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Respiratory oxygen uptake is associated with survival in a cohort of ventilated trauma and burn patients

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Abstract

Background: Little data is available in the literature about the role of end tidal oxygen in critically ill patients. We sought to identify the association between the level of respiratory oxygen and clinical outcomes in critically-ill ventilated trauma and burn patients.

Methods: A retrospective cohort of 55 trauma and burn patients from 2010 to 2016 was collected. Exposures of interest included a) expiratory end tidal oxygen (ETO₂) and b) the difference between FiO₂ and ETO₂ (uptake). Associations of clinical characteristics with ETO₂ and oxygen uptake were examined using a Spearman correlation. The relationships between discharge status, demographics, injury type, severity, and clinical characteristics were examined using chi-square (or Fisher's exact) tests and two-sample *t*-tests. Multivariable analyses using linear and logistic regression were performed to determine whether expiratory end tidal oxygen or oxygen uptake was an independent predictor of clinical outcomes.

Results: Mean age for the patients was 46.3 ± 18.2 years with 41 (74.6%) male and 34 (61.8%) white. In the cohort, 27 (49.1%) of patients had burns and 28 (50.9%) blunt trauma. Oxygen uptake was negatively correlated with lactic acid, minute ventilation, total ICU days, and ventilator days (*p* < 0.05). Patients who died demonstrated lower oxygen uptake than those alive, oxygen uptake remained significantly associated with discharge status after adjusting for potential confounders (*p* = 0.028).

Conclusion: A narrowed difference between ETO₂ and inspiratory oxygen is associated with increased mortality in a cohort of ventilated trauma and burn patients. Future research is needed to further elucidate the role of respiratory oxygen level in larger, prospective studies.

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Keywords

Respiratory oxygen; Survival; Trauma; Burn

1. Introduction

The perfect test to evaluate clinical conditions associated with oxygen level derangements in the intensive care unit (ICU) does not exist. While the level of oxygen in an arterial blood gas (ABG) analysis is frequently used to evaluate many disorders, it is not very specific. A decrease in arterial oxygen level is classically used for certain conditions including pulmonary thrombo-embolism (PE), adult respiratory distress syndrome (ARDS), and ventilator associated pneumonia (VAP). Conversely, an increased level of arterial hyperoxia has also been associated with poor outcome [1].

As measures of hypoperfusion, central venous blood oxygenation and anaerobic metabolism markers like lactic acid have been extensively investigated. Rivers et al. [2] implemented a protocol including normalizing central venous oxygen saturation (SvO₂) that resulted in improved survival in septic shock patients and lactate clearance in the emergency department (ED) has been associated with survival in septic patients too [3]. More recently, Isaza et al. [4] found that low central venous oxygen saturation (<65%) is associated with anastomotic leak in the postoperative period among trauma patients.

Whether changes in expiratory oxygen levels reflect the degree of anaerobic metabolism and can be used clinically to improve patient outcomes remains to be seen.

Although Szalados et al. [5] showed-in a case report of a single patient in septic shock- a correlation between oxygen uptake and clinical events such as upper airway obstruction and bronchospasm, little data is available in the literature regarding the clinical significance of measured oxygen levels in expiratory gases, particularly expiratory oxygen level in ventilated, critically ill patients. We sought to measure the association of the level of end-tidal oxygen with clinical outcomes in critically-ill ventilated trauma and burn patients. To the best of our knowledge, this has not been studied before and may lead to new techniques to improve patient outcomes.

2. Materials and methods

2.1. Study design and patient selection

The study was approved by the University of Alabama at Birmingham's Institutional Review Board for Human use. No consent was needed. The records of trauma and burn patients admitted to our level 1 trauma and burn center ICU who underwent metabolic cart investigations from July 2010–July 2016 were reviewed. The metabolic cart procedure was performed to evaluate the patients' nutritional status and needs. Time from admission to the procedure (the metabolic cart) was 18.3 ± 34.6 days (Mean $\pm$ SD). The results are the findings from a single use of the cart and not average of many tests.

Exposures of interest included a) expiratory end-tidal oxygen level (ETO₂) and b) the difference between fractional inspiratory oxygen level (FiO₂) and expiratory end-tidal Oxygen (ETO₂) (the uptake). We used end-expiratory O₂ values for this study as it has alveolar air and minimal or no dead space air [6].

Variables examined included demographics (age, race, gender), mechanism of injury (burn, trauma-blunt, trauma-penetrating), injury severity score (ISS), outcome measures including length of intensive care unit (ICU) stay, hospital length of stay (LOS), ventilator days and discharge status. Laboratory data were also collected (procedure day) from the patient's charts and included lactic acid level, serum creatinine level, white blood cell (WBC) count, hematocrit (Hct), arterial blood gas analysis (ABG) and international normalization ratio (INR) values. Ventilator settings data collected from the time of the procedure included mode of ventilation, compliance, peak inspiratory pressure (PIP), positive end-expiratory pressure (PEEP), minute ventilation (MV) and plateau pressure (PP) measurement.

The metabolic analysis was performed using the Ultima Series™ metabolic stress testing system (MGC Diagnostics, Saint Paul, Minnesota). The Ultima CPX analyzes the oxygen using a Zirconia analyzer, and analyzes the carbon dioxide using a NDIR (non-dispersive infrared) analyzer. The sample is obtained using a bidirectional, Pitot tube pneumotach. The CPX samples at a flow of 80–120 ml/min from the pneumotach, providing inspiratory and expiratory oxygen and carbon dioxide readings. The procedure included calibrating the Ultima CPX system within an hour before testing, then the direct connect pneumotach was placed in line between the patient's artificial airway and the ventilator circuit. The CPX Ultima was allowed to run for a minimum of 30 min and all aberrant data was edited out of the test before reporting.

2.2. Statistical analysis

Demographics, injury and clinical characteristics were summarized using descriptive statistics. Mean (standard deviation) or median (interquartile range) for continuous variables; frequency and percentage for categorical variables. The primary outcome was discharge status of two categories: dead and alive. Exploratory outcomes were hospital stay, ICU length of stay and ventilation day. A Spearman's correlation was used to assess the associations of expiratory end tidal oxygen level and oxygen uptake (FiO₂-ETO₂) with injury, clinical characteristics and outcomes. The relationships between discharge status and demographics, injury, clinical characteristics were examined using a chisquare (or Fisher's exact) test and a two-sample t-test (or Wilcoxon rank-sum test). Similarly for comparisons between burn and trauma patients. To determine whether expiratory end tidal oxygen level or oxygen uptake was predictive of discharge status, multivariable logistic regression analysis was performed with adjustment for clinically relevant variables such as age, gender, injury type and injury severity. The associations with exploratory outcomes were investigated using a multiple linear regression with the same adjustment as described above. All exploratory outcomes were log₁₀ transformed to achieve normality prior to analysis. A *p*-value <0.05 was considered statistically significant in two-tailed statistical tests. All analyses were conducted using SAS 9.4 (SAS Institute, Cary, NC).

To ensure the adequacy of our sample size for the significant difference in oxygen uptake between discharge status, a post-hoc power analysis was conducted using nQuery Advisor v7. With a sample size of 55, a type I error rate of 0.05 and a pooled standard deviation of 0.48, a two-sample *t*-test had achieved 83% power to detect a significant difference of 1.46 in oxygen uptake between the two discharge status.

3. Results

In a cohort of 55 critically-ill ventilated trauma and burn patients, the mean age was 46.3 ± 18.2 years, 74.6% were male and 25.5% were female. The racial makeup comprised 61.8% Caucasian and 38.2% African American. These 55 patients had an average injury severity score of 20.1 ± 13.6 , about half of them had burn injury and the remaining patients suffered blunt trauma. Of the 27 burn patients, 18.5% suffered from inhalation injury with an average TBSA of 33.7 ± 21.7 .

The median end tidal oxygen level for the patients was 33.3 (2.6) with an average oxygen uptake of 6.3 ± 1.9 . The patients stayed in hospital for 49.4 ± 52.3 days on average and spent 37.3 ± 36.5 and 30.1 ± 32.8 days in ICU and on ventilator, respectively. The mortality occurred in 20% of the patients and on average 17.8 days after the test day (Table 1). Eleven patients (20%) died (10 burns and 1 blunt trauma). Cause of death included sepsis in 6 (55%), respiratory arrest in 2 (18%), multi-system organ failure in 1 (9%), cardiogenic shock in 1 (9%) and pulmonary embolus in 1 (9%).

While no associations with end tidal oxygen level was detected for any injury/resuscitation, other ventilator and outcome measures, there was a significant positive correlation between end tidal oxygen level and fractional inspiratory oxygen level ($\rho = 0.73$, $p < 0.0001$). Oxygen uptake was negatively correlated with lactic acid procedure ($\rho = -0.32$, $p = 0.017$) and minute ventilation ($\rho = -0.34$, $p = 0.009$). Patients with increased oxygen uptake corresponded to shorter time spent in ICU and on ventilation ($\rho = -0.27$, $p = 0.048$; $\rho = -0.28$, $p = 0.04$ respectively) (Table 2).

After assessing the associations between patient characteristics (demographics, injury and clinical) and discharge status, there was a significant evidence of associations for injury type, lactic acid procedure, INR, arterial O₂ saturation, minute ventilation, fractional inspiratory oxygen, total days on ventilation and oxygen uptake ($p < 0.05$, Table 3), among other variables. Patients who died were twice as likely to be in blunt trauma (81.8% vs 40.9%), had higher lactic acid (2.1 ± 1.2 vs 1.1 ± 0.5), higher INR (1.2 ± 0.2 vs 1.1 ± 0.1), higher arterial O₂ saturation (97.5 ± 1.5 vs 96.1 ± 1.9), higher minute ventilation (11.6 ± 3.9 vs 9.5 ± 2.7) and longer duration on ventilation (38.9 ± 25.2 vs 27.8 ± 34.3) in comparison to those alive. Conversely, the fractional inspiratory oxygen and oxygen uptake were significantly lower for dead patients (37.2 ± 6 vs 40.8 ± 3.9 ; 5.1 ± 1.5 vs 6.6 ± 1.5 respectively) (Fig 1).

Comparing burn patients to trauma patients, there was no significant difference in demographics, injury severity, end-tidal oxygen level, respiratory oxygen uptake or outcomes, although burn patients had higher lactic acid level on procedure day, received

more packed red cells the 24 hours preceding the procedure and spent longer time in ICU and on ventilation (Table 4).

The multivariable analysis revealed that oxygen uptake was independently associated with discharge status ($p = 0.028$), there is a 52% decrease in the likelihood of mortality for every unit increase in oxygen uptake, given that all other variables in the model are held constant. No other significant association was found for either total hospital stay, ICU length of stay or total day on ventilation (Table 5).

4. Discussion

The significant finding of our study was a lower difference between fractional inspiratory oxygen and respiratory oxygen uptake ($\text{FiO}_2\text{-ETO}_2$) was associated with mortality. There was also a significant correlation between the uptake and ICU length of stay and ventilator days. This finding is significant as it suggests measuring expiratory oxygen levels (ETO_2) to assess respiratory oxygen uptake on a continuous basis may help predict patient outcomes and identify patients at increased risks of worse outcomes at an earlier stage of their illness to facilitate intervention.

The group of trauma and burn patients included in this study were severely injured (mean ISS of 20), with a mean of 30 days on the ventilator and prolonged length of stay in the hospital (mean LOS of 49 days). There was a significant correlation between the uptake and both ventilator days and Intensive Care Unit (ICU) days. Whether this effect is local, i.e., as a result of regional lung physiologic changes or from a systemic stress resulting in increased respiratory oxygen uptake, is not clear at this time.

Minute ventilation in this study was significantly (inversely) associated with respiratory oxygen uptake and oxygen concentration in the alveoli is known to be affected by the rate of entry of O_2 into the lungs and by the rate of absorption of oxygen into the blood [6]. Patients who died, despite having had a higher minute ventilation (and probably higher O_2 entry into the lungs) had lower respiratory oxygen uptake. Increased minute ventilation could be a marker of a sicker group of patients that had worse outcome and whose body is less able to utilize oxygen.

The $\text{PaO}_2/\text{FiO}_2$ ratio is used to classify the severity of lung injury and ARDS using the Berlin definition [7]. In this study, there was no difference between the $\text{PaO}_2/\text{FiO}_2$ ratios of those who died from those who lived, and since the mean value was 305 and 303 for the two groups it suggests a mild degree of injury at best (the patients were on low ventilatory settings, as noted in Table 4). While the mortality in ARDS increases with severity [7], there was no difference in the $\text{PaO}_2/\text{FiO}_2$ ratio between the two groups to detect a difference in mortality while there was a difference in the respiratory oxygen uptake that was identified and signaled a difference in mortality, this makes the uptake potentially a superior tool in patients with no apparent lung injury.

Respiratory oxygen uptake ($\text{FiO}_2\text{-ETO}_2$) was significantly associated with mortality in our study. While blood oxygen peak uptake is an established predictor of prognosis in heart failure (HF) patients [8], little is known about the respiratory uptake of oxygen and its

prognostic value in critically ill patients. In our cohort, the group of patients who died had a significantly higher blood lactic acid level and higher INR. While lactic acid has been associated with increased mortality in trauma and burn patients [9], respiratory oxygen uptake's impact on survival has not been studied.

While patients in our study had multiple reasons to have decreased oxygen extraction including sedation, paralysis, hypo nutrition, mechanical ventilation, and sepsis, [10] [11] currently there is no evidence to support that respiratory uptake of oxygen correlates with the oxygen extraction ratio in circulating blood. Since 55% of our cohort died from sepsis, it is possible that decreased respiratory uptake is an early marker of sepsis.

Szalados et al. [5], using a computer-assisted single breath analysis, showed a good correlation between oxygen uptake and clinical events including upper airway obstruction and bronchospasm; they did not demonstrate a correlation with clinical outcome. We found respiratory oxygen uptake strongly associated with mortality in a group of trauma and burn patients. When we compared burn patients to trauma patients we did not discover any significant difference in end-tidal oxygen level, respiratory oxygen uptake and hospital length of stay.

Lactic acid level was also significantly (inversely) correlated with the respiratory oxygen uptake in this study. Vandromme et al. [12] found lactic acid level in the emergency department was a better predictor of mortality compared to systolic blood pressure (SBP) in a retrospective review of 2413 trauma patients admitted over a 9-year period and Calloway et al. found serum lactate to be associated with increased mortality among elderly patients with blunt trauma [13]. Continuous respiratory oxygen uptake measurements in critically ill patients may allow earlier identification of patients experiencing clinically significant events without waiting for the return of a laboratory value.

The ProCESS study [14], using early goal directed therapy (EGDT) including blood transfusion, did not show improved survival, however ProCESS and other studies have demonstrated increased oxygen extraction in patients with sepsis and septic shock [15,16]. Patients with decreased respiratory uptake of oxygen in our study had significantly increased mortality and over half of those patients died from sepsis. Although the patients who died in our study were not in septic shock at the time of the respiratory uptake measurements, it is possible that decreased respiratory oxygen uptake is an early sign of sepsis in critically ill patients.

Our study has several limitations. First, it is retrospective in nature and the results cannot be generalized to all patients. Second, while we had arterial oxygen levels obtained from arterial blood gas, we did not have mixed venous oxygen saturation values available to us to compare with actual oxygen uptake from the blood. Third, the data were obtained from metabolic cart data used primarily to evaluate patients' nutritional status and not outcomes. Fourth, arterial blood gas (ABG) tests were not timed perfectly to correspond to the metabolic cart use; this could have affected the correlation between arterial oxygen level and expiratory oxygen levels.

Larger prospective studies are needed to confirm these findings in different disease states, including ventilator associated pneumonia (VAP), adult respiratory distress syndrome (ARDS), and pulmonary thromboembolism (PE). Additionally, patients with conditions not primarily related to pulmonary function, such as active hemorrhage, need to be measured. The value of measuring respiratory oxygen uptake to diagnose conditions associated with anaerobic metabolism and hyperlactatemia, including ischemic bowel, needs to be assessed as well.

5. Conclusion

We found a narrowed difference between ETO_2 and inspiratory oxygen to be associated with increased mortality in a cohort of ventilated trauma and burn patients. Future research is needed to further elucidate the role respiratory oxygen uptake plays in patient outcomes through larger, prospective studies.

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Fig. 1.

Box and whisker plot showing the difference in oxygen uptake by discharge status. The asterisk denotes the mean; the line inside the box depicts the median; the upper and lower hinges represent 25th and 75th percentile, respectively.

Table 1

Demographics, injury and clinical characteristics of trauma and burn patients

Patient characteristics, mean $\pm$ SD	All (n = 55)
Demographics	
Age (years)	46.3 (18.2)
Gender, n (%)	
Male	41 (74.6)
Female	14 (25.5)
Race, n (%)	
Caucasian	34 (61.8)
African American	21 (38.2)
Injury	
Injury Type, n (%)	
Burn	27 (49.1%)
Inhalation Injury	5 (18.5)
TBSA%	33.7 $\pm$ 21.7
Trauma	28 (50.9%)
Injury severity score (for trauma and burn patients)	20.1 $\pm$ 13.6
Clinical	
Lactic acid (procedure day)	1.3 $\pm$ 0.8
Hematocrit	26.5 $\pm$ 4.4
WBC	11.6 $\pm$ 5.1
INR	1.1 $\pm$ 0.2
Creatinine	0.9 $\pm$ 0.7
PEEP	6.5 $\pm$ 1.7
Compliance	40.4 $\pm$ 15.8
Plateau pressure	21.5 $\pm$ 4.6
Pressure support	10.3 $\pm$ 2.4
Peak inspiratory pressure (PIP)	21.1 $\pm$ 5
Arterial O ₂ saturation	96.4 $\pm$ 1.9
Minute ventilation	10 $\pm$ 3.1
pRBCs transfused/24-h	0.5 (0.8)
Fractional inspiratory oxygen (FiO ₂), n (%)	40.1 $\pm$ 4.5
End tidal oxygen level median, (IQR)	33.3 (2.6)
Oxygen uptake (FiO ₂ -ETO ₂)	6.2 $\pm$ 1.6
PaO ₂ /FiO ₂ ratio (calculated)	304 $\pm$ 92.3
Total hospital stay (days)	49.4 $\pm$ 52.3
ICU length of stay (days)	37.3 $\pm$ 36.5
Total days on ventilation	30.1 $\pm$ 32.8
Mortality, n (%)	
Alive	44 (80)
Dead	11 (20)

Table 2

Spearman's correlations of end-tidal oxygen and oxygen uptake with clinical characteristics and outcomes.

	ETO ₂ (End tidal)		Oxygen uptake	
	Spearman correlation coefficient	<i>p</i>	Spearman correlation coefficient	<i>p</i>
Injury/resuscitation				
Lactic acid	0.01	0.94	−0.32	0.017 [*]
Hematocrit	−0.1	0.46	0.19	0.17
INR	0.07	0.59	−0.27	0.05
RBCs transfused (24-h)	0.04	0.77	−0.24	0.08
ISS	−0.04	0.79	−0.1P6	0.24
Ventilatory				
PEEP	0.002	0.99	0.11	0.43
PS	−0.12	0.39	0.04	0.8
MV	0.17	0.23	−0.34	0.009 [*]
PIP	−0.13	0.34	−0.02	0.86
Plateau pressure	−0.02	0.91	0.17	0.25
Compliance	0.09	0.54	−0.03	0.83
FiO ₂	0.73	<0.0001	0.13	0.36
Clinical outcome				
Total hospital stay	0.22	0.11	−0.16	0.24
ICU length of stay	0.17	0.22	−0.27	0.048 [*]
Total days on ventilator	0.19	0.17	−0.28	0.04 [*]

PS = pressure support, PEEP = positive end expiratory pressure, MV = minute ventilation, PIP = peak inspiratory pressure, RBC = red blood cell, FiO₂ = fractional inspiratory oxygen %, ISS = injury severity score.

^{*} Denotes statistical significance at $p < 0.05$.

Table 3

Comparisons of demographic, injury, and clinical characteristics stratified by discharge status.

Patient characteristics, mean $\pm$ SD	Discharge status		
	Dead (n = 11)	Alive (n = 44)	P
Demographics			
Age (years)	50 $\pm$ 21	45.4 $\pm$ 17.5	0.46
Gender			1
Male	8 (73)	33 (75)	
Female	3 (27.3)	11 (25)	
Race			0.17
Caucasian	9 (82.8)	25 (56.8)	
African American	2 (18.2)	19 (43.2)	
Injury			0.015 *
Injury Type n(%)			
Burn	2 (18.2)	26 (59.1)	
Trauma	9 (81.8)	18 (40.9)	
Injury severity score	25.8 $\pm$ 21.4	18.6 $\pm$ 10.7	0.3
Clinical			
Lactic acid procedure (days)	2.1 $\pm$ 1.2	1.1 $\pm$ 0.5	0.024 *
Hematocrit	25.6 $\pm$ 4.8	26.8 $\pm$ 4.3	0.44
WBC	14.2 $\pm$ 7	11 $\pm$ 4.4	0.17
INR	1.2 $\pm$ 0.2	1.1 $\pm$ 0.1	0.014 *
Creatinine	1.4 $\pm$ 1.2	0.8 $\pm$ 0.4	0.13
PEEP	6 $\pm$ 0.8	6.6 $\pm$ 1.8	0.09
Compliance	40.6 $\pm$ 16.2	40.4 $\pm$ 15.9	0.98
Plateau pressure	20.3 $\pm$ 4.5	21.8 $\pm$ 4.6	0.41
Pressure support	10 $\pm$ 1.5	10.4 $\pm$ 2.6	0.66
Peak inspiratory pressure (PIP)	20.1 $\pm$ 6	21.4 $\pm$ 4.8	0.45
Arterial O ₂ saturation	97.5 $\pm$ 1.5	96.1 $\pm$ 1.9	0.036 *
Minute ventilation	11.6 $\pm$ 3.9	9.5 $\pm$ 2.7	0.043 *
RBCs transfused (unit of pack/24-h)	0.7 $\pm$ 0.8	0.4 $\pm$ 0.8	0.2
Fractional inspiratory oxygen (FiO ₂), n (%)	37.2 $\pm$ 6	40.8 $\pm$ 3.9	0.02 *
End tidal oxygen level median, (IQR)	33.5 (1.5)	33.2 (2.7)	0.82 ‡
Oxygen uptake (FiO ₂ -ETO ₂)	5.1 $\pm$ 1.5	6.6 $\pm$ 1.5	0.004 *
PaO ₂ /FiO ₂ ratio	305 $\pm$ 101.1	303.7 $\pm$ 91.2	0.97
Total hospital stay (days)	43.9 $\pm$ 29.3	50.8 $\pm$ 56.7	0.71 §
ICU length of stay (days)	41.7 $\pm$ 26.3	36.2 $\pm$ 38.8	0.17 §
Ventilator days	38.9 $\pm$ 25.2	27.8 $\pm$ 34.3	0.039 *§

* Denotes statistical significance at $p < 0.05$;

[§] p -value from statistical test performed on log-transformed variable.

[‡] Wilcoxon rank-sum test.

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Table 4

Comparisons of demographic, injury, and clinical characteristics stratified by injury type.

Patient characteristics, mean $\pm$ SD	Injury type		
	Burn (<i>n</i> = 27)	Trauma (<i>n</i> = 28)	<i>p</i>
Demographics			
Age (years)	44.7 $\pm$ 16	47.9 $\pm$ 20.1	0.52
Gender			1
Male	20 (74.1)	21 (75)	
Female	7 (25.9)	7 (25)	
Race			0.58
Caucasian	18 (66.7)	16 (57.1)	
African American	9 (33.3)	12 (42.9)	
Injury			
Injury severity score	18.1 $\pm$ 15.4	21.9 $\pm$ 11.4	0.31
Clinical			
Lactic acid (on procedure day)	1.6 $\pm$ 0.91	1.0 $\pm$ 0.43	0.004*
Hematocrit (on procedure day)	25.7 $\pm$ 4.0	27.4 $\pm$ 4.6	0.14
WBC	11.7 $\pm$ 9.5	11.5 $\pm$ 4.6	0.88
INR	1.17 $\pm$ 0.14	1.11 $\pm$ 0.16	0.14
Creatinine	1.04 $\pm$ 0.83	0.84 $\pm$ 0.47	0.23
PEEP	6.3 $\pm$ 1.15	6.6 $\pm$ 2.0	0.41
Compliance	43.91 $\pm$ 16.8	37 $\pm$ 14.1	0.14
Plateau pressure	20.5 $\pm$ 4	22.3 $\pm$ 4.9	0.18
Pressure support	9.9 $\pm$ 1.8	10.6 $\pm$ 2.8	0.27
Peak inspiratory pressure (PIP)	19.8 $\pm$ 4.8	22.3 $\pm$ 4.8	0.05
Arterial O ₂ saturation	96.9 $\pm$ 2.1	95.8 $\pm$ 1.4	0.039*
Minute ventilation	10.5 $\pm$ 3.2	9.4 $\pm$ 2.7	0.18
RBCs transfused (unit of pack/24-h)	0.74 $\pm$ 0.98	0.18 $\pm$ 0.39	0.009
Fractional inspiratory oxygen (FiO ₂), n (%)	39.3 $\pm$ 5	40.7 $\pm$ 4	0.25
End tidal oxygen level median, (IQR)	33.2 (3.1)	33.3 (1.8)	0.23 [‡]
Oxygen uptake (FiO ₂ -ETO ₂)	6.27 $\pm$ 1.83	6.29 $\pm$ 1.27	0.95
PaO ₂ /FiO ₂ ratio	316.1 $\pm$ 105.6	292.3 $\pm$ 77.4	0.35
Total hospital stay	59.8 $\pm$ 64.3	39.3 $\pm$ 35.5	0.09 [§]
ICU length of stay	44.4 $\pm$ 38.9	30.5 $\pm$ 33.1	0.03 [§]
Ventilator support days	35.2 $\pm$ 32.8	25 $\pm$ 32.4	0.03 [§]

* Denotes statistical significance at $p < 0.05$;[§] p -value from statistical test performed on log-transformed variable.[‡] Wilcoxon rank-sum test.

Table 5Multivariable analysis for oxygen uptake with patient outcomes[‡]

	Oxygen uptake	
	β-Coefficient (95% CI)	p
log ₁₀ (Total hospital stay)	0.02 (−0.12, 0.16)	0.78
log ₁₀ (ICU length of stay)	−0.03 (−0.16, 0.11)	0.70
log ₁₀ (Ventilator days)	0.14 (−0.19, 0.12)	0.66
	Adj. odds ratio (95% CI)	p
Discharge status (dead vs. alive)	0.48 (0.25–0.93)	0.028 [*]

[‡] Multivariable analysis with adjustment for age, gender, injury type and injury severity score.^{*} Denotes statistical significance at $p < 0.05$.