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Role of diaphragmatic ultrasound in mechanically ventilated patients versus non mechanically ventilated patients with diaphragmatic dysfunction in Intensive Care Unit

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Abstract

Respiratory muscle ultrasound is used to evaluate the anatomy and function of the respiratory muscle pump. It is a safe, repeatable, accurate, and non-invasive bedside technique that can be successfully applied in different settings, Mastery of this technique allows the intensivist to rapidly diagnose and assess respiratory muscle dysfunction in critically ill patients either mechanically ventilated or non mechanically ventilated.This paper provides an overview of the basic and advanced principles underlying ultrasonography of the diaphragm. We review different ultrasound techniques useful for monitoring of the respiratory muscle pump and possible therapeutic consequences. Ideally, respiratory muscle ultrasound is used in conjunction with other clinicolaboratory components of critical care to obtain a comprehensive evaluation of the critically ill patient. Introduction:Over the last 25 years, numerous studies have supported the advantage of ultrasonography (US) in the assessment of diaphragmatic function. Various ultrasonographic methods, such as measurement of diaphragmatic excursions by two dimensional (BD)[1,2] or M-mode[3,4] and changes in diaphragm thickness during inspiration[5], have been proposed. In this review, we report the role of diaphragmatic ultrasound in mechanically ventilated patients versus non mechanically ventilated patients with diaphragmatic dysfunction in Intensive Care Unit Aim of the Work This work aimed to illuminate the role of diaphragmatic ultrasound in mechanically ventilated patients versus non mechanically ventilated patients with diaphragmatic dysfunction in Intensive Care Unit Methods: 100 Patients were allocated into two main groups:

- Group I : Non mechanically ventilated patients
- Group II : Mechanically ventilated patients
- Each group was divided into three subgroups
- Subgroup I : Respiratory failure patients
- Subgroup II : Stroke patients
- Subgroup III : Sepsis patients

Diaphragmatic ultrasound was done for all allocated patients and different parameters as diaphragmatic thickness (DT), diaphragmatic thickness fraction (DTF) and diaphragmatic excursion (DE) were measured on the first day of admission and on the seventh day of admission. **The results** Evaluation of diaphragmatic thickness (DT)and diaphragmatic thickness fraction (DTF) : as percentage from the formula: (thickness at end inspiration– Thickness at end-expiration)/Thickness at end Expiration * 100. and diaphragmatic excursion (DE) are easily obtained and comparable parameters with clinical and laboratory parameters to evaluate either mechanically ventilated or non mechanically ventilated critically ill patients **Conclusion**: Diaphragmatic ultrasound parameters are useful in conjunction with other clinicolaboratory components of critical care to obtain a comprehensive evaluation of the critically ill patient**.**

Keywords: diaphragmatic ultrasound, and diaphragmatic excursion, and diaphragmatic thickness, diaphragmatic thickness fraction.

1. Introduction

Patients in intensive care units (ICUs) benefit greatly from the use of bedside ultrasonography (US). Emergency scenarios are particularly challenging because of the difficulties of transporting patients to the radiology department owing to the severity of their condition [6].

It has been shown that US is an accurate, safe, and easy-to-use bedside modality that overcomes many of the traditional constraints of imaging modalities [6].

Sonographic diaphragm assessment in the ICU has lately become more common due to the unique clinical conditions that need the examination of diaphragmatic function. After abdominal or heart surgery or in severely sick patients on artificial ventilation, patients may have abnormal diaphragmatic motility due to illnesses like phrenic nerve damage or neuromuscular diseases [7, 8].

Diaphragmatic dysfunction after surgery may be detected via bedside ultrasound, which may allow for a more precise change of the ventilator's settings based on the results of this screening test [9].

Doctors may utilise ultrasound to dynamically analyse the reasons of respiratory failure and weaning failure, which might include pulmonary or extrapulmonary issues, thanks to the introduction of critical care ultrasonography. Diaphragmatic motions, such as the amplitude, force, and velocity of contraction as well as particular patterns of motion and changes in diaphragmatic thickness during inhalation,

are now easily accessible at the bedside for bedside evaluations [10].

2.Aim of the work

The aim of this study is to illuminate the applications of diaphragmatic ultrasonography in intensive care unit

3.Patients and Methods

- This study was conducted prospectively in the Critical Care department, Benha University hospital from January 2020 to December 2021. The ethics committee of our institution approved the study protocol, and written informed consent was obtained from each patient's representative family

Inclusion Criteria: -

- mechanically ventilated patients &other ICU non mechanically ventilated patients with clinical evidence of DD who undergo DU &their sonographic findings will be correlated to clinical outcome.

Approval of patients.

Groups allocation:

- Patients were classified into two main groups :
- Group I : Non mechanically ventilated patients
- Group II : Mechanically ventilated patients
- Each group was divided into three subgroups
- Subgroup I : Respiratory failure patients
- Subgroup II : Stroke patients
- Subgroup III : Sepsis patients

Exclusion criteria:

Patients who sonographic findings couldn't be correlated with their clinical outcome.

Patients who have received sedative drugs or neuromuscular blocking agents within past 24 hours.

Patient refusal to participate in the study.

Measurements:

Two sets of clinical and US measurements were taken:

- The first measurement (Day zero) was done within 2 hrs of recruitment.
- The second measurement (Day 7) was done after 7 days.

Each set of measurements included:

- laboratory measurements: ABG: (PH, $PaCO_2$, PaO_2, HCO_3, and SaO_2), Hemoglobin (HB), and White blood cells (WBCs).
- Diaphragmatic US:

Evaluation of diaphragmatic thickness (DT)and diaphragmatic thickness fraction (DTF) : as percentage from the formula: (thickness at end inspiration– Thickness at end-expiration)/Thickness at end Expiration * 100.

and diaphragmatic excursion (DE).

3. Results

1. Socio-Demographic characteristics of the participants.

The mean age of cases in group1 was 59.8±12.35 years while in group2 it was 63.64±12.93 years. 27 Female patients and 23 male patients were allocated in group1 while group 2 consisted of 25 female patients and 25 male patients .As regard patients weight the mean weight of cases in group1 was 81.6±11.389 kg while in group2 it was 79.28±15.13 kg. Table (1(

2. laboratory results:

As regard patients ALT the mean value of cases in group1 was 43.14±19.75 while in group2 it was 50.1±32.99

As regard patients AST the mean value of cases in group1 was 55.66±19.36 while in group2 it was 43.62±58.48

As regard patients UREA the mean value of cases in group1 was 45.4±22 while in group2 it was 49.62±29.54

As regard patients CREATININE the mean value of cases in group1 was 1.852±0.700 while in group2 it was 1.996±0.80. Table (2)

Table (1) Demographic data of the studied patients (n=100)

		Group 1	Group2	Test	p.value
Age		59.8±12.35	63.64±12.93	1.518	.132
Sex	**M**	23	25	0.16	0.68
	F	27	25		
Weight		81.6±11.389	79.28±15.13	0.911	0.365

Table(2) Liver function & Kidney function tests of the studied patients(n=100)

	Group1	Group2	Test	p.value
Alt.	43.14±19.75	50.1±32.99	1.280	.204
Ast.	55.66±19.36	43.62±58.48	0.629	.532
Urea	45.4±22	49.62±29.54	0.81	0.42
Creatinine	1.852±0.700	1.996±0.808	0.952	0.344

As regard patients HB the mean value of cases in group1 was 9.94±1.95 while in group2 it was 9.22±1.77

As regard patients HCT the mean value of cases in group1 was 28.78±5.06 while in group2 it was 28.28±10.65

As regard patients PLATELETS the mean value of cases in group1 was 221.56±81.54 while in group2 it was 221.56±80.73

As regard patients TLC the mean value of cases in group1 was 20.46±7.11 while in group2 it was 20.46±5.48>

As regard cbc of the studied patients ,the **p** value of all its item was non significant except for the hb result which has **p** value of 0.059 which is statistically significant indicating the importance of HB as determinat factor in clinical outcome of the patients.

Table (3) CBC of the studied patients(n=100).

	Group1	Group2	Test	p.value
Hb	9.94±1.95	9.22±1.77	1.19	0.059
Hct	28.78±5.06	28.28±10.65	0.3	0.765
Plt	221.56±81.54	221.56±80.73	0.449	0.654
Tlc	17.86±7.65	20.46±5.78	0.960	0.040

Arterial Blood Gases

As regard patients PH the mean value of cases in group1 was 7.27±0.069 while in group2 it was 7.32±0.058 .
As regard patients PCO2 the mean value of cases in group1 was 47.76±15.32
while in group2 it was 41.3±11.15 .
As regard patients PO2 the mean value of cases in group1 was 72.04±14.25while in group2 it was 85.26±9.06 .
As regard patients HCO3 the mean value of cases in group1 was 24.38±5.86while in group2 it was 25.16±4.96 .

Table (4) arterial blood gases of the studied patients (n=100).

	Group1	Group2	Test	p.value
pH	7.27±0.069	7.32±0.058	-4.117	0.000
PCO2	47.76±15.32	41.3±11.15	2.409	0.018
PO2	72.04±14.25	85.26±9.06	-5.534	0.000
HCO3	24.38±5.86	25.16±4.96	-.718	0.475

Electrolytes:

As regard patients Na the mean value of cases in group1 was 140.14±4.91while in group2 it was 139.64±8.075 .
As regard patients K the mean value of cases in group1 was 3.64±0.82
while in group2 it was 3.65±0.98 .
As regard patients Mg the mean value of cases in group1 was 2.072±0.49while in group2 it was 2.23±0.49 .

Table (5) electrolytes of the studied patients (n=100).

	Group1	Group2	Test	p.value
Na	140.14±4.91	139.64±8.075	0.374	0.709
K	3.64±0.82	3.65±0.98	0.044	0.965
Mg	2.072±0.49	2.23±0.49	1.64	0.1

3- Radiological results:-

As regard patients DTF on admisssion the mean value of cases in group1 was 37.08±9.48 while in group2 it was 32.28±6.53
As regard patients DTF on day7 the mean value of cases in group1 was 37.66±7.82
while in group2 it was 34.64±6.61
As regard patients DE on admisssion the mean value of cases in group1 was 16.7±4.57while in group2 it was 17.92±4.81.
As regard patients DE on day7 the mean value of cases in group1 was 16.78±4.79while in group2 it was 18.36±5.32
As regard patients DT on admisssion the mean value of cases in group1 was 1.69±0.47while in group2 it was 1.59±0.43.
As regard patients DT on day7 the mean value of cases in group1 was 1.94±0.49while in group2 it was 1.61±0.48
As regard patients ICU LOS the mean value of cases in group1 was 9.68±3.27 days while in group2 it was 17.38±5.37 days

Table (5) diaphragmatic measurements of the studied patients (n=100).

		Group1	Group2	Test	p.value
DTf	Day 0	37.08±9.48	32.28±6.53	2.946	0.004
	Day 7	37.66±7.82	34.64±6.61	2.084	0.040
DE	Day 0	16.7±4.57	17.92±4.81	-1.299	0.197
	Day 7	16.78±4.79	18.36±5.32	-1.558	0.122
DT	Day 0	1.69±0.47	1.59±0.43	.809	0.420
	Day 7	1.94±0.49	1.61±0.48	3.447	0.001
ICU LOS		9.68±3.27	17.38±5.37	-8.656	0.000
Outcome		0.54±0.50	0.48±0.50	.595	0.553
improved (1)		37	18		
Not improved(0)		13	32		
Diagnosis	RF	16	16		
	ST	16	16		
	SP	18	18		

5. Discussion

Diaphragmatic ultrasound has been shown to play an important role in the clinical outcomes of both mechanically ventilated and non-mechanically ventilated patients.

The diaphragm, like all other organs, may contribute to the widespread organ failure seen in many patients who arrive in the ICU after a traumatic event.

Sepsis and illness severity dictate this, and it's linked to a greater fatality rate. Demoule and others [11[.

A second possibility is that people who have never had DD might develop it during their ICU stay. ICU-acquired neuromuscular problems have been linked to this condition. In addition, it might be a detrimental side effect of MV itself, known as VIDD [12].

According to Valette and colleagues [13], who studied medical ICU patients, the importance of DU in detecting DD and its link with patient outcomes has been confirmed in our investigation.

100 patients, ranging in age from 37 to 83, took part in our research. Each of the two primary categories of patients was then separated into three subgroups:

Non-mechanically ventilated patients were separated into three groups for the purposes of this study.

Group A: 16 ICU patients with Respiratory failure.

16 stroke patients were admitted to the ICU in subgroup b.

A total of 18 patients with sepsis were admitted to the ICU in this subgroup.

There were three subgroups of mechanically ventilated patients in Group 2;

Group A: 16 ICU patients with Respiratory failure.

ICU admissions with ischemic stroke in subgroup B: 16 patients

18 individuals were brought to the ICU with sepsis in Subgroup C.

There was a statistically significant difference in the mean age of cases between groups 1 and 2 (59.812.35 years vs. 63.6412.93 years, p =.00132). There were 25 female patients and 23 male patients in group 1, and 25 female patients and 25 male patients were in group 2. When it comes to patient weight, the average weight of patients in group1 was 81.6 kg, whereas the average weight of patients in group2 was 79.28 kg.

Ultrasound was used to assess diaphragmatic function in patients with chronic obstructive lung disease (COPD) during ICU admission, and these findings were in agreement with Adel et al. (14) who found that p value 0.18 did not show a statistically significant difference between the two groups of patients studied when it came to the age of the patients. We found that their age ranged from 57 to 66.2 years old, which is similar to our study's age range. As well as Adel et al [14].

In this investigation, there was no statistically significant difference in patient age between the groups analysed. NMV group 58.8612.23 and 62.4612.79, respectively, had a p value of 0.132 for the mean SD of the two groups of research. 63.3313.101 and 62.8812.625 in the (enhanced and non-improved) MV group respectively.

Hb, TLC, Ph, Pao2, and PaCO2 were all statistically significantly different among the groups examined in this study (arterial partial press of carbon dioxide).

MV patients had a statistically significant drop in haemoglobin, with a p value of 0.059, showing the relevance of haemoglobin as a clinical determinant.

For Ph, the NMV and MV groups differed statistically significantly (p value.000).

NMV and MV groups showed a statistically significant difference in Pao2 (p value.000).

With a p value of.018, the NMV and MV groups differed statistically significantly in Paco2.

There was a statistically significant difference between the NMV and MV groups in Tlc, and the p value was.040

Demoule et al. [11] also came to the same conclusion, concluding that severe sepsis and septic shock caused diaphragmatic dysfunction, resulting in the generation of free radicals, mitochondrial malfunction, calpain activation, and caspase activation. There was a higher risk of diaphragmatic ultrastructural damage and ventilator-induced DD in sepsis patients who were on mechanical ventilation, according to Demoule et al. [11].

Other laboratory results such as ALT, AST, Urea, Creatinine, Hct, Platlets, Hco3, Na, K, and Mg showed no statistically significant differences between the two groups of the research, with p values of.204,.532, 0.42, 0.344,0.765, 0.654, 0.709, 0.965, 0.1 correspondingly.

With p values of.004 at day 0 and.040 at day 7, there was a statistically significant difference between the study groups in terms of US measurement (DTF) and patient outcomes.

According to Goligher et al., [15], TF is viable and highly producible, which is in agreement with our findings.

On the other hand, a research conducted by Demoule et al. [11] demonstrated an association between US measurement (DTF) and patient outcomes such duration of stay in the intensive care unit (ICU), ICU mortality, and failure to wean off mechanical breathing, all with a p value of less than 0.01.

23 patients (53% of the group) had DD on admission, while the other group had no DD on admission (20 patients 47 percent).

A statistically insignificant change in DT at day 0 was found, whereas a statistically significant difference in (DT) at day 7 was found.

Farghaly and Hasan also agreed with similar findings on DT and DTF [16].

Their research was designed to examine the effect of diaphragmatic thickness and excursion, measured by US, in predicting patient outcomes.. Results from the DE and DTF tests on 54 patients admitted to the ICU demonstrate (87.5 percent , and 90 percent sensitivity

respectively and 71.5 percent , and 64.3 percent specificity respectively.)

Determination of DE at days 0 and 7 was not statistically significant, however (p value =.197,.122).

Umbrello et al., (17) found no link between DT and patient outcomes in a trial of 25 patients admitted to the ICU after surgery, with a p value of 0.981.

While Valette et al. (13) observed a strong link between DE and the diagnosis of DD in their research of 22 patients admitted to the medical ICU with acute respiratory failure, these findings regarding (DE) were not (ARF).

the following are the steps in diagnosing DD During unsupported deep breathing in 2D mode and M mode, paradoxical movement or immobility of the hemidiaphragm was characterised as diaphragmatic paralysis, whereas diaphragmatic paresis was defined by an excursion of less than 10 mm of the hemi-diaphragmDTF rather than DE was considered a credible indicator of respiratory effort and diaphragmatic contractile function by Umbrello et al. (17), who concurred with these findings on DTF and DE.

An earlier study by Farghaly and Hasan (2017a) found that DTF percentages below 34.2 percent were associated with the best sensitivity (90 percent) of all diaphragmatic parameters, but also with the highest false-positive rate (64.3 percent), when it came to accurately predicting good outcomes for patients.

DTF greater than 36% was linked to better patient outcomes by Ferrari et al., 2014, who observed this correlation.

According to Eman and Ahmad 2017, DE >1.5 cm has a 97.3 percent sensitivity, 85.2 percent specificity, 94.4 percent PPV, 90.6 percent NPV, and an accuracy of 91.9 percent when the cut-off value for DTF >30 percent is used, while DE >1.5 cm has an accuracy of 91.9 percent when the cut-off value for DE is used (87.9 percent).

In their research, DiNino et al., 2014 found that the combined sensitivity and specificity of DTF 30% for improved patient outcomes were 88% and 71%, respectively. The PPV and NPV were 91 percent and 63 percent, respectively, according to the results of this study. Patients' outcomes may be predicted by using ultrasound measurements in which the diaphragm thickens in the apposition zone.

There are conflicting and inconclusive results from related investigations, and the clinical importance of DE and DTF is currently debated. DE was shown to be highly linked with transdiaphragmatic pressure by Lerolle et al.(21), who hypothesised that DE may represent DD.

According to this study, there was a statistically significant difference in the length of time spent in the ICU between the two groups evaluated (improved and non-improved).

Mean and standard deviation were respectively 9.973.60 and 12.33.78. Demoule and colleagues (11), with p value 0.035, found this to be consistent.

With a p value of.158, it was insignificant in the MV group (improved and unimproved). The mean SD was 15.943.24 and 18.186.16 for the two groups, respectively.

6. Conclusion

When used in concert with other critical care components, diaphragmatic ultrasonography measurements may provide a thorough assessment of the critically sick patient.

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