Journal of Kathmandu Medical College, Vol. 11, No. 4, Issue 42, Oct.-Dec., 2022

Sonographic assessment of thickness of normal diaphragm by B mode ultrasound

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Abstract

Background: The thickness of diaphragm and diaphragmatic thickness fraction can be assessed by ultrasonography which can be used in early detection of the neuromuscular conditions and follow-up.

Objectives: To measure the thickness of diaphragm during inspiration and expiration; and diaphragmatic thickness fraction by B mode ultrasound in healthy patients.

Methods: An analytical cross-sectional study was conducted in 260 patients. Data were collected from 2020 July 10 to 2021 July 9 in Department of Radiology, BPKIHS after ethical clearance. Patients who were referred for sonographic evaluation and without neurological complains were included. Purposive sampling was done. Inferential statistical analysis was done applying SPSS v.11.5.

Results: Mean diaphragmatic thickness on deep inspiration was found to be 2.80 ± 0.57 mm (95% CI 2.73-2.87 mm) and 2.71 ± 0.53 mm (95% CI 2.64-2.77 mm) on right and left side respectively. Mean diaphragmatic thickness on end expiration was found to be 2.01 ± 0.41 mm (95% CI 1.96-2.06 mm) and 1.97 ± 0.40 mm (95% CI 1.92-2.01 mm) respectively on right and left side. Mean diaphragmatic thickness fraction was observed 40 ± 7.79% (22-67%) and 38 ± 7.98% (22-60%) on right and left side respectively. The mean difference between right and left side on inspiration was found to be statistically significant. A weak positive correlation of diaphragmatic thickness with BMI on both sides and on both during inspiration and expiration was seen. There was no statistically significant correlation of diaphragmatic thickness fraction with age and BMI.

Conclusion: Sonographic diaphragm thickness measurement and diaphragm thickness fraction can provide both anatomical and physiological evaluation quickly.

Key words: Diaphragm thickness; Diaphragmatic thickness fraction; Expiration; Inspiration; Ultrasound.

Access this article online

Website: www.jkmc.com.np

DOI: https://doi.org/10.3126/jkmc.v11i4.53549

HOW TO CITE

Devkota K, Gupta MK. Sonographic assessment of thickness of normal diaphragm by B mode ultrasound. J Kathmandu Med Coll. 2022;11(4):215-20.

Submitted: Jul 27, 2022
Accepted: Nov 24, 2022
Published: Dec 30, 2022

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ISSN: 2019-1785 (Print), 2091-1793 (Online)

INTRODUCTION

The diaphragm is a musculotendinous structure that separates the chest from the abdomen and plays a primary role in respiration.[1] It is composed of central non-contractile tendons, two major muscular portions: the costal and crural diaphragm and minor muscular portion contributed by the sternal part of the diaphragm. The costal part of the diaphragm is the main musculature for the act of respiration, specifically the inspiratory phase. When the diaphragm contracts and shortens during inspiration, the muscle thickens. The contractility of diaphragm is affected in neuromuscular disorders, often leading to respiratory insufficiency. Diffuse atrophy has been observed in patients on prolonged mechanical ventilation with diaphragm inactivity.[2]

There are limited studies worldwide and no studies yet in Nepal regarding the evaluation of the diaphragm, despite the valuable information it can provide in modern medicine practice. So, the study was conducted with an objective to measure diaphragmatic thickness during inspiration and expiration along with thickness fraction in this group of population. Results of the study will contribute to establish the reference value for diaphragmatic thickness, which in turn will help the radiologists in detection of pathological diaphragm; and clinicians in early detection and follow up of neuromuscular disorders.

METHODOLOGY

An analytical cross-sectional study was conducted after ethical approval in the Department of Radiology at B.P. Koirala Institute of Health Sciences (BPKIHS) from 2020 July 10 to 2021 July 9 (Ref. 466/076/077-IRC). Sample size was calculated using formula, sample size = $Z^2\sigma^2/(\mu-\dot{X})^2$. Considering 95% confidence interval, 80% diagnostic power and mean and standard deviation of 1.89 ± 0.51 mm with average thickness of 2.5 mm, the sample size was calculated to be approximately 260.[3] Purposive sampling was done. The patients referred for sonographic evaluation in radiology department for general health check-up who had normal laboratory evaluation, normal ultrasound scan report and wish to take part in the research voluntarily were included in the study. Patients with known chronic disease (e.g., diabetes mellitus, hypertension, chronic airway disease) and/or taking medication, known or suspected neuromuscular disorder, suspected diaphragmatic palsy/paresis, patients with cervical spine injury, patients with shortness of breath were excluded from the study.

After taking informed consent from the patient who fulfilled inclusion criteria, questionnaire regarding the information of the patients were filled by investigator as in structured proforma. Patient was asked to lie down in supine position comfortably. High frequency linear probe (3-16 MHz) of Samsung Hs70A machine was used to measure diaphragm thickness at the zone of apposition to the rib cage. The probe was placed at the anterior axillary line in longitudinal plane between 7th and 9th intercostal space of either side. Patients were asked to take deep inspiration and value of diaphragm thickness (DTi) was measured by use of calipers during deep inspiration on both sides. The value of diaphragm thickness was also obtained at the end of expiration (DTe) (Figures 1, 2). Diaphragmatic thickness fraction (DTF) was calculated as (DTi-DTe)/DTe.

Data were entered and analysed using SPSS Statistics for Windows, version 11.5 (SPSS Inc., Chicago, Ill., USA). Mean and standard deviation were derived for continuous variable. T-test was applied to measure significant differences between sexes and between the sides. Pearson's correlation was applied to see correlation of thickness and diaphragmatic thickness fraction with body mass index (BMI).

RESULTS

The mean age of the study sample was 40.85 ± 17.93 years with ratio of female to male being 1.4:1 out of 260 subjects in the study. Most common age group was 30-39 years (Table 1). Median height, weight and BMI of the study sample were 62.00 ± 13.75 kg, 1.57 ± 0.13 m and 24.95 ± 4.87 kg/m^2.

Mean diaphragmatic thickness on deep inspiration was found to be 2.80 ± 0.57 mm (95% CI 2.73-2.87 mm, range: 1.7-5.4 mm) and 2.71 ± 0.53 mm (95% CI 2.64-2.77 mm, range: 1.7-5.2 mm) on right and left side respectively. Similarly, mean diaphragmatic thickness on end expiration was found to be 2.01 ± 0.41 mm (95% CI 1.96-2.06 mm, range1.3-3.5 mm) and 1.97 ± 0.40 mm (95% CI 1.92-2.01 mm, range 1.2-3.8 mm) respectively on right and left side. Mean diaphragmatic thickness fraction was observed 40 ± 7.79% (22-67%) and 38 ± 7.98% (22-60%) on right and left side respectively. The mean difference between right and left side on inspiration was found to be statistically significant (Table 2). However, on expiration there was no statistically significant difference. There was no significant difference of all these parameters in relation to sex (Table 3).

There was a weak positive correlation of diaphragmatic thickness with BMI on both right and left side and on both during inspiration and expiration (Table 4). However, there was no correlation of dTF with BMI. Significant correlation was also not obtained between age and these parameters (Table 4).

Table 1: Distribution of age groups

Age groups (years)	Frequency (%)
0-9	10 (3.8)
10-19	22 (8.5)
20-29	45 (17.3)
30-39	52 (20.0)
40-49	48 (18.5)
50-59	39 (15.0)
60-69	23 (8.8)
70-79	16 (6.2)
>=80	5 (1.9)
Total	**260 (100.0)**

Table 2: Comparison of diaphragmatic thickness of right and left side (Mean ± SD)

Diaphragmatic thickness	Right	Left	p-value
dTi	2.80 ± 0.57	2.71 ± 0.53	<0.001
dTe	2.01 ± 0.41	1.97 ± 0.40	0.21
dTf	40 ± 7.79%	38 ± 7.98%	0.025

Table 3: Comparison of diaphragmatic thickness of right and left side with sex (Mean ± SD)

Diaphragmatic thickness	Male	Female	p-value
dTi (right)	2.79 ± 0.54	2.80 ± 0.59	0.767
dTi (left)	2.72 ± 0.52	2.70 ± 0.53	0.880
dTe (right)	2.00 ± 0.39	2.01 ± 0.42	0.281
dTe (left)	1.97 ± 0.40	1.96 ± 0.40	0.727

Table 4: Correlation of diaphragmatic thickness and thickness fraction with body mass index and age

	Body mass index		Age	
	r value	p-value	r value	p-value
dTi (right)	0.153	0.013	0.002	0.968
dTi (left)	0.155	0.012	-0.031	0.613
dTe (right)	0.126	0.042	0.22	0.729
dTe (left)	0.153	0.013	-0.039	0.532
dTf (right)	0.102	0.100	-0.049	0.430
dTf (left)	-0.033	0.596	0.045	0.467

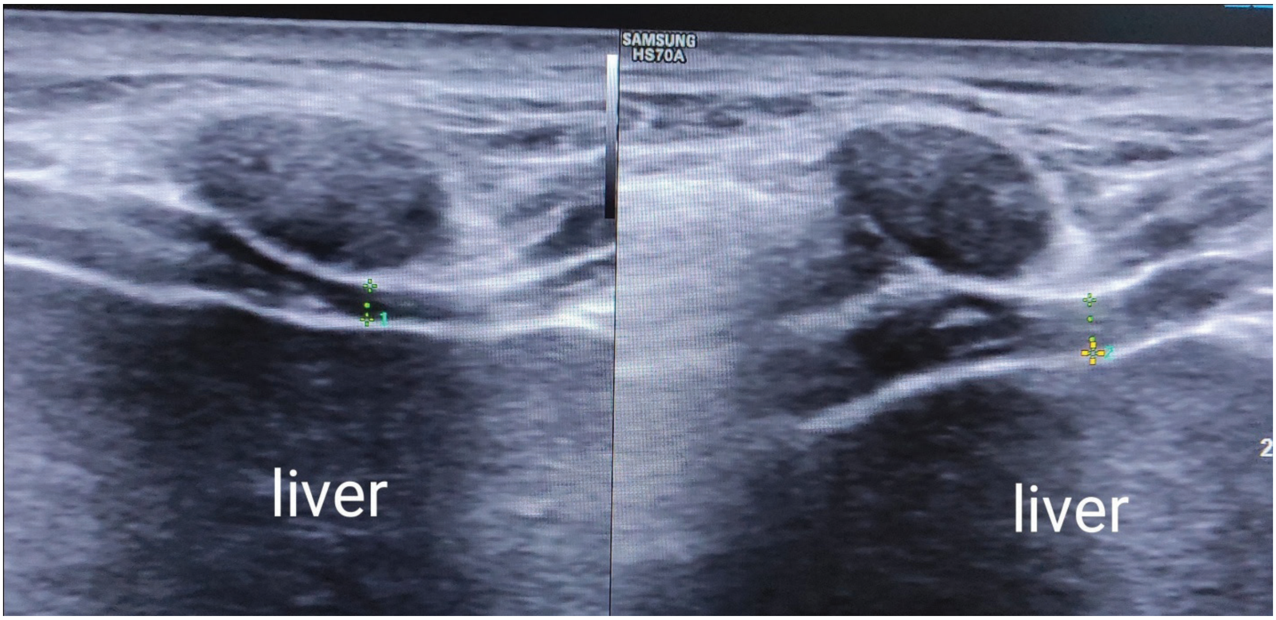

Figure 1: Measurement of right diaphragmatic thickness during expiration and inspiration respectively

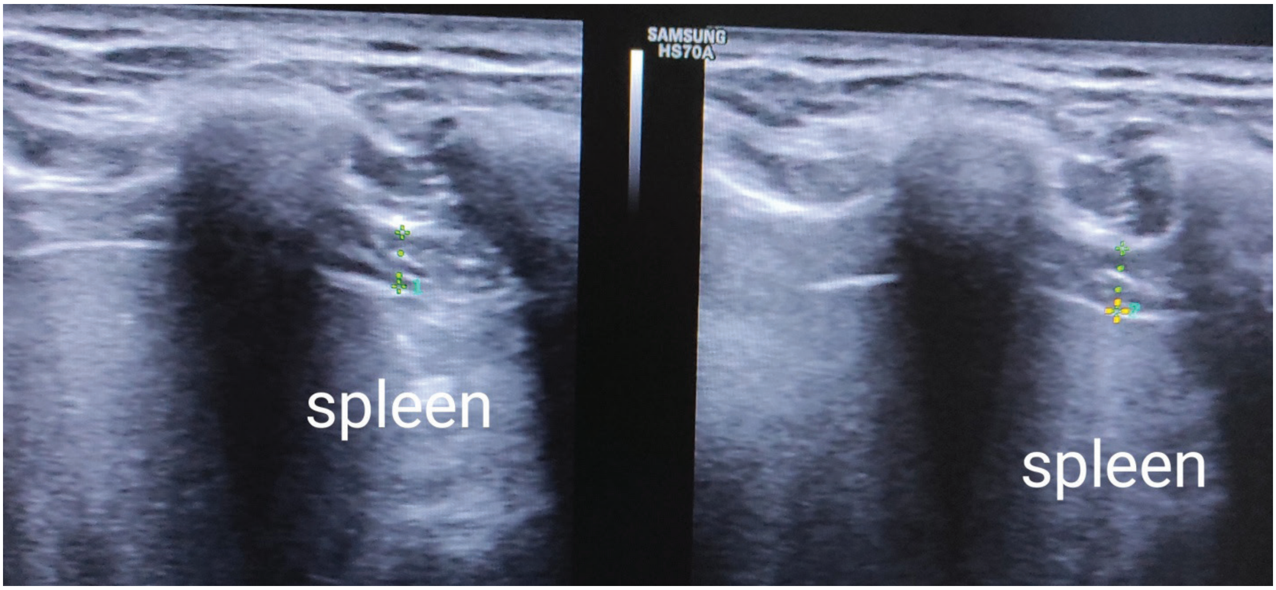

Figure 2: Measurement of left diaphragmatic thickness during expiration and inspiration respectively

DISCUSSION

The role of diaphragm evaluation has increased in the recent days in intensive care unit to evaluate diaphragmatic weakness in the patients and to see its progression. It may also be of help during weaning from mechanical ventilation.[4-6] Diaphragm thickness fraction can also be used intraoperatively to assess the acute phrenic paresis after interscalene block.[7] Besides this, the evaluation of diaphragm has also increased in the clinical diagnostic work up. In Duchenne muscular dystrophy, the diaphragm is shown to be affected earlier and more severely than other skeletal muscles.[8] Reduced muscle mass and intrinsic contractile weakness of the diaphragm was seen in osteogenesis imperfecta in mice study.[9] Diaphragm ultrasound may also be useful in evaluating diaphragm weakness or paralysis In patients with diseases that affect the central nervous system (ALS, poliomyelitis, spinal muscular atrophy, transverse myelitis), or the peripheral nervous system (ALS, Guillain Barré syndrome, neuropathy, Lyme disease) or the neuromuscular junction (myasthenia gravis, Lambert-Eaton syndrome).[10]

Multiple imaging modalities are available for the evaluation of diaphragm. X ray is relatively insensitive in diagnosing diaphragm pathology. The computed tomography (CT) and fluoroscopy possess radiation hazard. Although dynamic MRI can perform better evaluation among various imaging modalities, its availability, cost and operator dependence limit its use and is difficult to assess in critically ill patients.[11] Trans-diaphragmatic pressure measurement and electromyogram are invasive and technically challenging.[10,12] Ultrasound is safe, cheaper, easy to handle, portable, radiation-free, non-invasive, simple to operate, needs less expertise and one of the highly sensitive imaging modalities for evaluation of diaphragm and its related pathology. Diaphragmatic ultrasound is considered 93% sensitive and 100% specific for the diagnosis of neuromuscular diaphragmatic dysfunction.[13] M-mode ultrasound is little cumbersome and difficult to perform in routine evaluation. As B mode ultrasound is shown to be comparable to M-mode ultrasound in measuring diaphragmatic thickness, the authors of this study preferred B mode as it is more convenient in day to day practice.[14]

Various studies have been conducted previously to measure diaphragmatic thickness and diaphragmatic thickness fraction. The difficult visualisation of left hemidiaphragm due to small sonographic window in relation to spleen often makes the assessment of diaphragm difficult.[15] The mean diaphragmatic thickness during inspiration was found to be lower in this study than as measured by Seok et al.[12] and almost similar to the study done by Thimmaiah et al.[3] Previous studies have shown significant difference in diaphragmatic thickness between sex and no significant difference in thickness between both sides.[6,12] This study showed a different result with significant difference noted between the two sides and no differences among the sex. But the result was comparable to the study by Boon et al. who also showed no significant difference between right and left side at end expiration but there was slight difference of thickening ratio between the two sides.

Diaphragmatic thickness showed a weak positive correlation with BMI but not with age. Diaphragmatic thickness fraction did not show statistically significant correlation with both age and BMI. So, diaphragmatic thickness fraction is the least affected parameter. Previous studies have also labeled thickness fraction as a better measure as it is least affected by body habitus, age, and other factors.[12,16] At least 22% change in the thickness has been noted. Boon et al. also showed at least 20% change in thickness from end expiration to deep inspiration.[16]

Due to the wide variability of the diaphragmatic thickness, the authors of this study assume that diaphragmatic thickness fraction can be a better and reliable measure to assess the diaphragmatic function. However, its use in patients with poor respiratory effort may derive the false positive results where the baseline thickness values and comparing on the other side may be more trustworthy. Furthermore, the interobserver reliability could be the main limitation of this study. The present study also did not correlate sonographic findings with pulmonary function test for which the authors of this study recommend a larger study with interobserver agreement and correlation with pulmonary function test and also with M mode findings to fortify the findings in this study.

CONCLUSION

In conclusion, B mode ultrasound can be used as a quick, cheap, and efficient tool to evaluate diaphragm thickness and function, and without any fear of radiation hazard. Sonographic diaphragm thickness measurement and diaphragm thickness fraction can provide both anatomical and physiological evaluation and these values can be used to differentiate the normal functioning diaphragm from dysfunctioning diaphragm. These values can be used as reference values in this set-up. The deviation from the reference values should prompt the radiologists and clinicians for early detection of the pathological condition. Similarly, these values can also be helpful to monitor the disease progression and efficacy of treatment.

ACKNOWLEDGEMENT

The authors would like to thank all the co-operating participants and the staffs of Radiology, BPKIHS.

Conflict of interest: None
Source(s) of support: None

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