Since January 2020 Elsevier has created a COVID-19 resource centre with free information in English and Mandarin on the novel coronavirus COVID-19. The COVID-19 resource centre is hosted on Elsevier Connect, the company's public news and information website.

Anaesth Crit Care Pain Med 40 (2021) 100875

Contents lists available at ScienceDirect

Anaesthesia Critical Care & Pain Medicine

journal homepage: www.elsevier.com

Letter to the Editor

Diaphragmatic excursion: A possible key player for predicting successful weaning in patients with severe COVID-19

Keywords:
COVID-19
Diaphragmatic excursion
Ultrasound
Weaning
Mechanical ventilation
Rapid shallow breathing index

To the Editor,

The medical community is suffering from Coronavirus disease 2019 (COVID-19) pandemic. The cardinal cause of death in patients with COVID-19 is respiratory failure; therefore, respiratory support represents the mainstay of their management. Weaning of critically ill patients from mechanical ventilation (MV) is a critical decision for intensivists especially within a pandemic with a shortage of ventilators and an urge need for successful and timely patient disconnection from ventilatory support. Furthermore, failure of patient disconnection and subsequent re-intubation are independent causes of patient mortality. Thus, it is essential to reach adequate criteria for weaning with precise cut-off values. There is mounting evidence for the value of diaphragmatic excursion during weaning [1,2]. However, no data are available for its accuracy in patients with COVID-19. This study evaluates the accuracy of diaphragmatic excursion in predicting weaning outcomes.

Methods

A prospective observational study was conducted in a University Hospital after approval of the institutional research ethics board (N-3-2021) and obtainment of informed consents from the participants' next-of-kin. The study included 22 patients with severe COVID-19 who were invasively mechanically ventilated for 2 days or more. Patients were included when they met the basic criteria for weaning from invasive MV: resolution of the primary pathology, adequate cough, minimal tracheobronchial secretions, PaO_2/fraction of inspired oxygen ratio (P/F ratio) > 200 with positive end expiratory pressure $\leq$ 8 cmH_2O, respiratory rate < 30/min, appropriate *p*H for patients' baseline values, and stable haemodynamic profile on no/minimal vasopressor therapy. Patients with history of diaphragmatic pathology or recent thoracic or upper abdominal surgery were not included.

Ultrasound examination of the diaphragm (Fig. 1) was performed by an expert, using a Samsung HS60 ultrasound machine with a 3–5 MHz curvilinear probe in the semi-recumbent position 15 min after initiation of the SBT.

The probe was placed over one of the lower intercostal spaces in the right anterior axillary line for the right diaphragm, and the left mid axillary line for the left diaphragm. The ultrasound beam was directed to the hemi-diaphragmatic domes at an angle $\geq 70^{\circ}$ and M-mode tracing was initiated. Diaphragmatic excursion was measured as the vertical distance from the baseline to the highest point of inspiration. Three measurements were obtained, and their average was used in data analysis. The data collectors were blinded to the results of ultrasound examination.

Patients were subjected to a spontaneous breathing trial (SBT) on pressure support mode (pressure support 5 cmH2o, positive end-expiratory pressure 5 cmH2O) for 120 min and by its end the patient was extubated if the respiratory and haemodynamic parameters were stable. After extubation, the patients were followed up and divided into successful weaning group (patients who did not require any ventilatory support 72 h after extubation) and failed weaning group (patients who were re-intubated within 72 h after extubation and those who failed by the end of the SBT). The primary outcome of the study was the accuracy of diaphragmatic excursion to predict successful weaning. Other outcomes included: respiratory rate, P/F ratio, rapid-shallow breathing index (RSBI), vasopressor use, acute kidney injury, laboratory investigations, and Acute Physiology and Chronic Health Evaluation (APACHE) score.

The SPSS 21 (Chicago, IL) and MedCalc software were used for analyses. The data were checked for normality using the Shapiro-Wilk test. Data were presented as the means (standard deviations), medians (quartiles), and frequencies (%) as appropriate; and were compared using the Unpaired Student's *t* test, Mann-Whitney *U* test, or Fisher's exact test as appropriate. The area under receiver operating characteristic curve (AUC) (95% confidence interval [CI]) was calculated for predictors of successful weaning. The best cut-off values were determined using the Youden index. The level of significance was set at $p \leq 0.05$.

Results

Twenty-two patients were included in the study. Nine patients were successfully weaned, and 13 patients failed, either by the end of the SBT or after extubation. The successful weaning group had lower age, body mass index, APACHE score, and RSBI; and higher P/

Abbreviations: AUC, area under receiver operating characteristic curve; APACHE, Acute Physiology and Chronic Health Evaluation; COVID-19, Coronavirus disease 2019; MV, mechanical ventilation; P/F ratio, PaO_2/fraction of inspired oxygen ratio; RSBI, rapid-shallow breathing index; SBT, spontaneous breathing trial.

https://doi.org/10.1016/j.accpm.2021.100875

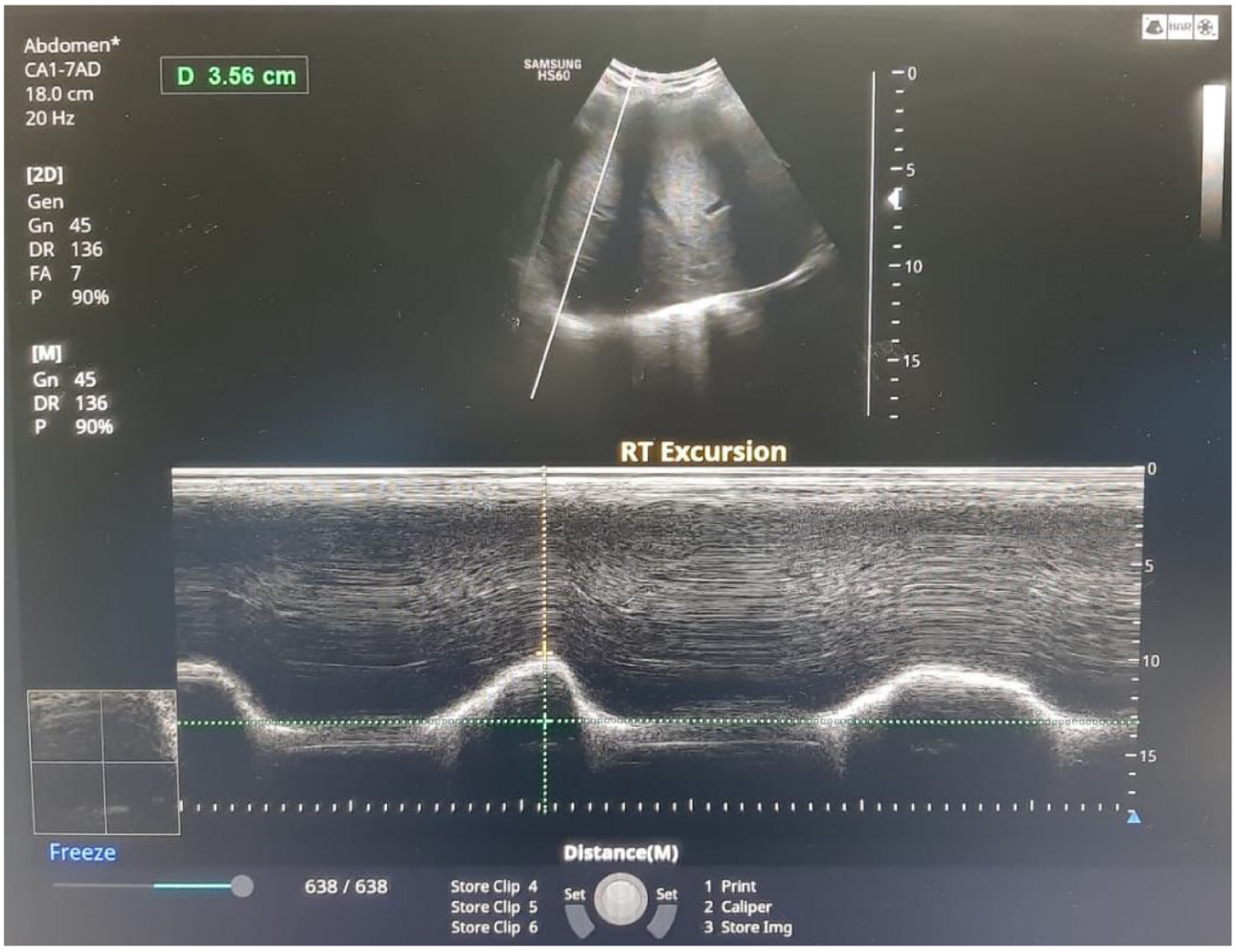

Fig. 1. Ultrasound examination of the diaphragm.

Table 1
Baseline characteristics and weaning predictors. Data are presented as means (standard deviations), medians (quartiles), and frequencies (%).

Variable	Successful weaning group (n?=?9)	Failed weaning group (n?=?13)	*P* value
Age (years)	58?±?10	65?±?10	0.19
Body mass index (kg/m^2)	25 (20–27) *	31 (25–36)	0.01
Male gender (%)	8 (89%)	6 (46%)	0.07
APACHE score	11 (9.5–12.5) *	20 (14.5–24.5)	< 0.01
Days of MV before weaning	3?±?1*	6?±?2	< 0.01
Interleukin-6 (pg/mL)	24 (10–40) *	100 (39–210)	0.01
Serum ferritin (ng/mL)	746 (394–2139)	840 (180–1364)	0.52
D-dimer (mcg/mL)	2.5 (0.74–4.6)	2 (1.2–6.0)	0.92
RSBI (breath/L)	75?±?20*	98?±?21	0.02
P/F ratio	302?±?40*	265?±?39	0.04
Diaphragmatic excursion (mm)			
Right	25 (20–28) *	10 (8.5–10.5)	< 0.01
Left	21 (17–24) *	7 (5.5–8.5)	< 0.01

APACHE: Acute Physiology and Chronic Health Evaluation, MV: mechanical ventilation, RSBI: rapid shallow breathing index, P/F ratio: PaO_2/fraction of inspired O_2.
* denotes statistical significance.

F ratio, and diaphragmatic excursion compared to the failed weaning group (Table 1).

The AUC for predicting successful weaning was highest for the diaphragmatic excursion (right side: AUC [95% CI]: 0.996 [0.838–1.000], sensitivity: 100%, specificity: 92%, cut-off value: 11 mm; left side: AUC [95% CI]: 1.000 [0.846–1.000], sensitivity: 100%, specificity: 100%, cut-off value: 12 mm) followed by the RSBI (AUC [95% CI]: 0.782 [0.557–0.927], sensitivity: 100%, specificity: 54%, cut-off value: ≤ 97) and the P/F ratio (AUC [95% CI]: 0.774 [0.547–0.992], sensitivity: 78%, specificity: 77%, cut-off value: 281) (Fig. 2).

Discussion

We report that diaphragmatic excursion can perfectly predict successful weaning in patients with COVID-19. The diaphragm is the key respiratory muscle, which is responsible for ≈ 70% of the

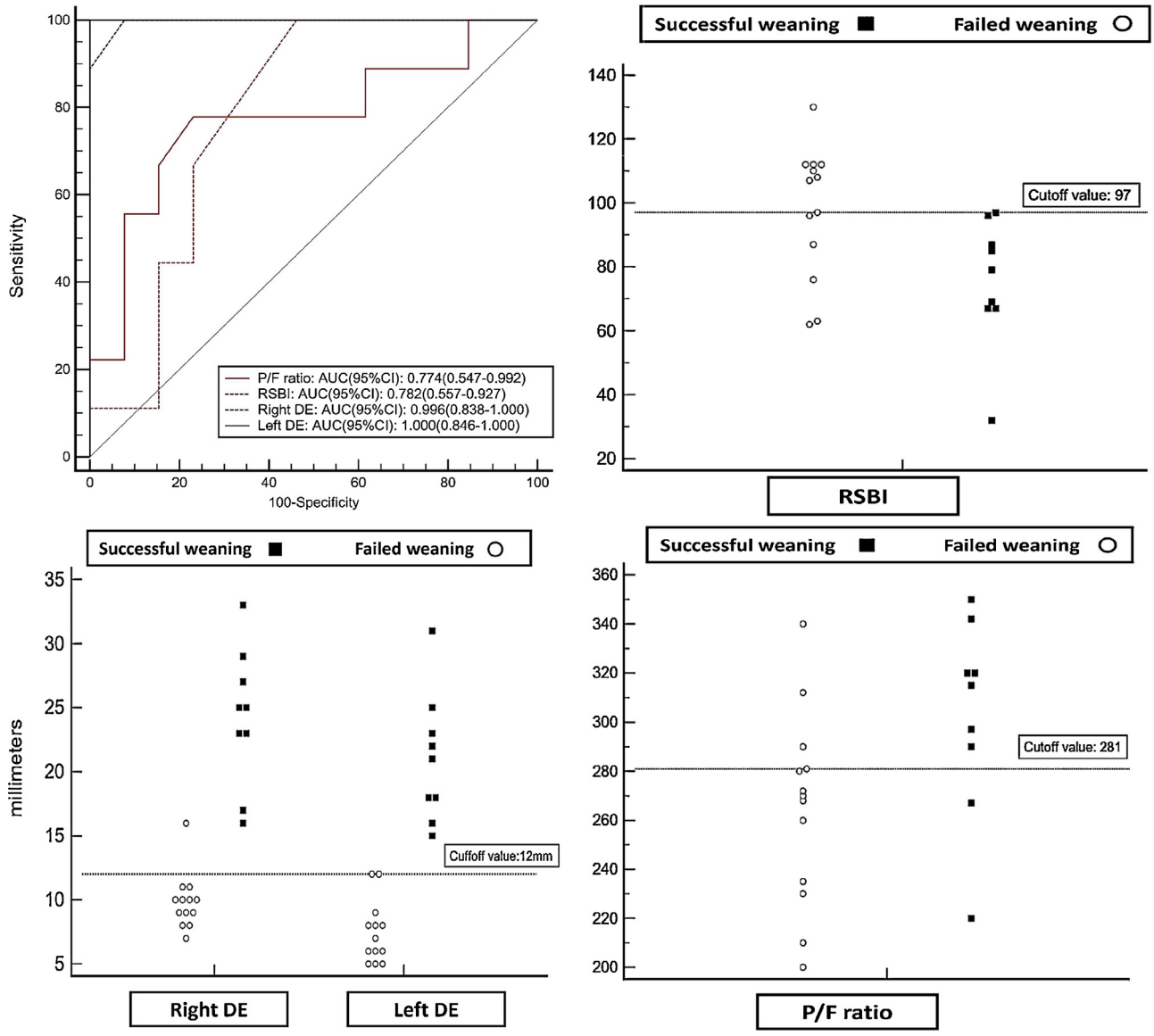

Fig. 2. Area under receiver operating characteristic curve (AUC) for predicting successful weaning.
Legend: Summarised results. Upper left panel: receiver operating characteristic curves for predicting successful weaning. Upper right panel: individual readings of the RSBI. Lower left panel: individual readings of the DE, individual readings of the P/F ratio. AUC: area under the curve, CI: confidence interval, DE: diaphragmatic excursion, P/F ratio: PaO2/fraction of inspired oxygen, RSBI: rapid shallow breathing index.

tidal volume during inspiration [1]. Diaphragmatic dysfunction is common in critically ill patients and a pivotal factor in failure of weaning from MV. Ultrasonographic evaluation of diaphragmatic dysfunction had gained interest as a simple and accurate measure for respiratory workload during MV. Diaphragmatic excursion is positively correlated with lung inspiratory volumes and can accurately reflect the muscle strength and function [2,3]. Furthermore, diaphragmatic excursion is an index for respiratory muscle fatigue during the SBT. Some authors had reported a lower accuracy for diaphragmatic excursion compared to most of the available data and suggested that this lower accuracy is due to the heterogeneity of the patients included in the meta-analyses [4,5]. Therefore, separate evaluation of different groups of patients is essential to find the validity of this useful measure during weaning. Our study is the first to evaluate the value for diaphragmatic indices in patients with COVID-19. We found an outstanding value for diaphragmatic evaluation during the SBT and none of the patients whose diaphragmatic excursion exceeded 12 mm were re-intubated.

The pandemic pattern of COVID-19 resulted in overwhelming number of patients that exceeded, sometimes, the hospital capacities and ended with collapse of the healthcare system in some countries. Thus, proper and timely weaning would help in faster discharge and subsequent bed clearance.

In conclusion, diaphragmatic excursion has an excellent ability for predicting weaning outcome in COVID-19 patients. A patient with diaphragmatic excursion $>$ 12 mm during the SBT is unlikely to be re-intubated.

Funding

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors

Registration

This study was not registered in a trials register; however, study protocol and any data related to this study can be available upon request from the corresponding author.

Conflict of interests

The authors declare that they have no conflict of interest with this work.

Acknowledgments

The authors would like to acknowledge all the residents and assistant lecturers in their department.

References

[1] Qian Z, Yang M, Li L, Chen Y. Ultrasound assessment of diaphragmatic dysfunction as a predictor of weaning outcome from mechanical ventilation: a systematic review and meta-analysis. BMJ Open 2018;8:1–10.
[2] Turton P, ALAidarous S, Welters I. A narrative review of diaphragm ultrasound to predict weaning from mechanical ventilation: where are we and where are we heading? Ultrasound J 2019;11:2.
[3] Zambon M, Greco M, Bocchino S, Cabrini L, Beccaria PF, Zangrillo A. Assessment of diaphragmatic dysfunction in the critically ill patient with ultrasound: a systematic review. Intensive Care Med 2017;43:29–38.
[4] Llamas-Álvarez AM, Tenza-Lozano EM, Latour-Pérez J. Diaphragm and lung ultrasound to predict weaning outcome: systematic review and meta-analysis. Chest 2017;152:1140–50.
[5] Le Neindre A, Philippart F, Luperto M, Wormser J, Morel-Sapene J, Aho SL, et al. Diagnostic accuracy of diaphragm ultrasound to predict weaning outcome: a systematic review and meta-analysis. Int J Nurs Stud 2021;117103890.

Mina Adolf Helmy, Lydia Magdy Milad, Safinaz Hassan Osman, Mai Ahmed Ali, Ahmed Hasanin*
Department of Anaesthesia and Critical Care Medicine, Cairo University, Cairo, Egypt

*Corresponding author at: Department of Anaesthesia and Critical Care Medicine, Faculty of Medicine, Cairo University, Cairo, Egypt
E-mail address: ahmedmohamedhasanin@gmail.com (A. Hasanin).

Available online 30 April 2021