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M -Mode Ultrasound Evaluation of Diaphragm-An Useful Modality in Clinical Practice

Dr. Vishwanath. T. Thimmaiah[1], Dr. Rajesh Raman[2], Dr. Keval P Jain[3]

[1]Associate Professor, Department of Radiodiagnosis, JSS medical college &Hospital , JSS University, MG Road, Mysuru -570004

[2]Associate Professor, Department of Radiodiagnosis, JSS medical college &Hospital , JSS University, MG Road, Mysuru -570004

[3]Department of Radiodiagnosis , JSS medical college &Hospital , JSS University, MG Road, Mysuru -570004

Abstract: ***Objectives**: M-mode ultrasound evaluation of diaphragm in various clinical conditions that affect Diaphragm movement. To apply M-mode ultrasound technique as a useful imaging modality in clinical practice. **Materials and methods**: Cross sectional study over a period of 6 months was done in 185 patients with clinical conditions that affects diaphragm. Diaphragmatic excursion from reference baseline was measured by M-mode using standard technique. Cramer's V and p value were used to find the association. **Results**: 185 patients with Diaphragmatic dysfunctions were categorized in to Group I (38.4%) with excursion of 0.8 to1.2cm and Group II (61.6%) with 0.3 to 0.8cm. Phrenic nerve injuries, nerve pathologies, post upper abdominal surgeries, post cardiac surgeries and sub diaphragmatic abscess had severe diaphragmatic dysfunction(Group II) compared to lower lobe consolidation, massive pleural effusion and gross ascites cases(Group I). Crammer's V and p value were significant in our study. **Conclusion**: M-mode is a useful technique that can be applied in routine clinical practice for evaluation of diaphragm in various clinical conditions that affects its movement. Being safe and easily available can be used as an initial imaging modality for assessment of diaphragm dysfunction.*

Keywords: M mode ultrasound, Diaphragm, Dysfunction

1. Introduction

Principal muscle for respiration and power for breathing is mainly by diaphragm muscle and its movement can be affected by various clinical conditions [1]. Properly functioning of diaphragm is needed for lung aeration and plays a prominent role in respiratory cycle. Diaphragmatic movement abnormalities can be seen in phrenic nerve injury , diaphragm muscle injury, Post cardiac surgeries, upper abdominal surgeries, massive pleural effusions, ascites, upper abdominal masses, basal pulmonary atelectasis , pneumonia, Central nervous system disease , brain infarcts , tumors and critically ill patients on prolonged ventilation [2][3].Diaphragm is often incompletely evaluated by clinicians despite its importance. Diaphragmatic dysfunctions are often under diagnosed due to their nonspecific and varied clinical manifestations. Evaluation of diaphragmatic kinetics is very important clinically as diaphragm plays an important role for spontaneous respiration.Various methods are available for assessing diaphragmatic movement clinically with many limitations. Trans diaphragmatic pressure measurement, phrenic nerve stimulation and electromyography are invasive and are very complex in nature [3]. Fluoroscopy and CT associated are associated with radiation exposure. Dynamic MRI is limited by availability and cost. M-mode uses a single beam on a B-mode image and records the successive positions of diaphragmatic structure over a time scale there by allowing quantifiable assessment of movement and velocity of diaphraghm. Ultrasound being real-time imaging modality, is easily-available ,relatively fast, cost effective, non ionizing and along with M-mode technique makes as ideal modality for assessment of diaphragmatic dysfunctions [4].

2. Materials and Methods

Inclusion criteria:
Adult Patients above 18 years of age with clinical conditions that affect diaphragmatic movements were included.

Exclusion criteria:
1) Patients with age less than 18 years.
2) Patients on mechanical ventilation.

Ultrasound (M mode) technique for Diaphragm excursion measurement:
All patients were examined in supine position and in quite respiration. Right dome of diaphraghm was abnormal in all cases. Anterior Subcostal view is obtained by placing low frequency probe (2 to 6 MHz) between midclavicualr and anterior axillary line in the right subcostal area using liver as acoustic window. Transducer is directed cranially, medially and dorsally to focus the ultrasound beam about 5cm lateral to the inferior vencaval foramen. B-mode is used to visualize diaphragm moving towards or away from transducer and imaging changed to M-mode with line of sight positioned to obtain maximum excursion of diaphragm, seen as a single thick echogenic line. Movement of diaphraghm is plotted against time curve. Direct measurement of amplitude of excursion of diaphragm on the vertical axis of the M-mode wave, tracing from baseline to the point of maximum inspiration is done(figure 3). Diaphragmatic movement of >1.2cm during quite respiration was taken as normal cut off value. Movement of ≤ 1.2 cms is considered as abnormal and categorized in to mild diaphragmatic dysfunction with 0.8-1.2cm (Group I) and severe dysfunction with 0.3-0.8cm (Group II).

Data Analysis

SSPS software with descriptive variables and inferential statistics (Cramer's V and p value)

3. Results

Among 185 patients with diaphragm dysfunctions, 71(38.4%) patients belong to Group I and 114(61.6%) to Group II with 92 male and 93 females. 55 (59.8%) male patients had severe diaphragmatic dysfunction with excursion of 0.3 to 0.8cm and 37 (40.2%) mild dysfunction with 0.8-1.2cm excursion. Among 93 females, 59 patients (63.4%)fall under Group I and 34 (36.6%) under Group II. Percentages within the age group were maximum for 50-60 years with 70.4% showing severe dysfunction and 21.6% showing mild dysfunction.

Among the causes for diaphragmatic dysfunction, Post abdominal surgery 63 (90%) was most common causing severe dysfunction and lower lobe consolidations 27 (87.10%)causing mild dysfunction. Among 24 phrenic nerve injury cases 22 (91.7%) show severe diaphragmatic dysfunction with only 2 patients showing mild dysfunction. Massive pleural effusion showed mild diaphragmatic dysfunction in 23 (92%) and severe dysfunction in 2 patients. Among all patients with gross ascites patients, only mild dysfunction was observed. 12 patients (70.6%) Post cardiac surgery and 4 (12.9%) lower lobe consolidation patients had severe dysfunction with all subdiaphragmatic collections showing mild dysfunction. Crammer's V value of 0.770 and p value of 0.001 were obtained , which shows significant association .

4. Discussion

Diaphragm is a primary muscle for ventilation and develops between 4-12 weeks of embryogenesis. It develops from components of septum transversum, pleuroperitoneal membrane, and medial dorsal portion of primary esophageal mesentery and marginal ingrowth from body wall. Transverse septum interiorly forms central tendon, fuses laterally with muscular body wall and posteriorly with esophageal mesentery and pleuroperitoneal folds[5]. Diaphragm is attached anteriorly to inferior sternum, xiphisternum, lower six ribs and posteriorly to upper lumbar vertebra. 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 inspiration and relaxation causes expiration. Along with respiration, diaphragmatic contractions also increase intra-abdominal pressure that helps in urination, defecation and prevention of gastro esophageal reflux[6].

Transdiaphragmatic pressure (Pdi) measurement is considered to be gold standard for diaphragmatic dysfunction, calculated as the difference between esophageal pressure (Pe) and gastric pressure (Pga). Being invasive and routinely not possible as it requires placement of esophageal and gastric probes for pressures measurement. For unilateral diaphragmatic dysfunction this method is insensitive as functioning contralateral diaphragm can alter Pdi pressures[7][8]. Pulmonary function tests are noninvasive and indirect method for diaphragmatic dysfunction evaluation. Accuracy and reproducibility of these testes are limited by patient's cooperation, residual lung volume, respiratory effort; age related decreased vital capacities and normal variabilites [9]. Diaphragmatic Electromyography is done by placing electrode in the dome of diaphragm and its movements assessed with normal unstimulated respiration or by stimulating phrenic nerve with electrodes. It is usefull in differentiating myopathic causes of diaphragmatic dysfunction from neurogenic cause, however this technique is limited by improper placement of probe, invasiveness, and cross talks from adjacent non diaphragmatic muscles and variable muscle to electrode distance in different individuals [10].

Chest radiograph can suspect diaphragmatic dysfunction in the form of elevated domes of diaphragm from the normal positions. However being non dynamic, less specific and radiation exposure makes it unsuitable for clinical practice for diaphragmatic movement assessment [11]. Fluoroscopy is most commonly used noninvasive imaging method for assessment of diaphragmatic dysfunction .Both unilateral and bilateral dysfunctions can be diagnosed with reduced or paradoxical movements of diaphragm, with few false positive and false negative results. Fluoroscopy assess both diaphragmatic movement and mediastinal shift on a real time basis , but has risk of radiation, availability and relying on the movement of anterior part of diaphragm to the highest point [12].Computed tomography can be used to assess diaphragmatic morphology but not its movement .Dynamic magnetic resonance imaging allows quantitative evaluation of movement, synchronicity and diaphragmatic velocity [13] . Limitations being high cost, difficult for ventilated patients and general contraindications [14]. Neuromuscular ultrasound is a noninvasive method for diaphragm evaluation which has been developed long back, first described by Cohen et al in the year 1969 [15] . First study on Diaphragm movement by ultrasound was done in the year 1975, since then various technical advancements have occurred in ultrasound along with M-mode for diaphragm assessment and presently considered as a first line noninvasive imaging modality for dysfunction evaluation [16].

Clinically diaphragmatic dysfunction presents as orthopnea, unexplained respiratory distress, paradoxical respiratory breathing, recurrent lung infections, unilateral lung collapse or respiratory failure. Diaphragm dysfunction can be due to paralysis by nerve pathology or weakness of intrinsic muscles. Normally right dome is slightly higher than the left and anteromedial portion higher than the posterolateral part which may be misinterpreted as signs of dysfunction. Unilateral dysfunction is more common and are incidentally discovered, bilateral being less common presents clinically with severe respiratory symptoms Dysfunction can be further worsened by underlying lung diseases or intraabdominal pathologies that can affect diaphragmatic movement indirectly[17]. Basal pulmonary collapse, basal pneumonias, lung tumors, upper abdominal intrabdominal masses, extensive pleural effusions and gross ascites decrease diaphragm excursions. Diaphragmatic movement may be reduced after upper abdominal surgeries and is the main determinant factor for post-operative pulmonary complications and its outcome. Traction, hypothermia, cauterizing or direct nerve injury to phrenic nerves are the causes for diaphragm dysfunction followed by surgeries[18]. During post operative day 1 and 2 diaphragmatic excursion decreases by 60 % of their preoperative value and increasing from day 3 onwards [19]. Post cardiac surgeries also causes reduced diaphragmatic movement leading to severe dysfunction in significant number of patients as the surgery involves severing of phrenic and intercostal nerves [20].

M mode is preferred noninvasive imaging modality for diaphragmatic dysfunction evaluation [21]. M-mode ultrasound, displays a single beam of a B-Mode image, evaluates a line of sight over time on the Y-axis as it changes over time on the X-axis. Supine position is preferred for diaphragmatic evaluation, as it provides greater excursion, increases paradoxical movement, greater reproducibility and less side to side variations. Movement of diaphragm is greater in supine position than in standing or sitting position for the same volume inspired having better correlation [22]. Supine position also exaggerates paradoxical movement if any, limiting compensatory expiration by anterior abdominal wall which may mask paralysis in some patients.

Intercostal, Anterior Subcostal, Posterior Subcostal and Subxiphoid views are among many standard views described for diaphragm evaluation. Intercostal view is obtained by placing high frequency probe over 7th to 9thintercostal space with limitations over zone of apposition and poor reproducibility for excursion assessment. Anterior Subcostal view is most commonly used and is obtained by placing lower frequency curvilinear transducer of 2 to 6 MHz between mid-clavicular and anterior axillary lines, in the anterior Subcostal region. Transducer is directed medially, cranially, and dorsally, so that the ultrasound beam reaches the posterior third of the diaphragm After B mode image is obtained, M mode is activated with the line of sight positioned to obtain maximum excursion of diaphraghm[23]. Posterior Subcostal view is similar to anterior Subcostal view except that high frequency transducer is placed posteriorly with patient in sitting position. Subxiphoid costal view is another usefull approach, particularly in children and for faster assessment that can be obtained by placing low frequency transducer below the xiphisternum in transverse direction [24] .

M-mode will record successive positions of diaphragm on a real time scale which helps in quantification of movement. Earlier excursions measurements of diaphragm were done in comparison to renal pelvis or portal vein [25]. Direct measurement of diaphragm movement is now possible with M mode, which can be applied in routine clinical practice and movement of diaphragm either towards or away from the transducer which can be correlated with respiratory cycles [26]. M-mode also differentiates diaphragmatic weakness from paralysis, where weakness is indicated by decreased amplitude of excursion during quite breathing and paralysis by paradoxical movement. M-mode provides mirror image of pressure changes that occur in esophagus in patients with partial mechanical ventilator support. M-mode can also be used for assessment of other parameters like, speed of diaphragmatic contraction, inspiratory time and duration of respiratory cycle. In our study M-mode was very usefull noninvasive imaging modality for evaluation of diaphragmatic dysfunction and Categorizing in to two groups with severe and mild dysfunction. All patients of both sexes with definite cause for diaphragmatic dysfunction has reduced movement of diaphragm. Maximum number of cases was between the age groups of 21 to 40 years. Post upper abdominal surgeries were the most common cause for severe dysfunction and lower lobe consolidation for mild diaphragmatic dysfunction in our study. M-mode examination was easy to perform with good repeatability and accurate data acquisition. Statistical significance with descriptive and inferential values obtained were significant, thereby making usefulness of M-mode modality as an imaging modality of choice for assessment of diaphragmatic dysfunction.

5. Conclusion

M-mode ultrasound is a feasible, reliable, repeatable and accurate noninvasive diagnostic imaging modality available for functional assessment of Diaphragm. M-mode provides qualitative and quantitative information regarding movement and appears to be a promising tool for diaphragmatic dysfunction evaluation. Further research is needed to define the further applications of M-mode modality for diaphragm dysfunction with Imaging protocols and standardization of reference values . M-mode ultrasound in future can be used as prime imaging modality for various clinical conditions that affect diaphragmatic movement.

6. Future Scope

M mode is a valid noninvasive imaging modality for diaphragmatic dysfunction evaluation that can be applied in routine clinical practice effectively.

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Table 1: Diaphragmatic excursions among Group I and Group II patients in various clinical Conditions that affects diaphragmatic movements

Clinical Conditions affecting diaphragmatic movement	**Diaphragmatic excursion**		**Total**
	Group - I (0.8-1.2cms)	**Group - II (0.3-0.8cms)**	
Phrenic nerve injury	2	22	24
	8.30%	91.70%	100.00%
Post upper abdominal surgery	7	63	70
	10.00%	90.00%	100.00%
Lower lobe consolidation	27	4	31
	87.10%	12.90%	100.00%
Post cardiac surgery	5	12	17
	29.40%	70.60%	100.00%
Massive pleural effusion	23	2	25
	92.00%	8.00%	100.00%
Sub-diaphragmatic abscess / collection	0	7	7
	0.00%	100.00%	100.00%
Gross ascites	6	0	6
	100.00%	0.00%	100.00%
Nerve pathology	1	4	5
	20.00%	80.00%	100.00%
Total	71	114	185
	38.40%	61.60%	100.00%

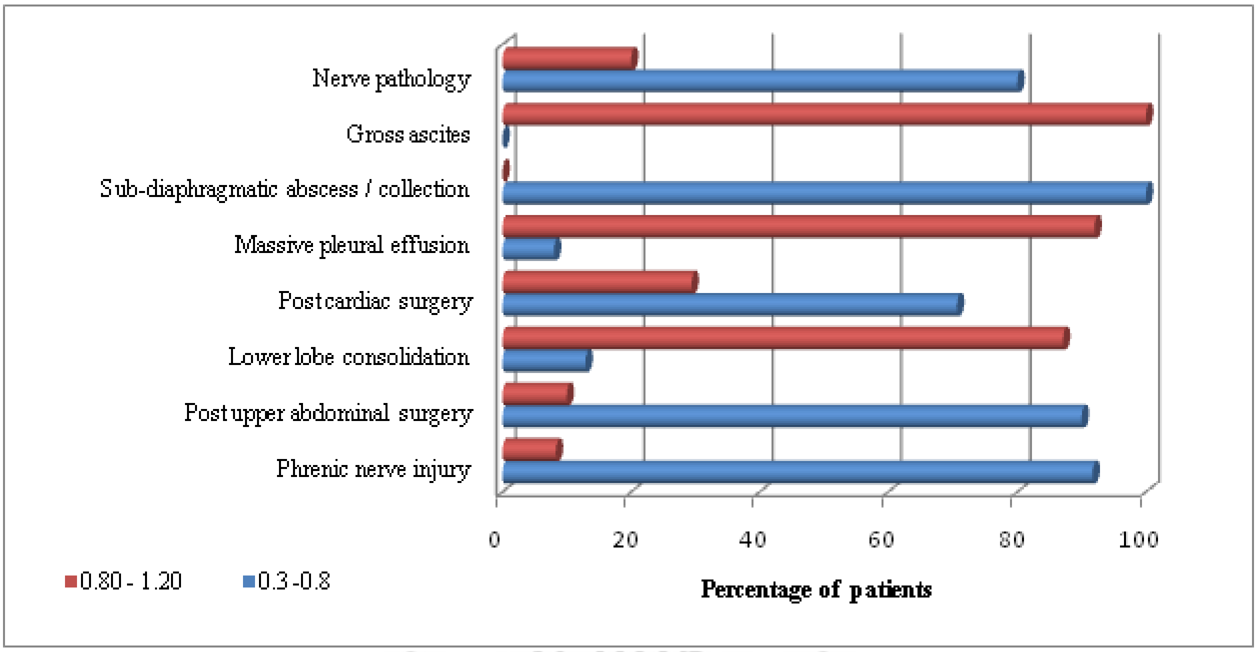

Figure 1: Bar diaphragm showing percentage of patients with various causes of Diaphragmatic dysfunction belonging to Group I and Group II.

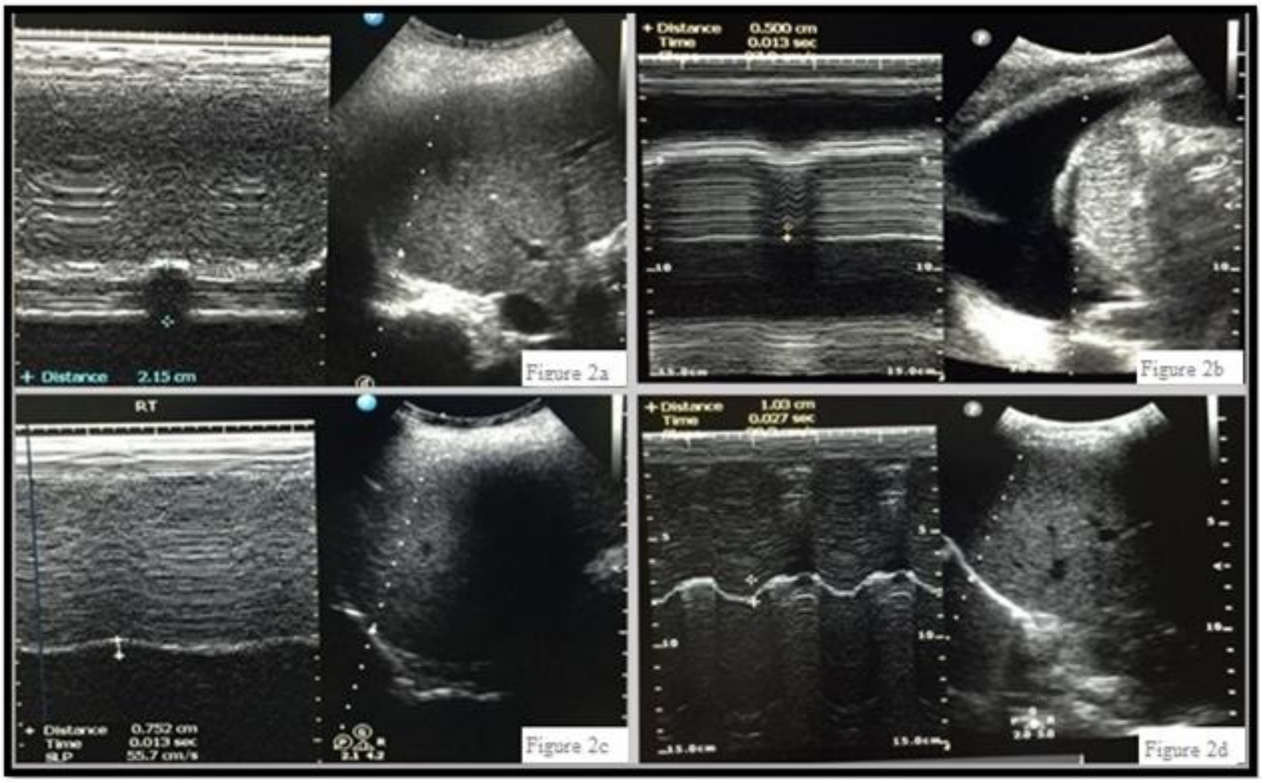

Figure 2: (a) Normal diaphragmatic excursion on M-mode ultrasound. (b) Diaphragmatic excursion in massive pleural effusion on M-mode. (c) Diaphragmatic excursion in post upper abdominal surgeries on M-mode. (d) Diaphragmatic excursion in lower lobe consolidation on M-mode.