostic Centre, Gondia. Data was collected from the existing record of 60 healthy, adult men and women. Permission was taken from the authorities to access the records and conduct the study.

Data was collected from participants who were examined in supine position. Diaphragmatic movement was measured through anterior sub-costal and sub-xiphoid approach by using M-mode sonography. Diaphragmatic thickness was measured through anterior-axillary sagital low intercostals approach by using B-mode sonography. Participants were examined with Ultrasound machine logic P5 or Voluson P8 or logic F6.

M Mode ultrasonography was done by using 4Mhz curvilinear probe, the diaphragm appeared as thin echogenic line. M mode tracings were obtained using liver window and spleen window for right and left diaphragm respectively. Measurements were made from the point of maximal excursion to the baseline in normal breathing & sniffing and maximal to the lowest point of excursion for deep breathing.

B Mode ultrasonography was done by using high frequency probe 12Mhz probe , the diaphragm appears as a three layered structure with central non-echogenic muscle and two echogenic layers , diaphragmatic pleural and peritoneum. Visualization of both the pleural and peritoneal membranes with an angle of incidence of the ultrasound beam close to 90 degree. The measurement was taken at zone of apposition, interiorly to the costophrenic angle, where the diaphragm contacts the inner aspect of the chest wall.

Data analysis was done in line of the objectives by using Microsoft excel. Qualitative variables were presented as percentage and Quantitative variables were presented as Mean ± SD. Student "t" test and Pearson's correlation coefficient was used as test of significance, $p<0.05$ was considered as significant.

RESULTS

Table 1: Demographic Characteristics and Baseline Parameters of study participants (n=60)

Characteristics		N (%) / Mean ± SD
Sex	Male	28 (47)
	Female	32 (53)
Age in completed years		32.4 ± 10.1
BMI in Kg/m^2		23.4 ± 3.4
Respiratory Rate per minute		18.7 ± 7.1

Out of total 60 study participants 32 (53%) were Female and 28 (47%) were Male. Minimum and Maximum age of the study participants was 19 years and 54 years respectively. Mean age of the study participants was 32.4 with standard deviation of 10.1 years. Minimum and Maximum BMI of the study participants was 15.9 Kg/m^2 and 32.8 Kg/m^2 respectively. Mean BMI of the study participants was 23.4 with standard deviation of 10.1 Kg/m^2. Minimum and Maximum Respiratory Rate of the study participants was 14 per minute and 22 per minute respectively. Mean Respiratory Rate of the study participants was 18.7 with standard deviation of 7.1 per minute.

Table 2: Sex wise comparison of baseline parameters

	Male (n=28) (Mean ± SD)	Female (n=32) (Mean ± SD)	P value
Age in completed years	30.64 ± 8.7	33.97 ± 11.3	0.8
BMI in Kg/m^2	23.2 ± 3.2	23.7 ± 3.7	0.7
Respiratory Rate per minute	18.3 ± 2.5	20.3 ± 9.7	0.4
Right Hemi-diaphragm motion in Cms. at quite breathing	1.8 ± 0.4	1.6 ± 0.3	0.08
Right Hemi-diaphragm motion in Cms. at Deep breathing	5.3 ± 1.5	5.5 ± 1.5	0.9
Right Hemi-diaphragm motion in Cms. at sniff	2.6 ± 0.6	2.7 ± 0.8	0.2
Left Hemi-diaphragm motion in Cms. at quite breathing	1.9 ± 0.4	1.6 ± 0.4	0.8
Left Hemi-diaphragm motion in Cms. at Deep breathing	5.6 ± 1.6	5.1 ± 1.3	0.09
Left Hemi-diaphragm motion in Cms. at sniff breathing	2.6 ± 0.5	2.6 ± 0.7	0.5
Right Hemi-Diaphragm Thickness Fraction	28.8 ± 6.9	26.6 ± 4.9	0.08
Left Hemi diaphragm Thickness fraction	35.1 ± 12.4	35.4 ± 12.2	0.8

Mean age of male was 30.64 with standard deviation of 8.7 years while mean age of Female was 33.97 with standard deviation of 11.3 years. Mean BMI of male was 23.2 with standard deviation of 3.2 Kg/m^2 while mean BMI of Female was 23.7 with standard deviation of 3.7 Kg/m^2.

In males average (Mean ± SD) motion of Right hemi-diaphragm during quit, deep and Sniff breathing was 1.8 ± 0.4, 5.3 ± 1.5 and 2.6 ± 0.6 cms respectively. Average (Mean ± SD) motion of left hemi-diaphragm during quit, deep and Sniff breathing was 1.9 ± 0.4, 5.6 ± 1.6 and 2.6 ± 0.5 cms respectively. Average (Mean ± SD) thickness fraction of right and left hemi-diaphragm was 28.8 ± 6.9 and 35.1 ± 12.4 respectively.

In females average (Mean ± SD) motion of Right hemi-diaphragm during quit, deep and Sniff breathing was 1.6 ± 0.3, 5.5 ± 1.5 and 2.7 ± 0.8cms respectively. Average (Mean ± SD) motion of left hemi-diaphragm during quit, deep and Sniff breathing was 1.6 ± 0.4, 5.1 ± 1.3 and 2.6 ± 0.7 cms respectively. Average (Mean ± SD) thickness fraction of right and left hemi-diaphragm was 26.6± 4.9 and 35.1 ± 12.2 respectively.

The observed difference in parameters of male and female was statistically insignificant.

Table 3: comparison motion of diaphragm during deep inspiration and sniff in relation to quite breathing

		Motion in Cms (Mean ± SD)	P Value
Right Hemi diaphragm	Quite breathing	1.7 ± 0.4	
	Deep Inspiration	5.4 ± 1.4	0.006
	Sniff	2.6 ± 0.7	0.36
Left Hemi diaphragm	Quite breathing	1.8 ± 0.4	
	Deep Inspiration	5.3 ± 1.5	0.001
	Sniff	2.6 ± 0.6	0.001

Average (Mean ± SD) movement of Right Hemi-diaphragm at base, deep inspiration and sniff was 1.7 ± 0.4, 5.4 ± 1.4 and 2.6 ± 0.7 respectively. Movement of right hemi diaphragm at deep inspiration was higher in comparison with the movement at base and this difference was statistically significant. Average (Mean ± SD) movement of Left Hemi-diaphragm at base, deep inspiration and sniff was 1.8 ± 0.4, 5.3 ± 1.5 and 2.6 ± 0.6 respectively. Movement of left hemi diaphragm at deep inspiration and sniff was higher in comparison with the movement at base and this difference was statistically significant.

Table 4: Comparison of thickness of diaphragm during Inspiration and Expiration

		Thickness in millimetres (Mean ± SD)	P Value
Right Hemi diaphragm	Inspiration	2.6 ± 0.5	0.003
	Expiration	1.9 ± 0.3	
Left Hemi diaphragm	Inspiration	2.6 ± 0.6	0.001
	Expiration	1.8 ± 0.4	

Average (Mean ± SD) thickness of right hemi diaphragm at Inspiration and Expiration was 2.6 ± 0.5 and 1.9 ± 0.3 mms respectively. This difference in thickness of Right hemi diaphragm during inspiration and expiration was statistically significant. Average (Mean ± SD) thickness of left hemi diaphragm at Inspiration and Expiration was 2.6 ± 0.6 and 1.8 ± 0.4 mms respectively. This difference in thickness of left hemi diaphragm during inspiration and expiration was statistically significant.

Table 5: Correlation of Diaphragmatic motion with Age and BMI

			Correlation Coefficient	P Value
Age in Years Vs	Right Hemi-diaphragm	Quite	0.04	0.75
		Deep	0.14	0.28
		Sniff	0.07	0.58
		Thickness Fraction	0.01	0.82
	Left Hemi-diaphragm	Quite	0.03	0.82
		Deep	0.02	0.89
		Sniff	0.01	0.97
		Thickness Fraction	0.09	0.93
BMI in Kg/m^2 Vs	Right Hemi-diaphragm	Quite	0.33	0.01
		Deep	0.11	0.39
		Sniff	0.06	0.67
		Thickness Fraction	0.03	0.83
	Left Hemi-diaphragm	Quite	0.37	0.001
		Deep	0.04	0.73
		Sniff	0.39	0.001
		Thickness Fraction	0.09	0.58

Correlation coefficient between age and movement of right hemi diaphragm at quite, deep and sniff was 0.04, 0.14 and 0.07 respectively. Correlation coefficient between age and movement of left hemi diaphragm at quite, deep and sniff was 0.03, 0.02 and 0.01 respectively. Correlation coefficient between age and thickness fraction of right & left hemi diaphragm was 0.01 & 0.09 respectively.

Correlation coefficient between BMI and movement of right hemi diaphragm at quite, deep and sniff was 0.33, 0.11 and 0.06 respectively. Correlation coefficient between BMI and movement of left hemi diaphragm at quite, deep and sniff was 0.37, 0.04 and 0.39 respectively. Correlation coefficient between BMI and thickness fraction of right & left hemi diaphragm was 0.03 & 0.09 respectively. Movement and thickness fraction of diaphragm was independent of age and BMI of the participants.

DISCUSSION

In India age group of 19to 54 years constitutes a significant size of population. This group is economically productive group. The range of BMI and Respiratory Rate was 15 – 32 $Kg/m^2$and 14 – 22 per minute respectively. These parameters were in line with the other studies conducted in similar study population. [15,16]

Movements in the right and left hemidiphragm during quite breathing, deep inspiration and sniff was comparable and there was no significant difference. During deep breathing the range of diaphragmatic movement increases by 2.5 to 3 times as comparison to the range of movement during quite breathing. The increase in the range of movement was independent of age, sex and BMI. Other studies, Eugenio O. Gerscovich*et.al*, conducted in western population reports that the range of movements during deep breathing increases by 3 to 3.5 times as compared to quite breathing. However other studies conducted in Indian as well as in western population reports that the increase in range of diaphragmatic movement during deep inspiration is independent of Age, sex and nutritional status. [17-19]

Thickness of right and left hemidiaphragm was comparable. Thickness during inspiration increases by 1.5 to 2 times in comparison during expiration and this was highly significant. The increase in thickness of diaphragm during inspiration was also reported in other studies in Indian as well as western population.

CONCLUSION

Present study defines normal range of diaphragmatic movement and thickness which can be utilized in diagnosis, prognostic follow up of diaphragmatic paralysis and for assessment in various clinical conditions that affect diaphragmatic dysfunction. Ultrasonography is useful in evaluating diaphragmatic motion and thickness in Indian population.

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Conflict of Interest: Nil

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