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Original Article

Reliability of airway occlusion pressure (P0.1) in predicting extubation failure in critically ill patients

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ABSTRACT

Background: The airway occlusion pressure (P0.1) reflects the central respiratory drive and correlates with patients' inspiratory effort. This study aimed to assess whether changes in P0.1 (ΔP0.1) during the spontaneous breathing trial (SBT), as well as SBT-induced changes in the products of P0.1 and the rapid shallow breathing index (RSBI) (Δ(P0.1 × RSBI)) and P0.1 and respiratory rate ((Δ(P0.1 × RR)), can predict extubation failure (EF) in critically ill patients.

Methods: In this bicentric prospective study, we enrolled 114 intensive care unit (ICU) patients who had been mechanically ventilated for more than 48 h and successfully tolerated a 30-min SBT on pressure support ventilation. Respiratory variables, including P0.1 and RSBI, as well as hemodynamic parameters, were recorded within 5 min of SBT initiation and at its completion. EF was defined as the need for reintubation and resumption of mechanical ventilation within 7 days. Areas under the receiver operating characteristic curves (AUCs) were calculated for both relative and absolute ΔP0.1, Δ(P0.1×RSBI), and Δ(P0.1×RR).

Results: Among the 114 patients, 23 (20.2%) experienced EF. At baseline, P0.1, P0.1×RR, and P0.1×RSBI values did not differ significantly between the success and failure groups. During the SBT, P0.1, P0.1×RR, and P0.1 × RSBI increased significantly in the failure group, while remaining unchanged in the success group. Absolute ΔP0.1 demonstrated poor predictive performance for EF, with AUC of 0.69 (P=0.005). In contrast, absolute Δ(P0.1×RSBI), and absolute Δ(P0.1 × RR) showed moderate predictive ability, with AUCs of 0.79 (P<0.001) and 0.76 (P<0.001), respectively. In the multivariable logistic regression analyses, the absolute, but not the relative, ΔP0.1, Δ(P0.1×RR), and Δ(P0.1×RSBI) remained independently associated with EF after adjustment for potential confounders.

Conclusions: Variations in P0.1 and in the combined parameters P0.1×RSBI and P0.1×RR during the SBT provided limited value for predicting EF in critically ill patients.

Trial Registreration: ClinicalTrials.gov, NCT05802745.

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Introduction

The discontinuation of mechanical ventilation, which involves the process of weaning followed by extubation, represents a pivotal stage in the management of critically ill patients, once ventilatory support is no longer required. Nevertheless, even among patients who fulfill standardized readiness criteria and successfully complete a spontaneous breathing trial (SBT), extubation failure (EF) occurs in approximately 10%–30% of cases.[1,2] EF is associated with prolonged mechanical ventilation, extended intensive care unit (ICU) stay, and increased morbidity and mortality.[2] Accordingly, recognizing patients at risk of EF at an early stage remains a crucial objective to improve clinical outcomes.

The withdrawal of ventilatory support often poses significant challenges for clinicians, largely due to the multifactorial and incompletely understood pathophysiology underlying weaning failure. EF may arise from diverse mechanisms, including respiratory, metabolic, and neuromuscular factors, with cardiac dysfunction playing a prominent role. Frequently, EF reflects an imbalance between the capacity of the respiratory muscle pump and the increased demands imposed by both cardiac and respiratory loads.[1,3]

Airway occlusion pressure (P0.1) is defined as the decline in airway pressure (Paw) measured 0.1 s after the onset of inspiration against an occluded airway.[4] Because the maneuver is imperceptible to the patient and does not alter breathing pattern, P0.1 is considered a reliable index of central respiratory drive. The brief occlusion duration minimizes the influence of patient response, rendering the measurement largely independent of respiratory mechanics.[5] Moreover, P0.1 has been shown to correlate with inspiratory effort,[6,7] and in patients receiving assisted mechanical ventilation, it may help identify excessive inspiratory effort.[8]

P0.1 is a non-invasive parameter readily available at the bedside, as it is integrated into most modern ventilators. Historically, elevated P0.1 values during SBTs have been associated with weaning failure,[9] suggesting that increased respiratory drive could predict unsuccessful liberation from mechanical ventilation. However, the few existing studies examining the relationship between P0.1 and EF are old and inconclusive.[10–12] We therefore hypothesized that patients who experience EF would exhibit higher P0.1 values during SBT. The primary objective of the study was to determine whether SBT-induced changes in P0.1 (ΔP0.1) can predict EF. The secondary objectives were to evaluate whether SBT-induced changes in derived P0.1 parameters can predict EF, and to assess whether ΔP0.1 and other derived parameters are independent predictors of EF.

Methods

This prospective study was conducted in two adult ICUs (Cleveland Clinic Abu Dhabi and Amiens University Hospital) between June 2023 and April 2025. The local Ethics Committees at each center approved the study (number: A-2023-014). Informed consent was obtained from all patients or their next of kin. The study was registered on ClinicalTrials.gov (NCT05802745).

Patients

All patients aged 18 years or older who received mechanical ventilation for at least 48 h and satisfied the weaning criteria were eligible for enrollment. The readiness-to-wean criteria we used have been described previously[1]: (1) the resolution or improvement of the underlying cause of respiratory failure for which the patient was intubated; (2) hemodynamic stability, defined as heart rate (HR) <140 beats/min and systolic blood pressure between 90 and 160 mmHg with no or minimal doses of vasopressors; (3) stable respiratory status, defined as oxygen saturation >90% with fraction of inspired oxygen (FiO_2) <0.5 (or arterial oxygen partial pressure [PaO_2]/FiO_2 ≥150 mmHg) and positive end-expiratory pressure (PEEP) ≤8 cmH_2O, respiratory rate (RR) ≤35 breaths/min, spontaneous tidal volume (Vt) >5 mL/kg, and no significant respiratory acidosis; (4) adequate mental status; (5) adequate cough.

The exclusion criteria were as follows: (1) having undergone tracheostomy; (2) do-not-reintubate orders; (3) pregnancy; (4) absence of informed consent; (5) SBT failure.

Weaning protocol

SBTs were performed in semirecumbent patients on pressure support ventilation (PSV) at 5 cmH_2O inspiratory pressure and 5 cmH_2O PEEP, as per the ICU protocol. Inspiratory oxygen fraction (FiO_2) was adjusted for the achievement of an arterial oxygen saturation value >90%, as measured by pulse oximetry (SpO_2). The SBT duration was 30 min as per ICU protocol. The criteria that were used for poor SBT tolerance were[13]: (1) diaphoresis; (2) use of accessory respiratory muscles; (3) RR >35 breaths/min; (4) SpO_2 <90% or FiO_2 ≥50%; (5) HR >140 beats/min or greater than a 20% increase from baseline; (6) Systolic blood pressure >180 mmHg or <90 mmHg; (7) development of cardiac arrhythmias; and/or (8) low level of consciousness. The decision to stop SBT was made by the physicians. Patients who failed SBT were shifted to their previous ventilator mode and were not enrolled in the study.

Patients who completed the SBT were extubated and followed up for 7 days. The medical team (physician, nurse, and respiratory therapist) involved in the extubation decision was blinded to the P0.1 results. EF was diagnosed if the patient was extubated but required reintubation within the following 7 days. Criteria for acute respiratory failure after extubation were the development of at least one of the following: (1) respiratory acidosis with pH <7.32 and arterial CO_2 pressure ($PaCO_2$) >45 mmHg; (2) arterial oxygen saturation (SaO_2) <90% with FiO_2 ≥50%; (3) RR >35 breaths/min; (4) clinical signs of respiratory fatigue.

Post-extubation respiratory failure management was not standardized and left to the physician's discretion.

Measurements

Demographic data, comorbidities, reasons for intubation, duration of invasive mechanical ventilation, ICU length of stay (LOS), hospital LOS, ICU mortality, hospital mortality, Sequential Organ Failure Assessment (SOFA) score and Simplified Acute Physiologic Score (SAPS II), fluid balance over 7 days, and the reasons for EF were collected.

Hemodynamic and ventilatory parameters, including P0.1, were recorded as the average of at least three measurements within 5 min of SBT and at 30 min after SBT initiation.

The rapid shallow breathing index (RSBI: RR/Vt, breaths/min•L), P0.1 × RSBI (cmH_2O × breaths/min•L),[11] and P0.1 × RR were calculated within the first 5 min and at the 30 min of SBT, respectively.

P0.1 was measured by means of the built-in system of the ventilator Getinge group, Servo-u®, Solna, Sweden.

Arterial and central venous blood gas levels were measured using GEM Premier 4000 (Instrumentation Laboratory Co, Paris, France) and Radiometer ABL 90 FLEX PLUS (Radiometer Medical ApS), within 5 min of SBT start and at 30 min after SBT initiation.

Changes in P0.1 (ΔP0.1), RR (ΔRR), RSBI (ΔRSBI), P0.1 × RSBI (Δ(P0.1 × RSBI)), and P0.1 × RR (Δ(P0.1 × RR)) between the beginning and end of the SBT were calculated as relative changes and as absolute changes.

Relative changes:

$$\frac{\text{parameter at the end of SBT - parameter at the beginning of SBT}}{\text{parameter at the beginning of SBT}} \times 100$$

Absolute changes:
parameter at the end of SBT−parameter at the beginning of SBT.

Statistical analysis

The normality of data distribution was assessed using the Shapiro–Wilk test and by visually checking the distribution (histogram) of each variable. Data were expressed as mean± standard deviation (SD) when they were normally distributed and as median and interquartile range (IQR) when they were non-normally distributed. Proportions were used as descriptive statistics for categorical variables. Comparisons of values between the extubation success and failure patients were performed using a two-tailed Student's *t*-test or the Mann–Whitney *U* test, as appropriate. Analyses of discrete data were performed using the Chi-square test or Fisher's exact test when the numbers were small. Pairwise comparisons between the different study time periods were assessed using a paired Student's *t*-test or a Wilcoxon matched-pairs signed-rank test, as appropriate.

Receiver operating characteristics (ROC) curves were constructed to evaluate the ability of ΔP0.1 and other parameters to predict EF. The areas under the ROC curves (AUCs) were compared using the Hanley–McNeil method.[14] The best cut-off values were selected based on the highest Youden index. Sensitivity, specificity, positive predictive value, negative predictive value, positive likelihood ratio, negative likelihood ratio, and their 95% confidence intervals (CI) were calculated for the best cut-off values.

Multivariable logistic regression analyses were conducted to determine whether ΔP0.1, Δ(P0.1 × RR), and Δ(P0.1 × RSBI) were independently associated with EF. Variables associated with EF ($P < 0.1$) in the univariate analysis during SBT, along with clinically relevant variables, were entered into the model. Potential collinearity was evaluated using Spearman's or Pearson's correlation coefficients before the analysis. The model's goodness-of-fit was assessed using the Hosmer–Lemeshow test.

Statistical analysis will be performed using STATA 17.0 (StataCorp LP, College Station, Texas, USA) and MedCalc 15.8 (MedCalc Software, Ostend, Belgium). $P < 0.05$ was considered statistically significant. All reported *P*-values are two-sided.

Variables are typically considered good clinical tools (with good discriminative properties) when the lower limit of the 95% CI for their AUC is greater than 0.75.[15] For this purpose, assuming an EF incidence of 20%, 65 patients were required to achieve 80% power and an alpha risk of 0.05. However, to perform a multivariable logistic regression analysis and adjust for at least five risk factors, we require including at least 20 patients with EF in our study to satisfy the minimum of five events (EF) per variable rule of thumb.[16] Therefore, a total of at least 120 patients are needed to be included in our study (100 patients with successful extubation and 20 patients with EF).

Results

Study population

Of the 3063 patients screened for mechanical ventilation, 255 were eligible for study participation. Among those patients, 134 patients showed SBT failure, and seven patients declined to participate in the study. Thus, the 114 patients who successfully completed their SBTs were enrolled. Of them, 23 patients developed acute respiratory failure within 7 days after extubation and required reintubation (Supplementary Figure S1).

The main characteristics of the cohort are summarized in Table 1. The primary reason for intubation and mechanical intubation at ICU admission was acute respiratory failure caused by pneumonia (38.6%). Prophylactic use of non-invasive ventilation and high-flow oxygen therapy after extubation did not differ between success and failure groups. ICU and hospital LOS were significantly longer, and hospital mortality was significantly higher in the failure group than in the success group (Table 1).

Comparisons between the success and failure groups at the baseline

Body mass index (BMI), SOFA score on ICU admission, and time to SBT were associated with EF (Table 1). At the beginning of SBT, only RSBI was significantly higher in the failure group compared to the success group (Table 2).

Comparisons between the values at the start and end of SBT

Respiratory rate, RSBI, P0.1, P0.1 × RR, and the P0.1 × RSBI products increased significantly from the beginning to the end of the SBT in the failure group, whereas they remained unchanged in the success group (Table 2). At the end of the SBT, these variables were significantly higher in the failure group than in the success group (Table 2). Both the relative and absolute changes in these variables were also significantly greater in the failure group (Table 3).

Ability of ΔP0.1, ΔP0.1×RSBI, and ΔP0.1×RR to predict EF

The ability of relative and absolute ΔP0.1 to predict EF was poor, with AUCs of 0.64 (95% CI: 0.54 to 0.73) and 0.69 (95% CI: 0.59 to 0.77), respectively (Table 4). In contrast, the relative and absolute Δ(P0.1 × RSBI) showed acceptable discrimination for predicting EF, with AUCs of 0.74 (95% CI: 0.65 to

Table 1
Characteristics and outcomes of the study population between the success and failure groups.

Variables	All patients (*n*=114)	Success group (*n*=91)	Failure group (*n*=23)	*P* value
Age (years)	64 (52–73)	64 (52–72)	67 (51–76)	0.300
Weight (kg)	80.6±20.9	82.5±20.4	72.8±21.8	0.047
BMI (kg/m^2)	27.3 (23.1–31.2)	27.5 (24.2–31.6)	24.5 (19.5–29.0)	0.030
BMI > 30 kg/m^2	38 (33.3)	33 (36.3)	5 (21.7)	0.220
Male	77 (67.5)	59 (64.8)	18 (78.3)	0.220
SAPS II score	48.2±16.3	47.7±16.3	50.6±16.6	0.450
SOFA on ICU admission	8.3±3.6	7.9±3.5	10.0±3.5	0.013
Charlson Comorbidity Index	3 (1–5)	3 (1–5)	3 (2–5)	0.160
Comorbidities				
Diabetes	31 (27.2)	24 (26.4)	7 (30.4)	0.700
Hypertension	58 (50.9)	46 (50.5)	12 (52.2)	0.900
COPD	19 (16.7)	16 (17.6)	3 (13.0)	0.760
Chronic heart failure	10 (8.8)	8 (8.8)	2 (8.7)	1.000
Obstructive sleep apnea	11 (9.6)	10 (11.0)	1 (4.3)	0.460
Reasons for intubation				
Pneumonia	44 (38.6)	36 (39.6)	8 (34.8)	0.810
Sepsis	22 (19.3)	18 (19.8)	4 (17.4)	1.000
Acute respiratory distress syndrome	10 (8.8)	7 (7.7)	3 (13.0)	0.420
Stroke	11 (9.6)	9 (9.9)	2 (8.7)	1.000
Cardiac arrest	9 (7.9)	7 (7.7)	2 (8.7)	1.000
Acute on chronic respiratory failure	10 (8.8)	8 (8.8)	2 (8.7)	1.000
Pulmonary edema	3 (2.6)	2 (2.2)	1 (4.3)	0.490
Others	5 (4.4)	4 (4.4)	1 (4.3)	1.000
Time to SBT (days)	7 (4–11)	6 (4–9)	11 (7–17)	0.001
Ventilatory settings on the SBT day				
PEEP (cmH_2O)	5 (5–6)	5 (5–6)	5 (5–7)	0.740
Inspiratory pressure (cmH_2O)	8 (7–10)	8 (7–10)	8 (7–10)	0.600
FiO_2 (%)	35 (30–40)	35 (30–40)	30 (30–40)	0.630
Tidal volume (mL/kg)	6.2 (5.1–7.6)	6.1 (5.2–7.6)	6.8 (5.1–8.5)	0.290
Respiratory rate (breaths/min)	21 (18–26)	20 (18–25)	23 (16–27)	0.340
SOFA on the SBT day	3 (2–4)	3 (2–4)	3 (2–5)	0.540
Hemoglobin on the SBT day (g/dL)	9.2 (8.2–10.2)	9.3 (8.4–10.3)	8.7 (7.8–10.0)	0.220
Fluid balance on the SBT day (mL)	711 (−331 to 2500)	796 (−252 to 3000)	607 (−462 to 1235)	0.570
Extubation to HFO_2 prophylactic	58 (50.9)	45 (49.4)	13 (56.5)	0.540
Extubation to NIV prophylactic	70 (61.4)	55 (60.4)	15 (65.2)	0.670
ICU LOS (days)	16 (10–30)	14 (9–22)	40 (26–57)	<0.001
Hospital LOS (days)	29 (19–46)	25 (15–40)	56 (32–75)	<0.001
Hospital mortality	13 (11.4)	6 (6.6)	7 (30.4)	0.001

Data are expressed as mean ± standard deviation, median (interquartile range), or *n*(%).
BMI: Body mass index; COPD: Chronic obstructive pulmonary disease; FiO_2: Inspired oxygen fraction; HFO_2: High flow oxygen therapy; ICU: Intensive care unit; LOS: Length of stay; NIV: Non-invasive ventilation; PEEP: Positive end-expiratory pressure; SBT: Spontaneous breathing trial; SAPS II: Simplified Acute Physiologic Score; SOFA: Sequential Organ Failure Assessment.

Table 2
Hemodynamic and respiratory parameters at the beginning and the end of SBT in the success and failure groups.

Variables	Success group (*n* = 91)		Failure group (*n* = 23)	
	Beginning SBT	30 min SBT	Beginning SBT	30 min SBT
Heart rate (beats/min)	89±18	91±19*	88±13	88±14
Systolic arterial pressure (mmHg)	131±21	133±20	141±19	141±18
Diastolic arterial pressure (mmHg)	63 (55–73)	64 (57–74)	65 (58–73)	65 (54–78)
Mean arterial pressure (mmHg)	86 (77–95)	89 (80–95)	86 (77–95)	91 (80–98)
Arterial pH	7.43 (7.39–7.45)	7.43 (7.39–7.47)	7.43 (7.40–7.46)	7.41 (7.38–7.45)
Arterial PCO_2 (mmHg)	40.0 (35.3–44.2)	39.9 (35.0–42.9)	40.0 (36.2–46.7)	40.9 (38.5–46.9)
Arterial bicarbonate (mmol/L)	27.5±3.9	27.2±4.0	28.0±4.3	27.5±4.0
FiO_2 (%)	35 (30–40)	35 (30–40)	30 (30–40)	30 (30–40)
PaO_2/FiO_2 (mmHg)	274 (229–350)	279 (229–352)	310 (196–386)	252 (187–342)
Arterial oxygen saturation (%)	97 (96–98)	98 (96–99)	98 (96–99)	97 (95–99)*
Arterial lactate (mmol/L)	1.1 (1.0–1.6)	1.2 (0.9–1.4)	1.1 (0.8–1.4)	0.9 (0.7–1.2)†
Tidal volume (mL)	479 (402–565)	500 (400–550)	417 (356–486)	403 (330–488)†
Tidal volume (mL/kg)	6.1 (4.7–8.1)	6.1 (4.7–7.6)	6.2 (4.4–7.3)	5.7 (4.1–7.4)
Respiratory rate (breath/min)	21 (18–26)	22 (18–25)	25 (20–28)	28 (24–30)†,*
Minute ventilation (L/min)	9.9 (8.7–12.9)	10.0 (8.9–11.4)	9.3 (8.1–11.7)	10.6 (9.7–12.1)*
RSBI (breath/(min•L))	45 (31–60)	44 (33–59)	55 (45–72)†	70 (51–91)†,*
P0.1 (cmH_2O)	1.6 (1.0–2.4)	1.5 (1.1–2.4)	1.7 (1.1–2.2)	2.2 (1.3–3.1)†,*
P0.1 × RSBI (cmH_2O × breath/ (min·L))	75 (42–124)	64 (42–117)	87 (63–140)	164 (73–195)†,*
P0.1 × RR (cmH_2O × breath/min)	34 (20–54)	32 (22–54)	37 (26–55)	52 (33–92)†,*

Data are expressed as mean ± standard deviation or as median (interquartile range).
FiO_2: Inspired oxygen fraction; P0.1: Airway occlusion pressure. PaO_2: Arterial oxygen partial pressure; PCO_2: Arterial carbon dioxide partial pressure; RSBI: Respiratory shallow breathing index; RR: Respiratory rate; SBT: Spontaneous breathing trial.
* $P < 0.05$ comparisons between the beginning and the end of SBT.
† $P < 0.05$ comparisons between success group and failure group.

Table 3
Changes in respiratory parameters between the end and the beginning of SBT.

Variables	Success group (n = 91)	Failure group (n = 23)	P value
Absolute ΔRR (breath/min)	0 (−1 to 1)	3 (1–5)	<0.001
Relative ΔRR (%)	0 (−4.8 to 5.9)	15.4 (3.4–20.0)	<0.001
Absolute ΔP0.1 (cmH_2O)	0.0 (−0.3 to 0.3)	0.4 (0–1)	0.005
Relative ΔP0.1 (%)	0.0 (−0.4 to 0.5)	0.4 (0.0–1.0)	0.040
Absolute ΔRSBI (breath/ (min·mL))	0.0 (−5.3 to 5.5)	7.3 (1.3–20.1)	<0.001
Relative ΔRSBI (%)	0.0 (−10.0 to 12.7)	13.9 (2.3–43.0)	<0.001
Absolute Δ(P0.1 × RSBI) (cmH_2O × breath/ (min·mL))	−1.0 (−11.0 to 18.0)	29.4 (12.1–96.8)	<0.001
Relative Δ(P0.1 × RSBI) (%)	−2.4 (−17.0 to 19.6)	40.3 (6.4–88.5)	<0.001
Absolute Δ(P0.1 × RR) (cmH_2O × breath/min)	1 (−6 to 8)	16 (4–30)	<0.001
Relative Δ(P0.1 × RR) (%)	3.6 (−17.2 to 20.6)	34.1 (13.6–81.3)	<0.001

Data are presented as median (interquartile range).
P0.1: Airway occlusion pressure; RR: Respiratory rate; RSBI: Respiratory shallow breathing index; SBT: Spontaneous breathing trial.

Table 4
Performance of different ventilatory parameters in predicting extubation failure.

Variables	AUC (95% CI)	P-value	Best cut-off value	Sensitivity (95% CI)	Specificity (95% CI)	PPV (95% CI)	NPV (95% CI)	LR^+ (95% CI)	LR^- (95% CI)
P0.1 at the end of SBT	0.65 (0.55–0.73)	0.030	>1.7	70 (47–87)	60 (50–70)	31 (19–45)	89 (78–95)	1.8 (1.2–2.5)	0.5 (0.3–1.0)
RR at the end of SBT	0.75 (0.66–0.83)	<0.001	>23	83 (61–95)	66 (55–75)	38 (25–53)	94 (85–98)	2.4 (1.7–3.4)	0.3 (0.1–0.7)
RSBI at the end of SBT	0.76 (0.66–0.83)	<0.001	>48.2	87 (66–97)	66 (55–75)	34 (22–48)	95 (85–99)	2.1 (1.6–2.8)	0.2 (0.1–0.7)
P0.1 × SBI at the end of SBT	0.75 (0.66–0.83)	0.030	>58.9	96 (78–100)	45 (35–56)	31 (20–42)	98 (87–100)	1.7 (1.4–2.1)	0.1(0.01–0.7)
P0.1 × RR at the end of SBT	0.71 (0.62–0.79)	<0.001	>29	91 (72–99)	45 (35–56)	30 (19–42)	95 (84–99)	1.7 (1.3–2.1)	0.2(0.05–0.7)
Absolute ΔP0.1	0.69 (0.59–0.77)	0.005	>0.5	48 (27–69)	90 (82–95)	55 (31–77)	87 (79–93)	4.8(2.3–10.3)	0.6 (0.4–0.9)
Relative ΔP0.1	0.64 (0.54–0.73)	0.030	>0.34%	52 (31–73)	75 (64–83)	34 (19–52)	86 (73–93)	2.1 (1.2–3.5)	0.6 (0.4–1.0)
Absolute ΔRR	0.84 (0.76–0.90)	<0.001	>2	65 (43–84)	93 (86–97)	71 (48–89)	91 (84–96)	9.9(4.3–22.7)	0.4 (0.2–0.7)
Relative ΔRR	0.82 (0.74–0.88)	<0.001	>7.1%	70 (47–87)	85 (75–91)	53 (34–72)	92 (84–97)	4.5 (2.6–7.9)	0.4 (0.2–0.7)
Absolute ΔRSBI	0.76 (0.68–0.84)	<0.001	>4.6	74 (52–90)	75 (64–83)	42 (27–59)	92 (83–97)	2.9 (1.9–4.5)	0.3 (0.2–0.7)
Relative ΔRSBI	0.74 (0.65–0.82)	<0.001	>6.1%	74 (52–90)	66 (55–75)	35 (22–50)	91 (81–97)	2.2 (1.5–3.2)	0.4 (0.2–0.8)
Absolute Δ(P0.1 × RSBI)	0.79 (0.71–0.86)	<0.001	>24.2	70 (47–87)	83 (74–90)	52 (33–70)	92 (83–96)	4.2 (2.7–7.2)	0.4 (0.2–0.7)
Relative Δ(P0.1 × RSBI)	0.74 (0.65–0.82)	<0.001	>21.8%	70 (47–87)	77 (67–85)	43 (27–60)	91 (82–96)	3.0 (1.9–4.8)	0.4 (0.2–0.7)
Absolute Δ(P0.1 × RR)	0.76 (0.67–0.84)	<0.001	>15.4	57 (35–77)	93 (86–97)	68 (43–87)	89 (81–95)	8.6(3.7–20.1)	0.5 (0.3–0.7)
Relative Δ(P0.1 × RR)	0.74 (0.65–0.82)	<0.001	19.6%	74 (52–99)	74 (63–82)	41 (26–58)	92 (83–97)	2.8 (1.8–4.3)	0.3 (0.2–0.7)

AUC: Area under the ROC curve; CI: Confidence interval; LR^+: Positive likelihood ratio; LR^-: Negative likelihood ratio; NPV: Negative predictive value; PPV: Positive predictive value; P0.1: Airway occlusion pressure; RR: Respiratory rate; RSBI: Respiratory shallow breathing index; RR: Respiratory rate; SBT: Spontaneous breathing trial.

0.82) and 0.79 (95% CI: 0.71 to 0.86), respectively (Table 4). The same findings were observed for the relative and absolute Δ(P0.1 × RR) (Table 4).

The AUCs of relative and absolute Δ(P0.1×RSBI) were significantly higher than those of relative and absolute ΔP0.1 (P=0.003 and 0.004, respectively) (Figure 1). However, the AUCs of relative and absolute Δ(P0.1×RSBI) did not differ from those of relative and absolute ΔRSBI (P=1.00 and 0.67, respectively). Also, the AUCs of relative and absolute Δ(P0.1×RR) were significantly higher than those of relative and absolute ΔP0.1 (P<0.001 and 0.007, respectively) (Figure 1). Moreover, the AUCs of relative and absolute Δ(P0.1×RR) did not differ from those of relative and absolute ΔRR (P=0.25 and 0.29, respectively).

The AUCs for the other variables are presented in Table 4. Fifteen (13.2%) patients failed extubation within 72 h. Redefining EF as occurring within 72 h did not significantly alter these results (Supplementary Table S1).

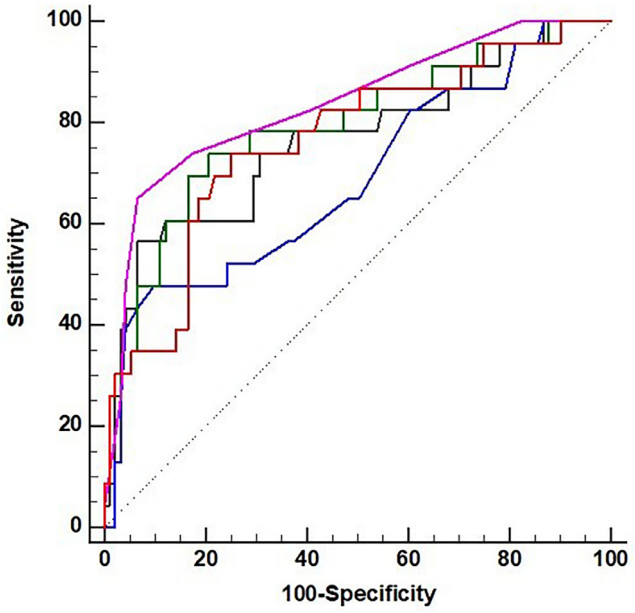

Figure 1. Receiver operating characteristic curves showing the ability of the absolute changes in P0.1 (ΔP0.1) (blue line, AUC=0.69), P0.1 × RSBI [Δ(P0.1×RSBI)] (green line, AUC=0.79), RSBI (ΔRSBI) (red line, AUC=0.76), P0.1×RR [Δ(P0.1×RR)] (black line, AUC=0.76, and RR (ΔRR) (pink line, AUC=0.84) between the beginning of the spontaneous breathing trial (SBT) and at 30 min of SBT to predict the extubation failure.
AUC: Areas under the ROC curves; P0.1: Airway occlusion pressure; RSBI: Respiratory shallow breathing index; RR: Respiratory rate; SBT: Spontaneous breathing trial.

Multivariable analysis for EF prediction

In the univariate analysis (Tables 1 and 3), seven variables (BMI, SOFA score on ICU admission, time to SBT, ΔRR, ΔRSBI, ΔP0.1, and Δ(P0.1×RSBI) were associated with EF (P<0.1). Because of potential collinearity among ΔRSBI and ΔRR (r=0.70), Δ(P0.1×RR) and ΔP0.1 (r=0.92), as well as ΔP0.1 and Δ(P0.1×RSBI) (r=0. 83), three separate multivariable models were constructed, each including five indepen-

dent variables (Tables 5, 6, and 7). It is worth noting that the correlations between Δ(P0.1 × RSBI) and ΔRR (r=0.45), and between Δ(P0.1×RR) and ΔRR (r=0.41), were moderate, indicating no significant concern for collinearity. Absolute ΔP0.1 (Table 5), absolute Δ(P0.1×RSBI) (Table 6), and absolute Δ(P0.1×RR) (Table 7) remained independently associated with EF after adjustment for BMI, SOFA score, time to SBT, and ΔRR. In contrast, the relative ΔP0.1, relative Δ(P0.1×RSBI), and relative Δ(P0.1×RR) were not independently associated with EF (Supplementary Tables S2, S3, and S4 supplementary file).

Precision of P0.1 measurements

The within-subject standard deviation (SD_{within}) of P0.1 (5 repeated measurements) across eight patients was 0.095 cmH_2O, corresponding to a within-subject coefficient of variation (CV_{within}) of 17.4%. The calculated relative least significant change (LSC = CV_{within} ×1.96 × $\sqrt{2}$) was 48.2%, indicating poor repeatability, while the absolute LSC (LSC = SD_{within} × 1.96 ×$\sqrt{2}$) was 0.26 cmH_2O.

Table 5
Multivariable logistic regression analysis of the relationship between absolute ΔP0.1 and extubation failure after adjusting for clinical confounding factors.

Variables	Odds ratio	95%CI	*P* value
Absolute ΔP0.1	4.12	1.24–13.67	0.020
BMI	0.97	0.89–1.04	0.410
SOFA score	1.20	1.00–1.45	0.053
Time to SBT	1.10	0.99–1.20	0.060
Absolute ΔRR	2.22	1.49–3.30	<0.001

BMI: Body mass index; CI: Confidence interval; P0.1: Airway occlusion pressure; RR: Respiratory rate; SOFA: Sequential Organ Failure Assessment; SBT: Spontaneous breathing trial.
Goodness-of-fit test: *P*-value = 0.74.

Table 6
Multivariable logistic regression analysis of the relationship between absolute Δ(P0.1 × RSBI) and extubation failure after adjusting for clinical confounding factors.

Variables	Odds ratio	95%CI	*P* value
Absolute Δ(P0.1×RSBI)	1.02	1.00–1.05	0.020
BMI	0.96	0.89–1.04	0.380
SOFA score	1.20	0.99–1.45	0.056
Time to SBT	1.08	0.99–1.19	0.090
Absolute ΔRR	2.02	1.38–2.96	<0.001

BMI: Body mass index; CI: Confidence interval; P0.1: Airway occlusion pressure; RR: Respiratory rate; RSBI: Respiratory shallow breathing index; SOFA: Sequential Organ Failure Assessment; SBT: Spontaneous breathing trial.
Goodness-of-fit test: *P* value = 0.83.

Table 7
Multivariable logistic regression analysis of the relationship between absolute Δ(P0.1×RR) and extubation failure after adjusting for clinical confounding factors.

Variables	Odds ratio	95%CI	*P* value
Absolute Δ(P0.1 × RR)	1.05	1.01–1.10	0.020
BMI	0.96	0.89–1.05	0.390
SOFA score	1.20	0.99–1.42	0.070
Time To SBT	1.11	1.00–1.22	0.040
Absolute ΔRR	2.05	1.40–3.00	<0.001

BMI: Body mass index; CI: Confidence interval; P0.1: Airway occlusion pressure; RR: Respiratory rate; SOFA: Sequential Organ Failure Assessment; SBT: Spontaneous breathing trial.
Goodness-of-fit test: *P* value = 0.81.

Discussion

The principal findings of our study can be summarized as follows: (1) variations in P0.1 (absolute or relative) during the SBT had limited predictive value for EF; and (2) variations in the combined parameters P0.1 × RSBI and P0.1 × RR exhibited moderate accuracy for predicting EF, outperforming ΔP0.1 but not differing significantly from ΔRSBI and ΔRR, respectively.

For weaning to be successful, the patient must sustain adequate but not excessive inspiratory effort during the SBT, reflecting the capacity to cope with the increased work of breathing (WOB) that occurs after withdrawal of ventilatory support. The patient's inspiratory workload, expressed as WOB and pressure time product (PTP), is traditionally assessed using esophageal pressure measurements and Campbell's diagram. Given its correlation with WOB, PTP, and muscle pressure,[6,7,17] P0.1 offers a practical, noninvasive means of estimating inspiratory effort, which may otherwise be underestimated during the SBT, and could aid in predicting extubation outcomes. However, studies evaluating the reliability of P0.1 as a predictor of EF have reported conflicting results. Indeed, Capdevila et al.[18] reported that P0.1 measured after a 20-min SBT using a T-piece reliably predicted extubation success, with an AUC of 0.93 ± 0.04 in 67 critically ill patients. Similarly, another study demonstrated that P0.1 assessed after a 30-min SBT predicted extubation success (defined as the ability to maintain spontaneous unassisted breathing for > 48 h after extubation) with an AUC of 0.86 (95% CI: 0.78–0.93) in 91 critically ill patients.[12] Conversely, Fernández et al.[11] observed in 114 patients that P0.1 measured during a 30-min SBT with 7 cmH_2O pressure support and zero PEEP was a poor predictor of EF (AUC = 0.59), defined as reintubation within 48 h. Likewise, Sassoon et al.[19], in a cohort of 45 patients, found that P0.1 recorded after a 5-min SBT with 5 cmH_2O continuous positive airway pressure for 1 h did not predict weaning success (AUC = 0.64 ± 0.12), defined as sustained spontaneous breathing without reintubation for over 48 h. In a meta-analysis including 12 prospective studies, P0.1 was found to be a useful predictor of successful weaning, with a pooled AUC of 0.81 (95% CI: 0.77–0.84).[20] However, substantial heterogeneity was present, and evidence of publication bias was detected. Moreover, the timing of P0.1 measurement, the weaning modality used, and the definitions of weaning success varied considerably across studies, thereby limiting the interpretability and generalizability of the meta-analytic findings. In a recent multicenter prospective study of 238 high-risk patients, SBT-induced changes in P0.1 demonstrated limited predictive value (AUC = 0.69) for EF, defined as the need for reintubation within 72 h after extubation.[21] In our study, ΔP0.1 was also a poor predictor of EF (Table 4), despite being independently associated with this outcome (Table 5). This limited predictive ability may partly stem from the fact that P0.1 does not always accurately represent respiratory neural drive. Its reliability can be affected by factors such as reduced inspiratory muscle strength,[22] lung hyperinflation, and changes in the mechanical configuration of the respiratory system. Recent data indicate that P0.1 demonstrates only moderate accuracy in identifying patients with high transdiaphragmatic pressure, as measured us-

ing a double-balloon esophageal–gastric catheter.[23] This may result from the fact that since P0.1 is derived from a very brief measurement window, it is more susceptible to high-frequency noise, including cardiac artifacts, and from changes in respiratory system mechanics and control center output that modify airway pressure waveform morphology and distort its relationship with total inspiratory muscle pressure.[24]

The combined index P0.1 × RSBI, which reflects the relationship between central respiratory drive and mechanical ventilatory output (neuro-ventilatory coupling), has been explored as a potential predictor of EF, although findings across studies remain inconsistent. Fernández et al.[11] found that P0.1 × RSBI during the SBT poorly predicted EF (AUC = 0.61). Conversely, Sassoon et al.[19] reported better discrimination for weaning success (AUC = 0.80 ± 0.09), though not significantly higher than P0.1 alone (AUC = 0.64 ± 0.12). Likewise, Liu et al.[12] showed that P0.1 × RSBI at 30 min of the SBT predicted extubation success with an AUC of 0.89 (95% CI: 0.80–0.94), comparable to P0.1 (AUC = 0.79) and with the same NPV (67%). Our results demonstrated that both absolute and relative Δ(P0.1 × RSBI) exhibited superior discriminative ability in predicting EF compared with ΔP0.1, but not with ΔRSBI. Nevertheless, the overall predictive performance remained moderate (Table 4), even though this parameter was independently associated with EF (Table 6). The discrepancies among studies may, in part, reflect differences in the respiratory strategies patients adopt during the SBT. EF typically results from an imbalance between ventilatory demand and the patient's capacity to meet it. Each patient attempts to satisfy this demand to the greatest extent possible, leading to varying adaptive patterns. Patients with high ventilatory demand may exhibit elevated P0.1 values and compensate by adopting a more economical breathing strategy, reducing Vt and consequently increasing the RR/Vt ratio (RSBI). Conversely, patients with relatively preserved ventilatory reserve may also increase P0.1 while maintaining a lower RR/VT ratio by sustaining an adequate Vt, though this may occur at the expense of increased respiratory discomfort or effort.[25] In contrast, some individuals with low P0.1 may adopt a rapid, shallow breathing pattern to minimize the elastic WOB. The mechanisms determining why a given patient favors one compensatory strategy over another remain unclear.

The composite index P0.1 × RR may capture both the intensity of each breath and the frequency of breathing. Its association with EF has not been previously examined. In our study, Δ(P0.1 × RR) showed better discriminative ability for predicting EF than ΔP0.1 alone, although not superior to ΔRR. Overall predictive performance remained moderate (Table 4), despite this parameter being independently associated with EF (Table 7). Notably, Δ(P0.1 × RR) and Δ(P0.1 × RSBI) demonstrated comparable predictive accuracy.

To the best of our knowledge, this is the first study to evaluate whether P0.1 and the composite indices P0.1 × RSBI and P0.1 × RR measured during SBT are reliable predictors of EF. Nonetheless, several limitations should be acknowledged. First, P0.1 values were obtained from the automated readings displayed by the ICU ventilator (Servo-u®, Getinge Group, Solna, Sweden) rather than from the reference method, which involves recording the airway pressure drop at the Y-piece with a dedicated pressure sensor following an end-expiratory occlusion manoeuvre. However, previous studies have demonstrated that P0.1 values derived from ICU ventilators, including the Servo-u®, correlate well with those measured using the reference technique.[26] Second, the Servo-u® ventilator estimates P0.1 without performing an actual occlusion, and therefore, our findings may not be fully generalizable to ventilators that use a true airway occlusion for measurement.[27] Nevertheless, similar results have been reported using ventilators equipped with an occlusion system,[11] suggesting that this limitation is unlikely to have significantly affected our findings. Third, all SBTs in our study were conducted using a 30-min PSV trial, which may limit extrapolation to other SBT modalities. However, this approach has been associated with higher extubation success rates compared with T-piece trials.[28] Fourth, EF was defined as reintubation within 7 days rather than within 72 h, as initially planned, to increase the number of EF events and thereby improve the study's statistical power. Importantly, our results remained unaltered when EF was alternatively defined as reintubation within 72 h. Fifth, the EF rate in our cohort was 20%, consistent with previous reports.[11,12,28] This relatively low incidence may partly explain the excellent negative predictive values observed across all tested variables, despite their limited discriminatory ability in predicting EF (Table 4). Sixth, the relative LSC of P0.1 was high (48.2%), reflecting poor repeatability of the relative ΔP0.1 and suggesting that this parameter is not suitable for bedside application.

Conclusions

Variations in P0.1 and in the combined parameters P0.1×RSBI and P0.1×RR during the SBT offered limited utility for predicting EF in critically ill patients.

CRediT Authorship Contribution Statement

Jihad Mallat: Writing – review & editing, Writing – original draft, Validation, Methodology, Formal analysis, Data curation, Conceptualization. **Nicolas Storme:** Writing – review & editing, Data curation. **Mohamed Askalany:** Writing – review & editing, Data curation. **Mohamed Helal:** Writing – review & editing, Data curation. **Mehraj Ud Din:** Writing – review & editing, Data curation. **Sujay Samanta:** Writing – review & editing, Data curation. **Sukhen Samanta:** Writing – review & editing, Data curation. **Fadi Hamed:** Writing – review & editing, Data curation. **Unmesh Edke:** Writing – original draft, Data curation. **Tiago Carvalho:** Writing – review & editing, Data curation. **Bruno De Oliveira:** Writing – review & editing, Data curation. **Hussam Elkambergy:** Writing – review & editing, Data curation. **Jamil Dibu:** Writing – review & editing, Data curation. **Ahmad Bayrlee:** Writing – review & editing, Data curation. **Haamid Siddique:** Writing – review & editing, Data curation. **Rehan Haque:** Writing – review & editing, Data curation. **Nahla Aljaberi:** Writing – review & editing, Data curation. **Samer Shoshan:** Writing – review & editing, Data curation. **Dnyaneshwar Munde:** Writing – review & editing, Data curation. **Mathieu Guilbart:** Writing – review & editing, Data curation. **Ujwal Dhundi:** Writing – review & editing, Data curation. **Noora Alhajri:** Writing – review & editing, Data curation. **Maryam Babar:** Writing – review & editing, Data curation. **Ahmed Taha:** Writing – review & editing, Data curation. **Mehdi Belfegas:** Writing – review & editing, Data curation. **Ayo**

Mandi: Writing – review & editing, Data curation. **Umar Khan:** Writing – review & editing, Data curation. **Ihab Ahmed:** Writing – review & editing, Data curation. **Tariq Omer:** Writing – review & editing, Data curation. **Yeldho Varghese:** Writing – review & editing, Data curation. **Praveen Ghisulal:** Writing – review & editing, Data curation. **Mathieu Metzelard:** Writing – review & editing, Data curation. **Vivek Kakar:** Writing – review & editing, Data curation. **Arvin Charles:** Writing – review & editing, Data curation. **Muhammed Kacherintavida:** Writing – review & editing, Data curation. **Cheikh El Mali:** Writing – review & editing, Data curation. **Christophe Beyls:** Writing – review & editing, Data curation. **Sridhar Venkatarmireddy:** Writing – review & editing, Data curation. **Rahul Amte:** Writing – original draft, Data curation. **Mohammed Aljasmi:** Writing – review & editing, Data curation. **Baraa Abduljawad:** Writing – review & editing, Data curation. **Khaled Ismail:** Writing – review & editing, Data curation. **Yazine Mahjoub:** Writing – review & editing, Formal analysis, Data curation. **Osama Abou Arab** Writing – review & editing, Formal analysis, Data curation, Conceptualization.

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Ethics Statement

This study was approved by the Cleveland Clinic Abu Dhabi Ethics Committee on March 22, 2023 (number: A-2023-014). Informed consent was obtained from all patients or their next of kin.

Conflict of Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Supplementary Materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.jointm.2026.01.001.

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