SONOGRAPHIC EVALUATION OF THE HEART, LUNG AND DIAPHRAGM DURING WEANING FROM MECHANICALLY VENTILATED CRITICALLY ILL PATIENTS

Nahed E. Youssef, Adel M. Alansary, Adel A. Habib,*Fady N. Guirguis

Department of Anesthesia and Intensive Care medicine Faculty of Medicine-Ain Shams University
*Intensive Care Registrar at Dar Al Fouad Hospital, Egypt

Corresponding Author:
Fady Nader AbdelmessihGuirguis

Mobile: (+2) 01005870543

E-mail:
fadyguirguiss@gmail.com

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ABSTRACT:

Background*: Failure of weaning is a commonly encountered problem that faces intensivists, unfortunately this is a multifactorial condition and includes multiple interplays between cardiac and pulmonary functions. Timing is critical when determining if a patient can be successfully extubated. Premature discontinuation of mechanical ventilation may lead to increased cardiovascular and respiratory stress, CO2 retention and hypoxemia with up to 25% of patients requiring reinstitution of ventilator support. Unnecessary delays in weaning from mechanical ventilation also can be deleterious.*

Aim of work: *To evaluate the value of echo, lung ultrasound and diaphragm ultrasound as a predictor of weaning outcomes compared to clinical weaning criteria.*

Patients and methods: *Fifty patients were involved in the present study. They were admitted in the ICU at a tertiary hospital. They received the conventional measurements for weaning and echo, lung ultrasonography diaphragm ultrasonography during weaning and after extubation. We assessed the TAPSE, EF, E/A ratio, lung score, diaphragm excursion and thickening. All ultrasonography findings were gathered and compared with some of the usual clinical weaning tools such as arterial blood gas and respiratory mechanics. The findings were statistically analyzed.*

Results:*31 patients were successfully weaned from mechanical ventilation according to the study criteria representing 62% and 19 patients failed weaning from mechanical ventilation representing 38%. Lung ultrasound and diaphragm thickening fraction only found to be significantly accurate predictors of weaning success or failure.*

Conclusion: *lung ultrasound score and diaphragm thickening fraction can be used as predictors of weaning outcomes.*

Key words: *Sonography, heart, lung, diaphragm, mechanical ventilation, critical ill patients, weaning*

INTRODUCTION:

Weaning is the gradual withdrawal of mechanical ventilation and the continuation of spontaneous breathing. Peñuelas et al. analyzed 2714 mechanically ventilated patients for more than 12 hours who were weaned and underwent scheduled extubation. They found that 1502 patients (55%) could be classified as simple weaning, 1058 patients (39%) as difficult weaning, and 154 (6%) as prolonged weaning (>7 days)[1]. Variables associated with prolonged weaning were: severity at

admission (according to Simplified Acute Physiology Score II), duration of mechanical ventilation before first attempt of weaning, chronic pulmonary disease other than chronic obstructive pulmonary disease, pneumonia as the reason to start mechanical ventilation, and level of positive end-expiratory pressure applied before weaning. The prolonged weaning group had a non-significant trend toward a higher rate of re-intubation, tracheostomy, and significantly longer length of stay and higher mortality in the intensive care unit[2].

Bickenbach et al. found that prolonged weaning and mechanical ventilation are independent predictors of ICU discharge and 1-year mortality[3]. Also Thille et al., found that, compared with successful extubation, failed extubation lead to a marked clinical deterioration[4]**.** Furthermore, unsuccessful weaning was associated with worse outcome[5]**,** higher risk of myocardial ischaemia[6]and perhaps psychological trauma[7]**.**

About 20% to 30% of patients found to be difficult to wean from mechanical ventilation. The pathophysiology of difficult weaning is complex. Accordingly, detecting the cause for difficult weaning and subsequently developing a management strategy require a dedicated clinician with in-depth knowledge of the pathophysiology of weaning failure. In the majority of patients, mechanical ventilation can be discontinued as soon as the underlying pathology for acute respiratory failure has been ameliorated. Weaning failure is when a weaned patient fails to pass a spontaneous-breathing trial or the needs re-intubation within 48 hours after extubation[8]. Identification of reliable predictors of weaning failure may represent potential avenues of treatment that could reduce the incidence of weaning failure and its associated morbidity.

Several ventilatory parameters have been evolved for identifying the right time for starting a weaning trial, however, none of them have met the criteria required to provide satisfactory accurate success rates[9].

AIM OF WORK:

Evaluate the ability of ultrasonography (Heart, lung and Diaphragm) to predict the weaning outcome during and after the weaning process compared to clinical data in critically ill patients.

PATIENTS AND METHODS:

50 patients were enrolled in a prospective observational study in the intensive care at a tertiary hospital.

This study included patients with ages 18 to 90 years from both sexes fulfilling weaning criteria after at least 48 hours of mechanical ventilation after amelioration or resolution of original cause for mechanical ventilation. The weaning criteria are:

Stable respiratory and hemodynamic conditions for SBT, Arterial line (all lines will be inserted under complete aseptic conditions), Minute Ventilation (MV) 5-8 liter per minute, Maximal Inspiratory Pressure (MIP) -20 to -30 cm H2O, Respiratory Rate (RR) <30 breath per minute, Rapid Shallow Breathing Index (RSBI) <104, PaO2/FIO2 ratio ≥ 150, FI02≤ 0.40, Sp02 ≥ 92%, PaO2 ≥ 60 and PEEP ≤8 cmH20., Heart rate 60-100 beat per minute, Systolic blood pressure 90-150mmhg, No or minimal vasopressors adrenaline or levophed< 200ng/kg/min., GCS>8, no continuous sedation infusion or neuromuscular blocking agents, Afebrile, Adequate heamoglobin ≥8 g/dl

Sonographic criteria for successful weaning:

Diaphragmatic excursion >1.1 cm, diaphragmatic thickening fraction (DTF) >30-36%, Systolic function > 40%, E/A <2,

Tricuspid Annular Plane Systolic Excursion (TAPSE) >1.2 , Lung score <13

While patients with laryngeal stridor, tracheostomy, arrhythmia, no echogenicity, paraplegia above the level of 8th thoracic vertebrae, Patients with any cause of diaphragmatic weakness or paralysis including muscular dystrophies, neuro-muscular diseases., Palliative ventilated patients with malignancy, ineffective cough, Inability to protect airways, GCS < 8, BMI > 35, Age < 18 year, and pregnant women were excluded from the study.

Sampling method:

All patients fulfilling inclusion criteria were included.

Ethical considerations:

Free and independent consent without coercion., Provision of informed consent., Maximize benefit and minimize harm., Equal opportunity to enjoy benefits., Provision of beneficial treatments to the population (social justice)., Risks and benefits; any measures taken to reduce risks., Confidentiality assurances.

Study tools:

Lung Ultrasound: Ultrasound was performed with a 5-MHz microconvex probe. Patient position: supine and lateral decubitus positions.

Technique: Each lung was divided into 3 zones underwent examination anteriorly and posteriorly using B-mode to assess the degree of lung aeration with total 12 zones to be examined. The final score, ranging from 0 to 36, is the sum of the values, from 0 to 3, assigned to the LUS patterns visualized in each of the 12 regions examined. The 12 anterior, lateral and posterior areas are defined by anatomic landmarks as stated in the consensus conference recommendations for point of-care LUS. The four ultrasound patterns identified for each area correspond to degrees of lung aeration. While this LUS score calculated on 12 chest regions allows the assessment of the grade of lung aeration at a precise moment, the next step is to score the variation in aeration in successive stages, for instance before and after treatment**(10)**.

Diaphragmatic Ultrasound: ***Diaphragm thickness*** will be measured using a 7–10 MHz linear ultrasound probe set to B mode. The right hemidiaphragm will be imaged at the zone of apposition of the diaphragm and rib cage (intercostally perpendicular to the chest wall) in the midaxillary line between the 8th and 10th intercostal. All patients will be studied with the head of bed elevated between 20° and 40°. End-expiration and end-inspiration was guided by flow time curve. The per cent change in diaphragmatic thickening between end-expiration and end-inspiration will be calculated as (thickness at end-inspiration (Tinsp.) −thickness at end-expiration (Texp.) /thickness at end-expiration(Texp.))×100 (Tinsp – Texp/Texp) and will be called diaphragmatic thickening fraction (DTF)[11]. ***Diaphragmatic-excursion***: The convex probe will be placed subcostally parallel to the intercostal space to measure the range of the diaphragmatic movement using M-mode method with the cursor crossing the diaphragm and assess the high and low peak points as indicator for the diaphragmatic mobility range**[12]**.

Diastolic dysfunction: Will be assessed by 4 chamber apical view, detecting mitral flow patterns with pulsed wave Doppler.

TAPSE will be assessed by M-mode in an apical four-chamber view, placing the M-mode cursor on the lateral tricuspid annulus. Maximum plane systolic excursion of the lateral annulus is measured.

Study procedures:

50 patients will be enrolled after 30 minutes of spontaneous breathing trial to assess the possibility of successful weaning and 30-120 minutes after extubation to assess high risk patients for reintubation. Assessment of the diastolic and systolic

dysfunction, right ventricular dysfunction using Tricuspid Annular Plane Systolic Excursion (TAPSE), lung aeration and diaphragmatic function by measuring the thickness and excursion will be done. Weaning, extubation and/or reintubation will be done according to clinical judgment by the imtensivist. The treating team will be blinded to the ultrasound results, and the research team will not have a role in deciding whether or not a patient will be extubated. A successful extubation is defined as spontaneously breathing for >48 h following extubation and the patient will be included in group "**S**". A failed extubation is defined as someone who was reintubated within 48 h and the patient will be included in group "**F**". The weaning will be according to the weaning criteria stated in inclusion criteria.

Statistical analysis:

Data will be coded, entered and analyzed using SPSS (statistical package for social sciences) version 20. Descriptive statistics will be done as regards all collected variables. The quantitative variables will be compared using paired t-test or one way ANOVA. The comparison of qualitative variables will be performed using chi-square test. P <0.05: significant

Patients were categorized in to two groups:

Group S: those who will succeed in spontaneous breathing for 48 hours after extubation.

Group F: those who will require re-intubation and mechanical ventilation within 48 hours after extubation.

RESULTS:

A total of 50 patients randomly of either gender were enrolled into the study. All the patients completed the study. Out of the 50 patients enrolled, 31 patients were successfully weaned from mechanical ventilation according to the study criteria representing 62% and 19 patients failed weaning from mechanical ventilation representing 38%.

Demographics:

Age (years) and gender were recorded for each patient at the beginning of the study and were compared statistically (table 1 and figure 7,8). The results were divided into patients successfully weaned and patients failed weaning process. The age range was from 33 to 86 years with an over-all mean of 60 years old and SD 13.63 the P value was 0.774 for the age value which represents no statistical significance between both groups.

Table 1: Age and gender of patients enrolled

	Group S (n=31)	Group F (n= 19)	p-value
Age(years)	59.58 ± 14.07	60.7 ± 13.22	0.774
Gender(M/F)	19/12	7/12	1

Respiratory rate was recorded for each patient after 30 minutes of SBT and were compared statistically (table 2) and found to be statistically significantly lower in the successful group with p value of 0.013`

Heart rate, systolic blood pressure, SpO2 and GCS was recorded for each patient after 30 minutes of SBT and were compared statistically as shown (table 2) and showed no statistical significance between the two groups with p value more than 0.05.

Table 2: Hemodynamics values, GCS in successful and failed groups

	Group S (n=31)	Group F (n= 19)	p-value
*RR	18.23±4.7	21.63±4.2	0.013
SpO2	97.2 ±2.4	96.9± 2.9	0.686
HR	76.9 ±10.09	78.57± 11.77	0.602
SBP	127.09 ±15.3	123.2± 18.43	0.425
GCS	14(12-15)	14(12-15)	0.697

Clinical weaning indices:

MV (figure 2) and MiP was both recorded for each patient after 30 minutes of SBT and were compared statistically as shown in table 3. MV was statistically significantly lower on those who succeeded the weaning process with p value of 0.016. As for MiP it showed a statistically significantly higher values in the successful group with a p value of 0.025.

As regard to TV, RSBI and PaO2/FiO2 ratio, they all showed no statistically significant difference in their values when recorded between both groups as their p value was above 0.05 (table 3).

Table 3: Values of clinical weaning indices in successful and failed groups

	Group S (n=31)	Group F (n= 19)	p-value
TV	0.54±0.11	0.58 ±0.11	0.212
*MV	9.99± 3.67	12.6±3.43	0.016
*MiP	-25.09± 2.63	-23.2 ±3.05	0.025
RSBI	35.55 ±9.63	38.7 ±11.68	0.182
PaO2/FiO2	243.7±53.1	251.6± 49.01	0.603

Ultrasound indices:

Diaphragmatic ultrasound

Diaphragmatic thickening fraction was recorded for each patient after 30 minutes of SBT and after 30-120 minutes after extubation were compared statistically as shown in table 4. In the patients who were successful in the weaning trial it showed a statistically significant higher values before and after extubation with p value lower than 0.001.

As for Diaphragmatic excursion its values showed no statistical significance between the 2 groups neither before nor after extubation.

Table 4: Diaphragmatic ultrasound measurements in relation to weaning outcome before and after extubation in successful and failed groups. Diaphragmatic excursion before extubation (diaph. Excursion 1). Diaphragmatic excursion after extubation (diaph excursion 2). DTF before extubation (DTF 1). DTF after extubation (DTF 2).

	Group S (n=31)	Group F (n= 19)	p-value
Diaph Excursion 1	1.36 ±0.38	1.09± 0.93	0.163
Diaph Excursion	1.28± 0.39	1.11± 0.98	0.392
*DTF 1	31.87± 5.41	25.6± 5.37	<0.001
*DTF 2	32.1±5.87	25± 5.65	<0.001

Lung Ultrasound:

Lung score was recorded for each patient after 30 minutes of SBT and after 30-120 minutes from extubation and the values was found to be statistically significantly lower in successful group before and after extubation with p value less than 0.001 (figure 1).

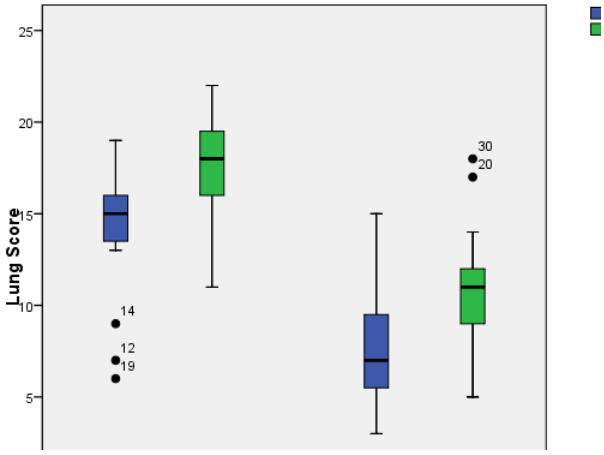

Diagram 1: Graph illustrating diaphragmatic thickening fraction values before and after extubation in successful and failed group

Echocardiographic indices:

TAPSE was recorded for each patient after 30 minutes of SBT and 30-120 minutes after extubation. Before extubation TAPSE records appeared to be statistically significantly lower in successfully weaned group only with a p value of 0.026 (table 5). EF and E/a ratio records were statistically insignificant in booth groups (table 5).

Table 5: Echocardiographic indices: EF, E/A ratio and TAPSE before extubation (EF 1, E/A ratio 1, TAPSE 1). EF, E/A ratio and TAPSE after extubation (EF 2, E/A ratio 2, TAPSE 2).

	Group S (n=31)	Group F (n= 19)	p-value
EF 1	53.58 ±6.29	54.78±4.89	0.479
EF2	53.1 ±4.78	54.05 ±3.55	0.455
E/a ratio 1	1.6 ±0.61	1.57 ± 0.66	0.864
E/a ratio 2	1.69 ±0.54	1.67 ± 0.68	0.872
TAPSE 1	1.84 ±0.24	2.005 ± 0.25	0.026
TAPSE 2	1.94±0.22	1.29± 0.246	0.759

DISCUSSION:

The importance DTF was obvious in the study done by Sujay Samanta et al, in this study, adult ICU patients about to receive their first T-piece were included. Ultrasound was used to measure diaphragm characteristics first at pressure support ventilation of 8cmH2O with positive end expiratory pressure of 5 cmH_2O and then later during their first T-piece trial. Results showed that DTF helped predicting the success of weaning and the readiness of patients for a trial of T-peace with sensitivity of 97% and specificity of 81% ($p<0.001$)[13]. Moreover, in another study done by Pirompanich and colleagues in 2018, patients underwent a spontaneous breathing trial (SBT) and for 1 hour then, both hemi-diaphragms were visualized, the DTF was calculated as a percentage, In addition, RSBI was calculated at 1 min after SBT. When

DTF was combined with RSBI, it greatly improved the accuracy for prediction of successful weaning[14]. However in this study, this combination was not tested as RSBI was used as an independent clinical predictor for weaning (along with other clinical values) and was not in the scope of this study. Worth mentioning, that in this study RSBI alone showed no statistical significance between successful and failure group. This might be due to the compensatory action of other respiratory muscles rather than the diaphragm, which would soon fail after liberation from mechanical ventilation. As regards to the significance of DTF in this study, it showed before extubation a highly significantly higher values in the successfully weaned group compared to the failed group, with p value less than 0.001,proving the results that was concluded by Samanta and Pirompancih and their colleagues. Furthermore, by following DTF in this study after extubation, it successfully predicted the need for re-intubation more accurately than clinical indices as there were also a highly significant difference in its values between the successful and failed group with p value less than 0.001.

Concerning diaphragmatic excursion, it showed no statistical significance in this study as a predictor of weaning outcome. A study that combined diaphragmatic excursion, lung ultrasound score and echocardiogram showed that diaphragmatic excursion had the least predictive value compared to markers of left ventricular diastolic dysfunction and loss of lung aeration[15]. Despite this, another recent study found that diaphragmatic excursion, and not thickening fraction, was the best predictor of extubation failure in patients undergoing their first spontaneous breathing trial [16]. These conflicting results, specifically between the study done by Yoo et al. and our study might be due to the lower pressure support (5 cmH2O or lower) used by Yoo and his colleagues during the spontaneous breathing trial as compared to the level of pressure support that we used (10 cmH2O) which obviously affected the diaphragmatic movement in our study. Generally speaking, as regards to diaphragmatic excursion, conflicting results might also be due to variation in the patient populations, particularly with respect to age and sex[17]. Many of the studies included both left and right sides of the diaphragm, but some reported measurements of the right side only. Furthermore, there is variation regarding the time point during a spontaneous breathing trial at which measurements are taken. Also positive end expiratory pressure increases end-expiratory lung volume; the corresponding increase in lung volume lowers the diaphragmatic dome, which can result in decreased diaphragmatic excursion[18].

Soummer and his colleagues derived a lung ultrasound based scoring system in 2012, where an end-SBT LUS <13 is predictive of extubation success. An end-SBT LUS >17 is predictive of post-extubationdistress[10]. In our study LUS had a significant value in predicting weaning outcome. Further studies also have proven its accuracy despite some differences in cut-off values for success and failure[19]. As for our study we used a cut off value of 13 according to Soummer and colleagues.

As regards to TAPSE in this study its results showed no statistical significance as a predictor of weaning outcome with p value of 0.759. Although some studies showed that low TAPSE upon admission are associated with delayed liberation from mechanical ventilation **(20)**. However, this study was dedicated to correlate the duration of weaning in patients who were ventilated with acute pulmonary edema only. So TAPSE might be of significance only in this type of patients who were not included in this study.

Cardiac dysfunction during weaning from mechanical ventilation has been

recognised as a likely contributing factor to weaning failure[21]. In the study by Caille and colleagues [22], E/A ratio before the SBT was not a discriminating parameter for weaning outcome, moreover, a statistically significant higher E/e' in patients who failed as compared to those who were successfully weaned was observed. Indeed, E/e' is thought to be a better echocardiographic index than E/A to detect an increase in LV filling pressure, at least in patients with systolic heart failure. Also in another study conducted by Konomi and his colleagues there was a trend for higher E/e' in patients failing to wean but it did not reach statistical significance. In our study, we only studied the E/a ratio during SBT and the variation in its results in our study was statistically insignificant with p value of 0.864 before extubation and 0.872 after extubation. However, a more detailed study should be done as regards to this.

Conclusion:

In this study, DTF and lung ultrasound were found to be accurate and promising predictors of weaning success or failure before and after extubation, whereas, cardiac echo showed no significance during the weaning process.

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تقييم عن طريق السونار للرئة والقلب والحجاب الحاجز أثناء الفطام من اجهزة التنفس الصناعي لمرضي الحالات الحرجه

ناهد عفت يوسف , عادل محمد الأنصاري ,عادل علاء الدين حبيب ,*فادي نادر عبدالمسيح جرجس

قسم التخدير والعناية المركزة كلية الطب جامعة عين شمس

*أخصائي العناية المركزة مستشفى دار الفواد

مقدمة: من المعروف بالفعل ان الحكم الاكلينيكي المعتمد علي المعطيات الاكلينيكية للفطام من جهاز التنفس الصناعي لا يكون احيانا دقيقا مما يؤدي الي الفطام المبكر او المتأخرو يؤثر بالسلب علي المريض.

فشل الفطام من اجهزة التنفس الصناعي هي مشكلة تواجه عادة متخصصي العناية المركزه, وهي مشكلة متعددة المحاور ما بين وظاءف القلب و وظاءف التنفس. التوقيت أمر بالغ الأهمية عند تحديد ما إذا كان المريض يمكن فطامه من جهاز التنفس الصناعي.

إن التوقف المبكر عن التهوية الميكانيكية قد يؤدي إلى اجهاد القلب والجهاز التنفسي واحتباس ثاني أكسيد الكربون ونقص الأكسجين مع ما يصل إلى٢٥٪من المرضى الذين يحتاجون إلى إعادة دعم أجهزة التنفس الصناعي.

التأخير الغير لازم في الفطام من التهوية الميكانيكية يمكن أيضا أن يكون ضارا. يمكن ان يؤدي الي مضاعفات مثل الالتهاب الرئوي و ضمور الحجاب الحاجز.

الهدف من البحث : تقييم دور الموجات فوق الصوتية (القلب والرئة والحجاب الحاجز) بالمقارنة مع البيانات الكلينينيه للمريض خلال محاولات التنفسي العفوية كجزء من الفطام من التهوية الميكانيكية في المرضى الذين يعانون من أمراض خطيرة.

المرضى والحالات: مرضي علي جهاز التهوئه لاكثر من ٤٨ ساعه, المطابقين للشروط وسيتم تسجيل٥٠ مريضا بعد ٣٠ دقيقة من محاكمة التنفس عفوية لتقييم إمكانية الفطام الناجح و٣٠- ١٢٠دقيقة بعد لتقييم المرضى الذين يعانون من مخاطر عالية لإعادة الإنعاش . سيتم تقييم إختلال البطين الأيمن و الأيسر وتهوية الرئة ووظيفة الحجاب الحاجز عن طريق قياس سمكه ومدى حركته بالسونار

النتائج : وجد أن تقييم درجة تهوئة الرئة و قياس سمك الحجاب الحاجز عن طريق السونار ذات أهمية إحصائية أثناء عملية الفطام من التنفس الصناعي حيث أنهم اظهروا قدرة على توقع نتيجة الفطام سواء بنجاح أو الفشل.

الخاتمة :ينصح باستخدام السونار روتينياً لقياس درجة تهوئة الرئة وسمك الحجاب الحاجز أثناء عملية الفطام من التنفس الصناعي مع الدلالات الاكلينيكية